AJA

Research Article

Sensitivity and Specificity of Pure-Tone and Subjective Hearing Screenings Using Spanish-Language Questions

Alyssa Everett,[a] Aileen Wong,[a] Rosie Piper,[b] Barbara Cone,[a] and Nicole Marrone[a]

Purpose: The purpose of this study is to determine the sensitivities and specificities of different audiometric hearing screening criteria and single-item and multi-item hearing disability questionnaires among a group of Spanish-speaking adults in a rural community.
Method: Participants were 131 predominantly older (77% 65+ years) Hispanic/Latinx adults (98%). A structured Spanish-language interview and pure-tone threshold test data were analyzed for each participant. The sensitivities and specificities of three single questions and the Hearing Handicap Index for the Elderly–Screening (HHIE-S; Ventry & Weinstein, 1983) in Spanish, as well as three audiometric screening criteria, were evaluated in relation to the pure-tone threshold test for detecting hearing loss.
Results: Sensitivity and specificity of audiometric screening criteria varied, but the highest sensitivity was found for the criterion of > 25 dB HL at 1–4 kHz in either ear. The single self-perception question, "*¿Cree usted que tiene pérdida de audición?* (*Do you think you have a hearing loss?),*" was shown to be the most sensitive self-report screening compared to other single-item questions and the HHIE-S. This single question was as sensitive as an audiometric screening to detect a moderate hearing loss (> 40 dB HL in either ear). Results from the Spanish HHIE-S indicated poor performance to detect hearing loss in this population, consistent with previous research.
Conclusions: Among older Spanish-speaking adults, self-reported hearing status had varying sensitivities depending on the question asked. However, of the tools evaluated, the self-perception question proved to be a more sensitive and specific tool than a multi-item screen. Objective audiometric testing (> 25 dB HL) resulted in the highest sensitivity to detect a mild hearing loss.

Older adults (aged 65 years or older) are a rapidly growing and diverse demographic group in the United States. The Hispanic/Latinx population comprises 8% of older Americans, and this number is projected to increase (Krogstad, 2017; U.S. Census Bureau, 2018). There has also been a 46% increase of the Hispanic/Latinx population living in rural areas, based on population density, from 2000 to 2010 (Housing Assistance Council, 2012; U.S. Census Bureau, 2010). This population faces many health disparities (National Hispanic Council on Aging, 2017), one of which includes access to hearing health care. One study found that the prevalence of hearing loss was 33% in Mexican American men and 18% for women in the age range of 45–74 years (Cruickshanks et al., 2015). While the prevalence of hearing loss in the Hispanic/Latinx population is comparable to that of non-Hispanic/Latinx, Caucasian individuals, there is a disparity in access to hearing health care for Hispanic/Latinx adults with hearing loss (Nieman et al., 2016). Challenges such as geographic access to hearing providers (Coco et al., 2018; Nieman et al., 2016), few bilingual service providers (American Speech-Language-Hearing Association [ASHA], 2018), and financial barriers (Estrada et al., 1990) may contribute to disparities in hearing health care access.

The number of adults over 65 years of age with hearing loss in both ears will continue to grow: By the year 2030, the prevalence is projected to reach nearly 35 million Americans (Goman et al., 2017). This brings to light some important considerations regarding impact at the individual and societal levels. Hearing loss among older adults is independently associated with hospitalization, poor self-reported health, social isolation, and cognitive decline (Genther et al., 2013; Mick et al., 2018). Determining who in the population has a hearing loss is imperative to providing

[a]Department of Speech, Language, and Hearing Sciences, The University of Arizona, Tucson
[b]Mariposa Community Health Center, Nogales, AZ
Correspondence to Nicole Marrone: nmarrone@email.arizona.edu

Editor-in-Chief: Sumitrajit Dhar
Editor: Monita Chatterjee
Received May 4, 2019
Revision received September 13, 2019
Accepted October 16, 2019
https://doi.org/10.1044/2019_AJA-19-00053

Disclosures: *The authors have declared that no competing interests existed at the time of publication.*

appropriate treatment and management. Huddle et al. (2017) concluded that management of hearing loss may help lessen the economic burden and individual impact due to medical expenditures and cognitive decline. In order to detect and manage the burden of hearing loss at a population level, sensitive and specific hearing screening procedures are needed.

Sensitivity and specificity are important measures of test performance to consider when choosing a screening method. The sensitivity of a test measures how accurately a test identifies those with a target condition, such as hearing loss. Specificity indicates the performance of the test with respect to correctly detecting those who do not have the target condition.

Clinicians differ in terms of selecting screening methods and criteria for defining when to refer adults for hearing evaluation. For example, the ASHA (n.d.a) Practice Portal distinguishes between screenings for disorder, impairment, and disability. The pass/fail criteria cited are determining whether "responses are obtained in both ears to pure-tone air-conduction stimuli at 25 dB HL at 1000 Hz, 2000 Hz, and 4000 Hz." Another screening method from the reference *Geriatrics at Your Fingertips* (Reuben et al., 2017) states that screening for hearing loss should be done by asking the single question, "Do you feel you have a hearing loss?" This reference suggests that, if a patient answers "yes" to this question, a referral to an audiologist for evaluation should be made.

The U.S. Preventative Services Task Force (USPSTF) evaluated the literature regarding the accuracy of various subjective screening tests for detecting hearing loss in adults 50 years or older (Chou et al., 2011). These self-report (subjective) screenings included single questions such as "Does the participant think that he/she has a hearing loss?" as well as a 10-item questionnaire, the Hearing Handicap Index for the Elderly–Screening (HHIE-S; Ventry & Weinstein, 1983). The review focused on individuals who were not previously identified with a hearing loss (Chou et al., 2011). For the single-item question, the range in sensitivities was between 27% and 100% across 11 studies. For the HHIE-S, the range of sensitivities for this multi-item questionnaire was between 25% and 100% across 21 studies when a score of > 8 was used as the criterion. The USPSTF concluded that more research is needed to determine the subjective screening measure(s) that most accurately detect a hearing loss.

The wide range of sensitivity measures across studies documented by the USPSTF (Chou et al., 2011) makes it challenging to reach a conclusion or provide recommendations for which screening measures to use in clinical practice. One factor contributing to this wide range of screening test sensitivity was that the audiometric screening criteria for a hearing loss varied across studies. Furthermore, there was variability in the wording of the single-item question to self-report hearing loss across studies. Gates et al. (2003) evaluated the sensitivity and specificity of the single question "Do you have a hearing problem now?" with respect to their pure-tone screening criteria of 40 dB HL or greater at 1.0 and 2.0 kHz in one ear or at 1.0 or 2.0 kHz in both ears. They found a 71% sensitivity and 72% specificity for the single question. Conversely, when Clark et al. (1991) evaluated a similar question, "Would you say that you have any difficulty hearing?" and used a different screening criterion of 25 dB HL or greater at 1.0, 2.0, 3.0, and 4.0 kHz in the better ear, a sensitivity of 56% and a specificity of 82% were determined. Overall, these sensitivity and specificity values represent only fair (screening) test performance at best.

High variability was also seen for the sensitivities and specificities on the HHIE-S, with the cutoff score of > 8 being considered a hearing handicap. The original study analyzed the sensitivity and specificity of the HHIE-S in older adults relative to a criterion of hearing thresholds > 40 dB HL at 1000 or 2000 Hz in both ears (Ventry & Weinstein, 1983). These authors found a sensitivity of 72% and a specificity of 66%. Using the same audiometric criteria, Gates et al. (2003) evaluated adults 70 years and older (aged 72–94 years) from the Framingham Heart Study (Moscicki et al., 1985) and found a 36% sensitivity and 92% specificity for the HHIE-S in English. However, when an audiometric criterion of 25 dB HL or greater at 1.0, 2.0, and 4.0 kHz in the better ear was used, the sensitivity for the English version of the HHIE-S was reported as 53% and the specificity was 84% (Lichtenstein et al., 1988).

Another potential problem is determining how generalizable the results are to a diverse population. Most studies of self-reported hearing disability and screening have been carried out in non-Hispanic/Latinx adults. Only two studies have evaluated the test performance characteristics of self-reports of hearing loss in the Hispanic/Latinx population: one study with a single question and another study adapted the HHIE-S and translated it into Spanish. Torre et al. (2006) evaluated the sensitivity and specificity of the single question "*¿Usted siente que ha perdido su sentido de oido? (Do you feel you have hearing loss?)*" given in Spanish. They surveyed 32 Hispanic/Latinx Americans 60 years and older and found a sensitivity of 76% and a specificity of 73% for this question. Lichtenstein and Hazuda (1998) established excellent agreement between the English and Spanish versions of the HHIE-S at the level of individual questions. Agreement was established by implementing both the English and Spanish versions to 20 bilingual adults and compared their responses using a binary "yes both answers were in agreement" or "no the answers differed." Agreement for each question ranged from 82% to 94%. Although the agreement between English and Spanish versions of the HHIE-S is high, its sensitivity and specificity for detecting hearing loss in this community has not been established in the current literature. Given the paucity of test performance data for subjective measures, it is not yet possible to recommend either one for clinical practice, specifically in the Hispanic/Latinx population. The current study directs the focus on the predominantly Mexican American Hispanic/Latinx population residing in southern Arizona.

There is a clear discrepancy between subjective self-report hearing screening measures and actual hearing

sensitivity, as seen by the wide range of sensitives and specificities. Research on this discrepancy has shown that the accuracy of self-report can be affected by age, sex, personality, and behavior (Chan, 2009); bias from social desirability (Dolcini et al., 1996); and motivation (Hofmann et al., 2005). Self-report can also be affected by race, ethnicity, and socioeconomic status (Hindelang et al., 1979; Menkin et al., 2017; Pinder et al., 2016). Our study is motivated by the literature suggesting group differences in self-report measures and limited prior research including diverse populations.

There have been few prior comparisons of multiple audiometric and self-report screening methods within the same cohort of older adults (Bess et al., 1989). The purpose of the current study is to determine the sensitivities and specificities of different hearing screening criteria, including self-reported hearing disability (using single- and multi-item questionnaires), among a group of Spanish-speaking adults in a rural community. Our goal is to identify a reliable, valid, and efficient hearing screening tool that can be used with Spanish-speaking older adults for medical providers (e.g., primary care physicians, geriatricians) and other clinicians (e.g., audiologists, speech-language pathologists). Implementation of this type of tool may assist with early detection and may reduce the negative impact of untreated hearing loss. The specific objectives of this study are as follows:

1. to determine the sensitivity and specificity of three different audiometric screening criteria (described later in the Audiometric Screening Criteria section under Method section) with respect to a pure-tone threshold test;
2. to determine the sensitivity and specificity of the three single-item questions relative to a pure-tone threshold test: "*¿Cree usted que tiene pérdida de audición? (Do you think you have hearing loss?),*" "*¿Creen sus familiares o amigos que usted tiene pérdida de audición? (Do your family members or friends think you have a hearing loss?),*" and "*¿Tiene problemas para oir por teléfono? (Do you have problems hearing on the telephone?)*"; and
3. to evaluate the sensitivities and specificities of the HHIE-S questionnaire in Spanish using multiple cutoff scores relative to a pure-tone threshold test.

This research was undertaken in a rural, Hispanic/Latinx population in the border region of Arizona as a part of a larger clinical trial. The clinical trial recruited persons to attend a communication education and support group facilitated by community health workers (CHWs) in collaboration with audiologists. Participation included hearing testing and individualized counseling provided by audiologists (Clinical Trials Registration: NCT03255161). In this paradigm, an individual may seek a hearing screening because he or she believes they need help hearing or communicating better and brings their primary communication partner(s) with them to the program to form a communication dyad. Both members of the dyad received pure-tone threshold tests and answered self-report, subjective hearing questions prior to enrollment into the study.

Method

Participants

The data analyzed was a subset of those who participated in the clinical trial of Oyendo Bien. The current analysis included those with available interview and hearing test data. The data collected resulted in records from 131 adults, including 40 men and 91 women aged 29–92 years (M = 70.1 years, SD = 11.1 years). These individuals participated in community-based hearing evaluations held in community meeting spaces in Santa Cruz County, Arizona. Participants were recruited by CHWs or *promotoras de salud* from a Federally Qualified Health Center that provides medical, dental, and preventative care to over 22,000 people. Due to the proximity to the border with the Mexican State of Sonora, the participants recruited were 98% Hispanic/Latinx and the CHW demographic was also 93% Hispanic/Latinx. Marrone et al. (2017) provides an in-depth description of the data collection setting.

Audiologic Testing

All audiologic testing was conducted by state-licensed and ASHA-certified audiologists and their supervised audiology graduate students. Otoscopy was performed before any testing was completed. Tympanometry was administered as needed based on otoscopic findings or case history. Pure-tone tests employed a portable audiometer (MA 41, MAICO Diagnostics; Madsen Xeta, Otometrics). Testing was completed in a quiet room with noise levels monitored using Type 2 sound-level meters using the A-weighted scale. Pure-tone testing was halted if noise levels were excessive, guided by recommendations for ambient noise levels from the American National Standards Institute (2003).

Pure-Tone Threshold Test

A pure-tone threshold test was used as the "gold standard" for determination of hearing loss. Ear-specific pure-tone thresholds were measured via air and bone conduction at 1.0, 2.0, 3.0, 4.0, 6.0, and 8.0 kHz using insert (85%) or supra-aural (15%) head phones. Forty-three of the 131 participants were not tested at 3000 Hz because it was added in a later change in protocol for the clinical trial. Furthermore, two participants did not have right ear thresholds tested due to cerumen blockage of the external auditory meatus. For the purpose of the current analysis, hearing loss was considered present if pure-tone sensitivity was greater than 25 dB HL at any frequency, 1000–8000 Hz in either ear (ASHA, n.d.b).

Audiometric Screening Criteria

The sensitivities and specificities for pure-tone screening test criteria were calculated in relation to the determination

of hearing loss using the pure-tone threshold test; in this case, thresholds greater than 25 dB HL for any test frequency of 1000–8000 Hz in either ear were considered to be a hearing loss. The sensitivities and specificities for all screening methods were calculated based on methods to evaluate the utility of clinical tests (Lalkhen & McCluskey, 2008; Turner & Nielsen, 1984; Turner et al., 1984):

$$\text{Sensivitity} = \frac{\text{True positives}}{\text{True positives} + \text{False negatives}} \quad (1)$$

$$\text{Specificity} = \frac{\text{True negatives}}{\text{True negatives} + \text{False positives}} \quad (2)$$

The following three pure-tone screening criteria were evaluated:

1. Criterion A: Thresholds greater than 25 dB HL at a single frequency (1000, 2000, or 4000 Hz) in either ear (Gomez et al., 2001) and as cited by ASHA (n.d.a).
2. Criterion B: Thresholds greater than 40 dB HL at any single frequency (1000, 2000, or 4000 Hz) in either ear (Eekhof et al., 1996; Sindhusake et al., 2001).
3. Criterion C: Thresholds greater than 40 dB HL at 2000 Hz in both ears (Gates et al., 2003).

Single-Question Screenings

Three, single-item questions were analyzed for their potential to screen for the presence of hearing loss: (a) "*Do you think you have hearing loss?* Yes/No/I don't know" ("¿*Cree usted que tiene pérdida de audición*?" Sí/No/No sé), (b) "*Do your family members or friends think you have a hearing loss?* Yes/No/I don't know" (*"¿Creen sus familiares o amigos que usted tiene pérdida de audición?"* Sí/No/No sé), and (c) "*Do you have problems hearing on the telephone?* Always/Sometimes/Never" (*"¿Tiene problemas para oir por teléfono?"* Siempre/Algunas veces/Nunca). For the purposes of this sensitivity and specificity study, responses of "sometimes" and "always" were grouped to create a binary categorical response variable "yes," whereas "never" was categorized as a "no." Sensitivities and specificities were determined for each single-item question, relative to the pure-tone threshold test for the full sample (without hearing loss, $n = 13$; with hearing loss, $n = 118$).

Multiquestion Screening

The HHIE-S, with ten 4-point questions, was evaluated for sensitivity and specificity with a > 8 cutoff score (Ventry & Weinstein, 1983), relative to the pure-tone threshold test. Each question can receive 0, 2, or 4 points depending on the individual's answer, resulting in a minimum score of 0 and a maximum score of 40. Spanish translations of the HHIE-S were nearly entirely consistent with Lichtenstein and Hazuda (1998). As part of the functional translation process for Oyendo Bien (Colina et al., 2017), one question from the HHIE-S, "*Does a hearing problem cause you to attend religious services less often than you would like?*" was changed to meet the cultural preferences of the community, "*Is it difficult to hear a conversation with a group of people?*" Results were categorized by HHIE-S total scores: 0–8 (*no self-perceived hearing disability*), 10–24 (*mild-to-moderate disability*), and 26–40 (*severe disability*). If the participant rated themselves > 8, they were considered to have a subjective hearing disability based on the published scoring method (Ventry & Weinstein, 1983). Two of the 131 participants answered nine out of 10 questions on the HHIE-S. Because their total scores exceeded the > 8 cutoff, they were still included in the data set. Table 1 provides a summary of the criteria used to characterize the hearing screening methods evaluated in this study.

Procedure

Participant recruitment, enrollment, and data collection took place over the course of a 3-year time period as part of a larger clinical trial (Randomized Controlled Trial of a Community Health Worker Program on Hearing Loss [Oyendo Bien; NCT03255161]). All human data collection was approved by the University of Arizona Institutional

Table 1. Definitions of screening criteria used.

Variable	Criteria label	Definition
Audiometric Screening Criteria	Criterion A	> 25 dB HL in either ear at 1.0, 2.0, or 4.0 kHz
	Criterion B	> 40 dB HL in either ear at 1.0, 2.0, or 4.0 kHz
	Criterion C	> 40 dB HL in both ears at 2.0 kHz
Self-Report Screening Questions	Self-perception of hearing loss	¿Cree usted que tiene pérdida de audición? (Do you think you have hearing loss?) Yes = positive, No = negative
	Family perception of hearing loss	¿Creen sus familiares o amigos que usted tiene pérdida de audición? (Do your family members or friends think you have a hearing loss?) Yes = positive, No = negative
	Functional perception (telephone)	¿Tiene problemas para oir por teléfono? (Do you have problems hearing on the telephone?) Yes = positive, No = negative
	Multi-item screening questionnaire	Hearing Handicap Index for the Elderly–Screening (administered in Spanish) > 8 = positive, < 8 = negative

Review Board prior to recruitment. The research program recruited participants and their communication partner(s) (dyads/triads), one with suspected hearing loss and one (or two) as their primary communication partner(s) (who may or may not also have hearing loss). Those dyads/triads who met the clinical trial eligibility requirements, including having at least one person with audiometrically confirmed hearing loss, were invited to participate in *Oyendo Bien*, a 5-week Spanish-language hearing health education program (Marrone et al., 2017).

The CHWs contacted individuals and families within the community to participate in free hearing screening events with their primary communication partner. Individuals were recruited via word of mouth, flyer, and radio announcements in the community. Participants were provided with a verbal explanation of the informed consent and a hard copy in their preferred language. Extra efforts were taken by the CHWs and research staff to ensure full understanding of the study in order to remain culturally sensitive. Following informed consent, the participant engaged in an interview process in their preferred language (Spanish or English). This interview included additional questions inquiring about various aspects of their hearing health and communication for the purpose of eligibility assessment and baseline data collection for the randomized controlled trial. The CHWs conducted these interviews in either Spanish (96%) or English (4%). Within the interview, the three single-item questions and the HHIE-S were administered. Analyses of additional interview items are forthcoming.

Results

Demographics of the Sample

Table 2 presents the demographic characteristics of the participants in this study. Notable aspects of the sample include the following: (a) There were more women than men; (b) the majority of the participants' ages fell between 65 and 74 years; (c) the participant pool is predominantly Hispanic/Latinx, only 2.3% report as non-Hispanic/Latinx; and (d) the majority of participants (58%) had less than a high school education. This sample is reflective of the demographics in Nogales, AZ, for adults over age 65 years (U.S. Census Bureau, 2017).

Pure-Tone Threshold Test

Pure-tone threshold tests of the 131 participants showed that 118 had hearing loss and 13 had normal hearing. The criterion used to classify hearing status was based on pure-tone thresholds greater than 25 dB HL at any frequency between 1000 and 8000 Hz in either ear. The degree of hearing loss found ranged from mild to profound, and configurations varied between flat and steeply sloping. Figure 1 displays the mean and range of thresholds (minimum and maximum) of participants. Results are displayed separately for right and left ears.

Table 2. Demographic characteristics of study participants.

Characteristic	Cohort (*N* = 131)
Gender, *n*	
Men	40 (30.5%)
Women	91 (69.5%)
Age groups, *n*	
< 45 years	4 (3.1%)
45–54 years	6 (4.6%)
55–64 years	20 (15.3%)
65–74 years	57 (43.5%)
75–84 years	30 (22.9%)
85+ years	14 (10.1%)
Ethnicity, *n*	
Hispanic	128 (97.7%)
Non-Hispanic	3 (2.3%)
Education, *n*	
Less than high school	76 (58.0%)
High school/GED	26 (19.8%)
More than high school	27 (20.6%)
No response	1 (0.76%)
Other (vocational)	1 (0.76%)
Audiometric hearing ability, *n*	
No hearing loss	13 (9.9%)
Hearing loss	118 (90.1%)

Note. GED = General Educational Development.

Audiometric Screening Criteria

The sensitivities and specificities for the three audiometric screening criteria (displayed in Figure 2) are referenced to the pure-tone threshold test. For audiometric screening Criterion A (a threshold of > 25 dB HL at any

Figure 1. Average pure-tone thresholds of left (X) and right (O) ears across 131 participants (at 3 kHz, *n* = 87). The range of thresholds is indicated with solid gray lines for the right ear and dashed gray lines for the left ear. Note that, for both ears, the maximum thresholds across all frequencies overlap. Overall, the average pure-tone audiogram indicated mild-to-moderately-severe, sloping high-frequency hearing loss in this cohort with no significant differences between the ears for the majority of participants.

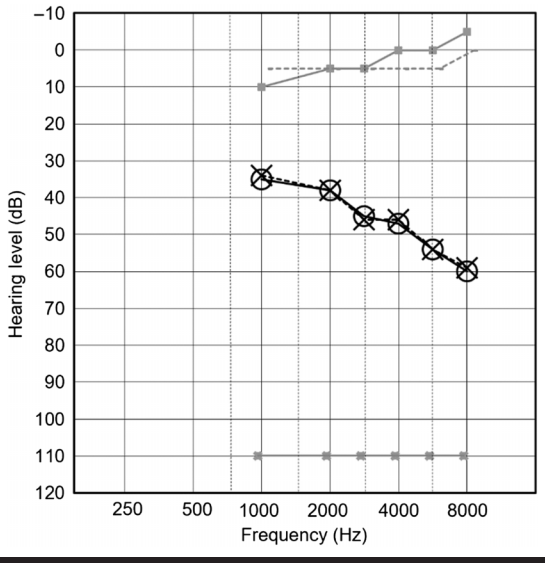
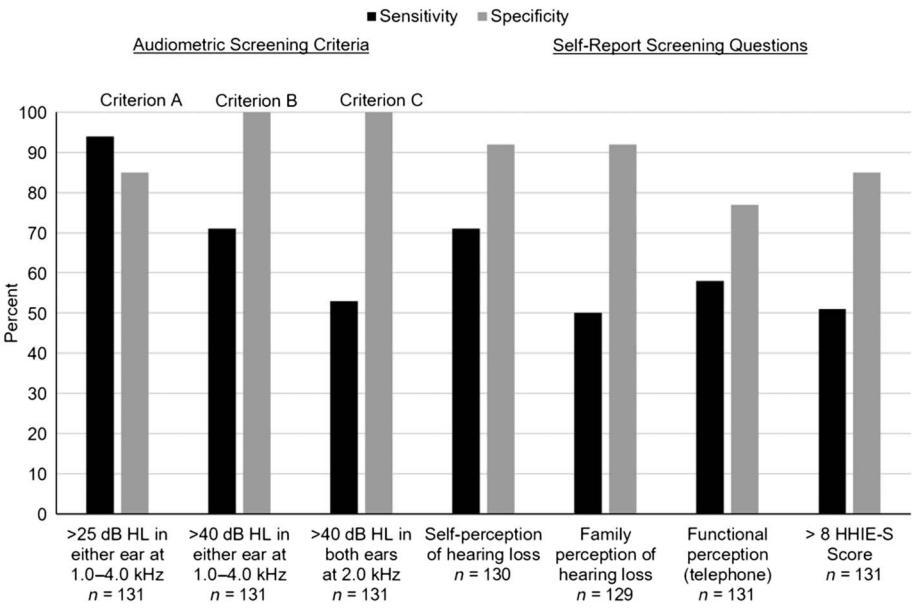


Figure 2. Comparison of screening performance values across audiometric criteria and self-report questions administered in Spanish. The sensitivity and specificity of each screening tool is referenced to a pure-tone threshold test (criterion of > 25 dB HL at any octave frequency). Those with pure-tone thresholds > 25 dB HL for any frequency between 1.0 and 8.0 kHz in either ear were determined to have a hearing loss. HHIE-S = Hearing Handicap Index for the Elderly–Screening.



Scores are referenced to the pure-tone hearing test, using the criterion of > 25 dB HL at any frequency between 1.0 and 8.0 kHz in either ear.

single frequency [1.0, 2.0, or 4.0 kHz] in either ear), the sensitivity was 94% with a specificity of 85%. Screening Criterion B (a threshold of > 40 dB HL at any single frequency in either ear) resulted in a sensitivity of 71% and a specificity of 100%. Screening Criterion C (> 40 dB HL at 2000 Hz in both ears) had a sensitivity of 53% and a specificity of 100%.

Single-Question Screenings

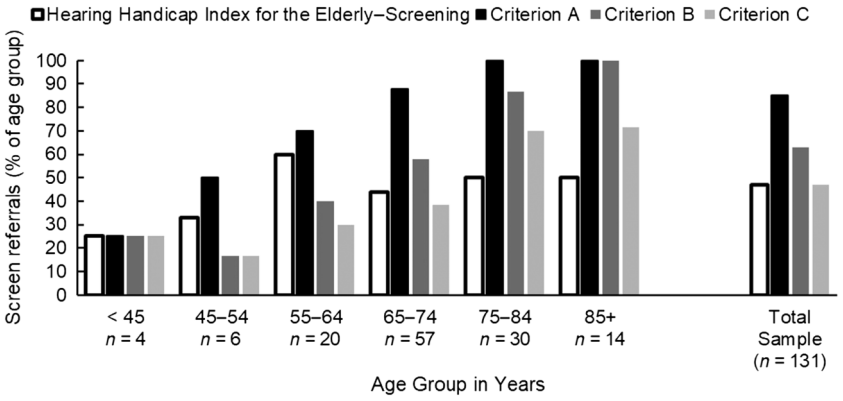
The sensitivity and specificity for each of the single questions used as a screening tool were also determined with respect to the pure-tone threshold test. For the self-perception of hearing loss question, "*¿Cree usted que tiene pérdida de audición? (Do you think you have a hearing loss?),*" the sensitivity was found to be 71% and the specificity was 92% (see Figure 2). The family perception of hearing loss question, "*¿Creen sus familiares o amigos que usted tiene pérdida de audición? (Do your family members or friends think you have hearing loss?),*" had a sensitivity of 50% and a specificity of 92%. Finally, "*¿Tiene problemas para oir por teléfono? (Do you have problems hearing on the phone?),*" a functional representation of hearing loss, resulted in a sensitivity of 58% and a specificity of 77%. Of the single questions, the highest sensitivity was with the question on the individual's self-perception of hearing loss. The highest specificity was equivalent (92%) among the self-perception and family perception questions.

Multiquestion Screening

The sensitivity for the administration of the HHIE-S in Spanish was determined using a criterion cutoff score of > 8. This cutoff score was used because it is the published criterion of the HHIE-S (Ventry & Weinstein, 1983). The HHIE-S results were again compared to the pure-tone threshold test, with a criterion of hearing loss defined as > 25 dB HL for frequencies between 1000 and 8000 Hz in either ear. This resulted in a sensitivity of 51% and specificity of 85%.

Further analysis of the HHIE-S multiquestion screening in Spanish examined results by self-report in comparison to audiometric screening methods. Results are displayed in Figure 3 with participants grouped by age. The percentage of screen referrals from the HHIE-S declines then plateaus after ages 55–64 years. By contrast, the percentage of referrals from audiometric screening Criterion A increased steadily for each decade, reaching 100% by ages 75–84 years. Similarly, Criteria B and C also increased in screen referrals, though the onset is delayed, not beginning to increase until 55–64 years. The discrepancy in trends between audiometric screening and self-report highlights potential differences between objective identification versus functional impact of hearing loss. One possible explanation for the discrepancy may be the relationship between self-report of disability and severity of hearing loss. A second possibility is that the cutoff criteria for the screening methods are not aligned with one another for achieving similar sensitivity

Figure 3. Percentage of screen referrals across age groups using Criterion A (thresholds greater than 25 dB HL at a single frequency [1000, 2000, or 4000 Hz] in either ear), Criterion B (thresholds greater than 40 dB HL at any single frequency [1000, 2000, or 4000 Hz] in either ear), and Criterion C (thresholds greater than 40 dB HL at 2000 Hz in both ears). The number of referrals increases with age, most prominently for Criterion A, yet the average total score on the Hearing Handicap Index for the Elderly–Screening (administered in Spanish) remains relatively unchanged above approximately 65 years.

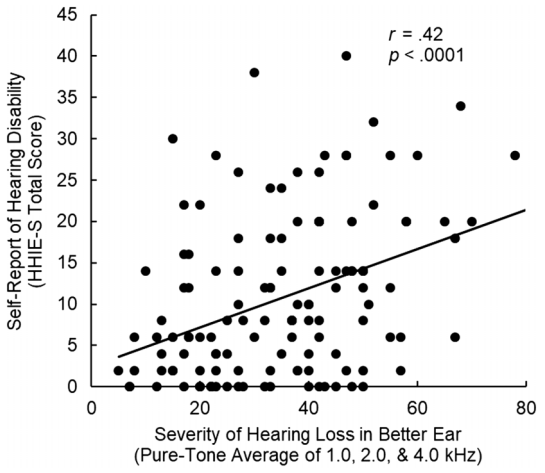


and specificity. The next analyses explored these possibilities in two ways: (a) evaluated the correlation between severity of hearing loss and self-report of disability and (b) explored how the sensitivity and specificity would change with varying cutoff scores.

First, we performed a two-tailed Pearson correlation analysis between the pure-tone average (defined in this study as 1.0, 2.0, and 4.0 kHz in the better ear) and the HHIE-S total score (see Figure 4). As severity of hearing loss in the better ear increased, there was a moderate positive correlation with amount of self-reported hearing disability on the HHIE-S, $r(129) = .42$, $p < .0001$. The same relationship existed between the high-frequency pure-tone average of the worse ear and the HHIE-S total score (not pictured; $r(129) = .44$, $p < .0001$).

Second, we evaluated the sensitivity and specificity of the HHIE-S administered in Spanish as the criterion score was varied (see Figure 5). The sensitivity and specificity scores were calculated relative to the pure-tone threshold test results. With a lower cutoff, the sensitivity of the HHIE-S total score increases. At a cutoff score of > 4, the sensitivity and specificity are both approaching 70%. Comparatively, when Cassarly et al. (2020) lowered the cutoff to > 4 instead of > 8, their results on the HHIE-S (English version) indicated that sensitivity increased to 76.4% from 62.7%.

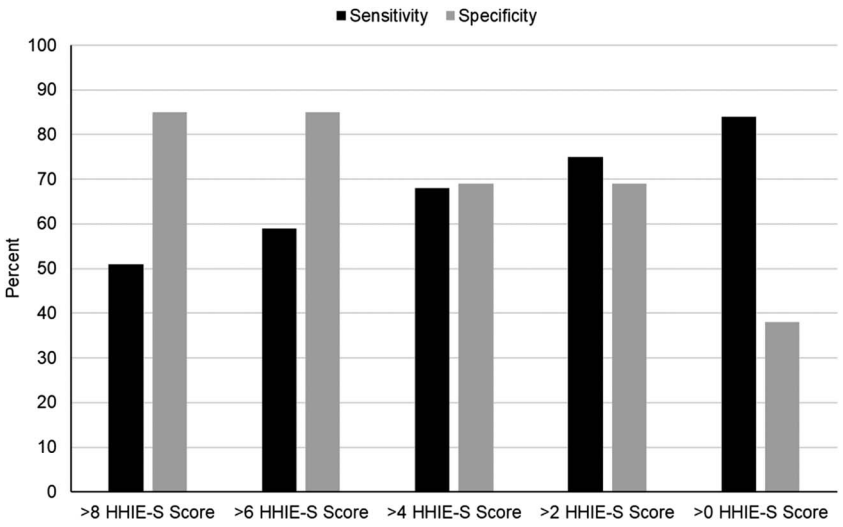
Figure 4. Scatter plot of all participant's pure-tone averages (1.0, 2.0, and 4.0 kHz) in the better ear against the total scores on the Hearing Handicap Index for the Elderly–Screening (HHIE-S) administered in Spanish. Two-tailed Pearson correlations between these two variables resulted in a positive, moderate relationship.



Agreement Between Single-Question Screenings and Multiquestion Screening

Comparing single- versus multiquestion screenings is important when considering potential options that can be implemented in clinical practice. Knowing more information about the agreement between the two subjective measures used in this study will help inform providers of whether or not these measures would be interchangeable. Recall, the highest sensitivity of the three single-question screenings was found for the self-perception of hearing loss question "*¿Cree usted que tiene pérdida de audición? (Do you think you have a hearing loss?)*" The responses to this single question were compared for agreement to the total scores on the HHIE-S delivered in Spanish using the cutoff score of > 8. Cohen's kappa provides a percentage of agreement between responses to the two assessments, taking into consideration random agreements (Landis & Koch, 1977). A cross-tabulation matrix for the unweighted kappa was created based on results from the 130 participants who provided answers to both screening methods. The results of the intertest reliability analysis are kappa = .50, 95% confidence interval (CI) [.35, .65]. This kappa coefficient

Figure 5. Sensitivity and specificity are shown for varying nine cutoff scores on the Hearing Handicap Index for the Elderly–Screening (HHIE-S; administered in Spanish) in reference to the pure-tone test thresholds greater than 25 dB HL at any test frequency, 1000–8000 Hz in either ear.



suggests that there is only a weak agreement between responses on these two self-report measures (McHugh, 2012)

Discussion

The aims of this research were to measure (a) the sensitivity and specificity of three audiometric screening criteria, (b) the sensitivities and specificities of three Spanish-language single-question screenings, and (c) the sensitivity and specificity of the HHIE-S questionnaire in Spanish. Identifying the most sensitive and specific criteria for referring individuals for hearing loss is crucial in order to select a screening method appropriate for clinical practice and economizing resources. The current cohort from a rural community on the southern Arizona border is unique given the significant representation of older Hispanic/Latinx adults with limited access to hearing health care.

When considering the different screening criteria evaluated in this study, the most sensitive measure was the pure-tone air-conduction screening test using Criterion A, > 25 dB HL at 1.0, 2.0, or 4.0 kHz in either ear. Although Criteria B and C resulted in 100% specificity, the sensitivity of a test should be of paramount importance when the target condition (hearing loss) has a high prevalence. For example, in the age range of 60–69 years, the prevalence of hearing loss in at least one ear is 44.86% and continues to increase with each age range: 68.15% for those aged 70–79 years and 90.29% for those older than 80 years (Goman & Lin, 2016). Thus, Criterion A will detect more individuals with hearing loss who may benefit from a referral for audiological evaluation. The other pure-tone screening criteria evaluated in this study had higher specificity but decreased sensitivity. Criterion C, in fact, resulted in the poorest sensitivity of 53%, indicating a sensitivity close to chance.

Overall, the results of this study suggest that the probability of detecting a hearing loss based on self-report of single questions are not as sensitive as pure-tone screening using Criterion A. If self-report screening measures were utilized independently for this population, our results indicate that 29%–50% of the population would not be identified as at risk for hearing loss. A comparison was made between the current findings for the self-perception question (*¿Cree usted que tiene pérdida de audición? Do you think you have a hearing loss?*) and previously published findings (see Table 3). The average sensitivity across six studies, including the current findings, was 68% (*SD* = 6.7%), and the average specificity was 80% (*SD* = 7.2%). The sensitivities found in the current results for the self-perception of hearing loss question are comparable, within ± 5%, to four of the five studies previously cited (Gates et al., 2003; Nondahl et al., 1998; Rawool & Keihl, 2008; Torre et al., 2006). However, our specificity for the same single question is significantly higher than the previous literature suggests. In fact, this question was as sensitive as an audiometric hearing screening criterion to detect a moderate hearing loss (> 40 dB HL in either ear). A possible explanation for the discrepancies in results across studies may be that the criterion used to define a hearing loss differs. For example, some studies considered hearing levels at 500 Hz (Nondahl et al., 1998; Rawool & Keihl, 2008; Sever et al., 1989; Torre et al., 2006), whereas ours did not include this frequency. Additionally, some used a cutoff of > 40 dB HL (Gates et al., 2003; Ventry & Weinstein, 1983), whereas all others used > 25 dB HL.

Ventry and Weinstein (1983) originally concluded that the HHIE-S is not a screening used to detect hearing

Table 3. Single-question screening results.

Study	Screening question	Age	Ethnicity/language	Definition of a case	Sensitivity	Specificity
Current	¿Cree usted que tiene pérdida de audición? (Do you think you have hearing loss?)	29–92	Hispanic/Spanish	Pure-tone audiometry (portable audiometer): > 25 dB HL at 1000, 2000, or 4000 Hz in either ear	0.71 [0.62, 0.79]	0.92 [0.62, 1.0]
Current	¿Creen sus familiares o amigos que usted tiene pérdida de audición? (Do your family members or friends think you have a hearing loss?)	29–92	Hispanic/Spanish	Pure-tone audiometry (portable audiometer): > 25 dB HL at 1000, 2000, or 4000 Hz in either ear	0.50 [0.40, 0.60]	0.92 [0.60, 1.0]
Current	¿Tiene problemas para oir por teléfono? (Do you have problems hearing on the telephone?)	29–92	Hispanic/Spanish	Pure-tone audiometry (portable audiometer): > 25 dB HL at 1000, 2000, or 4000 Hz in either ear	0.58 [0.49, 0.67]	0.77 [0.46, 0.94]
Rawool & Keihl (2008)	Do you think you have a hearing loss?	65–89	Non-Hispanic/English	Pure-tone audiometry (portable audiometer): ≥ 25 dB HL at 500, 1000, 2000, 3000, and 4000 Hz in better ear	0.68 [0.43, 0.87]	0.81 [0.48, 0.98]
Torre et al. (2006)	¿Usted siente que ha perdido su sentido de oido? (Do you feel you have hearing loss?)	42–88	Hispanic/Spanish	Pure-tone audiometry: (portable audiometer) ≥ 25 dB HL at 500, 1000, 2000, and 4000 Hz in poorer ear	0.76 [0.59, 0.88]	0.73 [0.50, 0.89]
Gates et al. (2003)	Do you have a hearing problem now?	72–93	Non-Hispanic/English	Pure-tone thresholds: > 40 dB HL at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in 1 ear	0.71 [0.63, 0.78]	0.72 [0.67, 0.76]
Clark et al. (1991)	Would you say that you have any difficulty hearing?	60–85	Non-Hispanic/English	Pure-tone audiometry: ≥ 25 dB HL at 1000, 2000, 3000, and 4000 Hz in better ear	0.56 [0.47, 0.65]	0.82 [0.75, 0.88]
Nondahl et al. (1998)	Do you feel you have hearing loss?	43–84	Non-Hispanic/English	Pure-tone thresholds: ≥ 25 dB HL at 500, 1000, 2000, and 4000 Hz in either ear	0.67 [0.64, 0.70]	0.80 [0.77, 0.83]

Note. Values in brackets are 95% confidence intervals. ≥ 25 dB = greater than a mild hearing loss. > 40 dB = greater than a moderate hearing loss.

loss; rather, it is a screening for perceived functional disability. Our analysis of the HHIE-S results is in agreement with this statement as the measure had poor sensitivity in identifying hearing loss. Comparisons of our findings for the HHIE-S to previous literature can be seen in Table 4. Our results indicated a sensitivity of 51% (95% CI [42%, 60%]) and a specificity of 85% (95% CI [54%, 97%]), and all studies together show a range of 32%–72% sensitivity and 66%–97% specificity. The average sensitivity of the HHIE-S across eight studies, including our own, was 53% (*SD* = 14.8%), and the average specificity was 85% (*SD* = 9.6%). For the findings summarized in both Tables 3 and 4, it should be noted that the definition of hearing loss, screening criteria, and language of administration differ across studies, which could impact the calculated percentages. Although the HHIE-S is a widely used self-assessment of disability questionnaire, it is not a sensitive tool for identifying adults at risk for hearing loss. This finding is consistent with the previous literature.

Saunders et al. (2018) showed that the HHIE-S (English version) had approximately 40% screen failures regardless of increasing age in community hearing screenings. These results were similar with our findings (see Figure 3) that show approximately 44% referrals on the HHIE-S (Spanish version) regardless of age in a community setting using the > 8 cutoff score. Our findings and those of Saunders et al. point to the fact that pure-tone thresholds do not predict self-reported hearing disability. One possibility for the discrepancy between audiometric and self-report screenings observed in both studies is that, as we age, high frequencies typically decrease before mid and low frequencies, and these threshold changes may not contribute as much to change in self-report of disability on the HHIE-S questions.

The sensitivity findings for the HHIE-S for the current study were comparable to two of the eight previous studies (Lichtenstein et al., 1988; McBride et al., 1994; see Table 4), and the specificity was additionally comparable to the results of Cassarly et al. (2020). The variations in our results compared to others may be related to the demographic differences and the specific questions being asked. This is the second time that single-item self-report questions have been evaluated in the Hispanic/Latinx population in Spanish and the first time that the HHIE-S has been used in this population for the purpose of calculating sensitivity and specificity. The current sensitivity results with the single-question screening on self-perception of hearing loss are comparable to that of Torre et al. (2006), which is the only other study in which a translation into Spanish was used. Across the eight studies reviewed, differences in culture, phrasing of the questions, language of administration, translations of the questionnaires, or the use of a trusted member of the community to conduct the interview may be likely explanations for the differences found.

Kamil et al. (2015) analyzed self-reported hearing loss as compared to audiometric results from the National Health and Nutrition Examination Survey. In the National Health and Nutrition Examination Survey, the sample is selected to be representative of the U.S. population, with oversampling of some minority groups and adults 60 years and older. Kamil et al. reported that older participants with audiometrically documented hearing loss were less likely to self-report hearing loss as compared to younger adults. Hispanic/Latinx adults were less likely to self-report hearing loss compared to age-matched White and Black counterparts. Furthermore, these researchers found that less education (< high school) was significantly associated with less self-report in the presence of audiometrically defined hearing loss. While it is possible that demographic factors could influence likelihood of self-report of hearing loss in our study, another possible influence is that the recruitment pool is drawing from primarily individuals interested in a program on hearing loss plus their frequent communication partners (who may or may not have had the same perceptions of their own hearing). Yet, by examining the sensitivity and specificity of multiple questions within the same population, we also see an important influence of the specific question being asked. Therefore, in research, which examine demographic influences on self-report, the role of the selected question should also be considered.

The single-question and HHIE-S questionnaire findings indicate the need for more than self-report in accurately detecting those with hearing loss. An important finding is the large range of sensitivities among the single question across studies (50%–76%). These findings suggest that, at best, 24% of the population or about 7.2 million people would remain undetected with this screening metric alone. Although the HHIE-S is a screening tool for hearing disability, decreasing the cutoff score on the HHIE-S may provide more utility for detecting hearing loss. When the cutoff score was decreased to > 2, for example, the sensitivity increased to 75% while still maintaining an acceptable 69% specificity.

It is important to bear in mind the possible sampling bias in these results. Our participants were recruited for a community program on hearing loss, suggesting that at least one person in a communication pair will likely have a hearing loss. Additionally, volunteering to participate in such a program may imply that the participant's self-assessment of their hearing difficulties is different than the population who does not participate in the program. Because of this, the prevalence of hearing loss and the sensitivity of the questionnaires, within this sample population, may be positively skewed. However, we still determined that 29% of individuals reported that they did not have a hearing loss when in fact they did. This again suggests that self-report alone is likely not sensitive enough to detect hearing loss.

Another viable option we explored for detecting hearing loss is to refer based on age. As displayed in Figure 3, the pure-tone screen failures using Criterion A increase with age, reaching 70% for the 55- to 64-year-old age group. For our participants aged 60 years and older, 94% had a hearing loss based on the pure-tone threshold test (n = 114). This high prevalence suggests that age alone puts an individual at a higher risk for hearing loss (see also Goman & Lin, 2016). Additionally, they would likely benefit from

Table 4. Multiquestion screening (Hearing Handicap Index for the Elderly–Screening), positive result = score > 8.

Study	Age (years)	Ethnicity/language	Definition of a case	Sensitivity	Specificity
Current	29–92	Hispanic/Spanish	Pure-tone audiometry (portable audiometer): > 25 dB HL at 1000, 2000, or 4000 Hz in either ear	0.51 [0.42, 0.60]	0.85 [0.54, 0.97]
Lichtenstein et al. (1988)	> 65	Non-Hispanic/English	HFPTA: ≥ 25 dB HL at 1000, 2000, and 4000 Hz in better ear	0.53 [0.43, 0.63]	0.84 [0.74, 0.91]
McBride et al. (1994)	> 60	Non-Hispanic/English	HFPTA: ≥ 25 dB HL at 1000, 2000, and 4000 Hz in better ear	0.48 [0.39, 0.58]	0.86 [0.79, 0.94]
Sever et al. (1989)	60–84	Non-Hispanic/English	SFPTA: ≥ 25 dB HL at 500, 1000, and 2000 Hz in better ear	0.71 [0.48, 0.89]	NR
Nondahl et al. (1998)	43–84	Non-Hispanic/English	Pure-tone thresholds: ≥ 25 dB HL at 500, 1000, 2000, and 4000 Hz in either ear	0.32 [0.29, 0.35]	0.97 [0.95, 0.98]
Gates et al. (2003)	72–93	Non-Hispanic/English	Pure-tone thresholds: > 40 dB HL at 1000 or 2000 Hz in both ears or 1000 and 2000 Hz in 1 ear	0.36 [0.28, 0.44]	0.92 [0.89, 0.94]
Ventry & Weinstein (1983)	NR	NR	> 40 dB HL at 1000 or 2000 Hz in both ears	0.72 [0.56, 0.85]	0.66 [0.52, 0.77]
Cassarly et al. (2020)	*M* = 70.4	Non-Hispanic/English	> 25 dB HL at 500, 1000, 2000, and 4000 Hz in worse ear	0.63 [0.59, 0.66]	0.84 [0.81, 0.86]

Note. Values in brackets are 95% confidence intervals. ≥ 25 dB = greater than a mild hearing loss. HFPTA = High-Frequency Pure-Tone Average. SFPTA = Speech-Frequency Pure-Tone Average. > 40 dB = greater than a moderate hearing loss. NR = not reported.

a referral to an audiologist for full evaluation and discussion of management options. A limitation of this strategy is that, if a person does not self-report or believe they have a hearing loss, a referral for audiologic evaluation based on age alone may not be followed. In these situations, an in-office pure-tone screening could be implemented to demonstrate the need for more in-depth assessment.

Detecting hearing loss is important for providing appropriate treatment and management, yet due to time constraints, lack of knowledge, and underresourced clinics, hearing screenings are often not routinely incorporated into primary care appointments (Cohen et al., 2005; Newman & Sandridge, 2004). In fact, Mahboubi et al. (2018) found only 14.6% of physicians screened for hearing loss at an appointment. Additionally, of the patients who had a hearing complaint at their primary care visit, only 59.9% were referred to an audiologist or otolaryngologist (Mahboubi et al., 2018). While a single question about hearing may not be the most sensitive measure as compared to pure-tone screening, it is efficient and may invite conversation about communication needs and pursuing hearing health care.

Other screening procedures such as otoscopy may provide opportunity for making necessary medical referrals. Screening methods beyond otoscopy are needed to detect hearing loss so that older adults can obtain a referral to a professional who can assess their hearing and provide specific treatment options. When developing a clinical protocol, it is important to consider (a) what level of hearing loss you are trying to identify in order to choose the appropriate cutoff scores (Dobie et al., 2004; Lichtenstein et al., 1988), (b) if you are detecting audiometric hearing loss or self-report of disability, and (c) which question is being asked (sensitivity and specificity, language, etc.).

Detecting hearing loss in its early stages is important because of its association with accelerated cognitive decline and dementia (Lin et al., 2013; Livingston et al., 2017). It is critical to establish effective screening methods for implementation in routine primary care appointments. Based on the findings of the current study, the sensitivity and specificity of self-reported hearing loss varies depending on the question asked among the older Hispanic/Latinx population living near the U.S.–Mexico border. Determining the most sensitive question for a given population is important so that early management strategies such as health promotion programs on hearing loss could be implemented.

Limitations and Future Directions

One limitation to this study was that there were twice as many women as there were men in the sample that could potentially influence the results. Gender imbalance may skew the data because hearing loss in Hispanic/Latinx adults is more prevalent in men compared to women (Cruickshanks et al., 2015). Additionally, Kamil et al. (2015) found that older women and Hispanics with hearing loss were less likely to self-report hearing loss compared to other demographic groups with hearing loss. Choi et al. (2019), Kim et al. (2017), and Wang et al. (2019) analyzed self-report data from Korean and Chinese population samples and found that women were more likely to overestimate their hearing loss as compared to men who were more likely to underestimate their hearing loss. Although the literature may not be conclusive on the effect of gender and culture on self-report of hearing loss, we still acknowledge this limitation of our study sample.

Beyond the methods used here, there are other methods that could be employed for hearing screening. Such examples include otoacoustic emissions, auditory brainstem response, automated or self-administered tests of pure-tone thresholds, and/or speech in noise. Otoacoustic emissions and auditory brainstem response screenings can be readily performed in physician offices or health clinics to screen for hearing status, though more commonly in pediatric settings (Barker et al., 2000; Bonfils et al., 1990; Cone-Wesson et al., 2000; Widen et al., 2000). Self-administered hearing screenings can be accessed via online/tablet and telephone means (Yeung et al., 2015). For example, the National Hearing Test (Watson et al., 2012) presents three-number sequences in adaptive signal-to-noise ratios over the phone to determine left and right ear thresholds in signal-to-noise ratio. The National Hearing Test has been validated for screening hearing loss in adults (Williams-Sanchez et al., 2014). These tests and others available to the public are additional screening measures that could be implemented for the purpose of detecting hearing loss in adults and warrant sensitivity and specificity analyses.

Conclusion

This study sheds light on important topics for health care clinicians as the U.S. population is aging and diverse. In order to accurately identify which individuals need further evaluation, it is important that we continue to conduct research that is inclusive of diverse populations and to adapt health care practices that are culturally appropriate and reliable. This includes the use of sensitive and specific screening measures that are suitable for non–English-speaking populations. Among older, Spanish-speaking adults, self-reported hearing status had a lower sensitivity for identifying mild hearing loss as compared to an audiometric screening criterion of > 25 dB HL. Of note, an audiometric screening criterion to detect moderate hearing loss (> 40 dB HL) was as sensitive as asking a single question, *¿Cree usted que tiene pérdida de audición?* (*Do you think you have hearing loss?*). However, of the tools evaluated here, this single-item question proved to be a more sensitive and specific tool than a multi-item screen. Our findings suggest the utility of a pure-tone screening test using a criterion of greater than 25 dB HL at a single frequency (1000, 2000, or 4000 Hz) in either ear provides the highest sensitivity for a screening measure to determine risk for hearing loss and need for comprehensive audiologic evaluation. Providing audiometric screenings in primary care and community settings should be investigated as a method for identifying those at risk and supporting more personalized recommendations for pursuing hearing health care.

Acknowledgments

Research reported in this publication was supported by National Institute on Deafness and Other Communication Disorders Award R33DC013681 (awarded to PI: Marrone). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. We gratefully acknowledge The University of Arizona audiology clinical faculty and graduate students for their contributions to hearing testing, especially Daisey Sanchez, Adriana Sanchez, Laura Coco, Clemente Morales, Giau Le, Julie Peterson, Erica Hansen, and Stephanie Adamovich. We are also grateful to the contributions of our community partners and participants.

References

American National Standards Institute. (2003). *Maximum permissible ambient noise levels for audiometric test rooms* (Rev. ed.) (ANSI S3.1-1999). New York, NY: Author.

American Speech-Language-Hearing Association. (2018). *Demographic profile of ASHA members providing bilingual services, year-end 2018*. Retrieved from https://www.asha.org/uploadedFiles/Demographic-Profile-Bilingual-Spanish-Service-Members.pdf

American Speech-Language-Hearing Association. (n.d.a). *Adult hearing screening* (Practice Portal). Retrieved September 10, 2019, from https://www.asha.org/Practice-Portal/Professional-Issues/Adult-Hearing-Screening/

American Speech-Language-Hearing Association. (n.d.b). *Hearing loss: Ages 5+* (Practice Portal). Retrieved from September 10, 2019, https://www.asha.org/Practice-Portal/Clinical-Topics/Hearing-Loss/

Barker, S. E., Lesperance, M. M., & Kileny, P. R. (2000). Outcome of newborn hearing screening by ABR compared with four different DPOAE pass criteria. *American Journal of Audiology, 9*(2), 142–148.

Bess, F. H., Lichtenstein, M. J., Logan, S. A., & Burger, M. C. (1989). Comparing criteria of hearing impairment in the elderly: A functional approach. *Journal of Speech and Hearing Research, 32*(4), 795–802.

Bonfils, P., Dumont, A., Marie, P., Francois, M., & Narcy, P. (1990). Evoked otoacoustic emissions in newborn hearing screening. *The Laryngoscope, 100*(2), 186–189.

Cassarly, C., Matthews, L. J., Simpson, A. N., & Dubno, J. R. (2020). The Revised Hearing Handicap Inventory and Screening tool based on psychometric reevaluation of the Hearing Handicap Inventories for the Elderly and Adults. *Ear and Hearing, 41*(1), 95–105. https://doi.org/10.1097/AUD.0000000000000746

Chan, D. (2009). So why ask me? Are self-report data really that bad. In C. L. Lance & R. J. Vandenberg (Eds.), *Statistical and methodological myths and urban legends: Doctrine, verity and fable in the organizational and social sciences* (pp. 309–336). New York, NY: Taylor & Francis.

Choi, J. E., Moon, I. J., Baek, S. Y., Kim, S. W., & Cho, Y. S. (2019). Discrepancies between self-reported hearing difficulty and hearing loss diagnosed by audiometry: Prevalence and associated factors in a national survey. *British Medical Journal, 9*(4), e022440.

Chou, R., Dana, T., Bougatsos, C., Fleming, C., & Beil, T. (2011). Screening adults aged 50 years or older for hearing loss: A review of the evidence for the US preventive services task force. *Annals of Internal Medicine, 154*(5), 347–355.

Clark, K., Sowers, M., Wallace, R. B., & Anderson, C. (1991). The accuracy of self-reported hearing loss in women aged 60–85 years. *American Journal of Epidemiology, 134*(7), 704–708.

Coco, L., Titlow, K. S., & Marrone, N. (2018). Geographic distribution of the hearing aid dispensing workforce: A teleaudiology planning assessment for Arizona. *American Journal of Audiology, 27*(3S), 462–473.

Cohen, S. M., Labadie, R. F., & Haynes, D. S. (2005). Primary care approach to hearing loss: The hidden disability. *Ear, Nose & Throat Journal, 84*(1), 29–31.

Colina, S., Marrone, N., Ingram, M., & Sánchez, D. (2017). Translation quality assessment in health research: A functionalist alternative to back-translation. *Evaluation & the Health Professions, 40*(3), 267–293.

Cone-Wesson, B., Vohr, B. R., Sininger, Y. S., Widen, J. E., Folsom, R. C., Gorga, M. P., & Norton, S. J. (2000). Identification of neonatal hearing impairment: Infants with hearing loss. *Ear and Hearing, 21*(5), 488–507.

Cruickshanks, K. J., Dhar, S., Dinces, E., Fifer, R. C., Gonzalez, F., II, Heiss, G., Hoffman, H. J., Lee, D. J., Newhoff, M., Tocci, L., Torre, P., III, & Tweed, T. S. (2015). Hearing impairment prevalence and associated risk factors in the Hispanic Community Health Study/Study of Latinos. *JAMA Otolaryngology—Head & Neck Surgery, 141*(7), 641–648.

Dobie, R. A., Van Hemel, S., & National Research Council. (2004). *Hearing loss: Determining eligibility for social security benefits*. Washington, DC: National Academies Press.

Dolcini, M. M., Adler, N. E., & Ginsberg, D. (1996). Factors influencing agreement between self-reports and biological measures of smoking among adolescents. *Journal of Research on Adolescence, 6*(4), 515–542.

Eekhof, J. A., De Bock, G. H., de Laat, J. A., Dap, R., Schaapveld, K., & Springer, M. P. (1996). The whispered voice: The best test for screening for hearing impairment in general practice? *British Journal of General Practice, 46*(409), 473–474.

Estrada, A. L., Treviño, F. M., & Ray, L. A. (1990). Health care utilization barriers among Mexican Americans: Evidence from HHANES 1982–84. *American Journal of Public Health, 80,* 27–31.

Gates, G. A., Murphy, M., Rees, T. S., & Fraher, A. (2003). Screening for handicapping hearing loss in the elderly. *Journal of Family Practice, 52*(1), 56–62.

Genther, D. J., Frick, K. D., Chen, D., Betz, J., & Lin, F. R. (2013). Association of hearing loss with hospitalization and burden of disease in older adults. *JAMA, 309*(22), 2322–2324.

Goman, A. M., & Lin, F. R. (2016). Prevalence of hearing loss by severity in the United States. *American Journal of Public Health, 106*(10), 1820–1822.

Goman, A. M., Reed, N. S., & Lin, F. R. (2017). Addressing estimated hearing loss in adults in 2060. *JAMA Otolaryngology—Head & Neck Surgery, 143*(7), 733–734.

Gomez, M. I., Hwang, S. A., Sobotova, L., Stark, A. D., & May, J. J. (2001). A comparison of self-reported hearing loss and audiometry in a cohort of New York farmers. *Journal of Speech, Language, and Hearing Research, 44*(6), 1201–1208.

Hindelang, M. J., Hirschi, T., & Weis, J. G. (1979). Correlates of delinquency: The illusion of discrepancy between self-report and official measures. *American Sociological Review, 44*(6), 995–1014.

Hofmann, W., Gawronski, B., Gschwendner, T., Le, H., & Schmitt, M. (2005). A meta-analysis on the correlation between the Implicit Association Test and explicit self-report measures. *Personality and Social Psychology Bulletin, 31*(10), 1369–1385.

Housing Assistance Council. (2012). Race & ethnicity in rural America. *Rural Research Briefs,* 1283–1288.

Huddle, M. G., Goman, A. M., Kernizan, F. C., Foley, D. M., Price, C., Frick, K. D., & Lin, F. R. (2017). The economic impact of adult hearing loss: A systematic review. *JAMA Otolaryngology—Head & Neck Surgery, 143*(10), 1040–1048.

Kamil, R. J., Genther, D. J., & Lin, F. R. (2015). Factors associated with the accuracy of subjective assessments of hearing impairment. *Ear and Hearing, 36*(1), 164–167.

Kim, S. Y., Kim, H. J., Kim, M. S., Park, B., Kim, J. H., & Choi, H. G. (2017). Discrepancy between self-assessed hearing status and measured audiometric evaluation. *PLOS ONE, 12*(8), e0182718.

Krogstad, J. M. (2017). *U.S. Hispanic population growth has leveled off*. Washington, DC: Pew Research.

Lalkhen, A. G., & McCluskey, A. (2008). Clinical tests: Sensitivity and specificity. *Continuing Education in Anesthesia Critical Care & Pain, 8*(6), 221–223.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*(1), 159–174.

Lichtenstein, M. J., Bess, F. H., & Logan, S. A. (1988). Diagnostic performance of the Hearing Handicap Inventory for the Elderly (Screening Version) against differing definitions of hearing loss. *Ear and Hearing, 9*(4), 208–211.

Lichtenstein, M. J., & Hazuda, H. P. (1998). Cross-cultural adaptation of the Hearing Handicap Inventory for the Elderly–Screening Version (HHIE-S) for use with Spanish-speaking Mexican Americans. *Journal of the American Geriatrics Society, 46*(4), 492–498.

Lin, F. R., Yaffe, K., Xia, J., Xue, Q. L., Harris, T. B., Purchase-Helzner, E. Satterfield, S., Ayonayon, H. N., Ferrucci, L., Simonsick, E. M., & Health ABC Study Group. (2013). Hearing loss and cognitive decline in older adults. *JAMA Internal Medicine, 173*(4), 293–299.

Livingston, G., Sommerlad, A., Orgeta, V., Costafreda, S. G., Huntley, J., Ames, D., Ballard, C., Banerjee, S., Burns, A., Cohen-Mansfield, J., Cooper, C., Fox, N., Gitlin, L. N., Howard, R., Kales, H. C., Larson, E. B., Ritchie, K., Rockwood, K., Sampson, E. L., & Mukadam, N. (2017). Dementia prevention, intervention, and care. *The Lancet, 390*(10113), 2673–2734.

Mahboubi, H., Lin, H. W., & Bhattacharyya, N. (2018). Prevalence, characteristics, and treatment patterns of hearing difficulty in the United States. *JAMA Otolaryngology—Head & Neck Surgery, 144*(1), 65–70.

Marrone, N., Ingram, M., Somoza, M., Sánchez Jacob, D., Sanchez, A., Adamovich, S., & Harris, F. P. (2017). Interventional audiology to address hearing healthcare disparities: Oyendo Bien pilot study. *Seminars in Hearing, 38*(2), 198–211.

McBride, W. S., Mulrow, C. D., Aguilar, C., & Tuley, M. R. (1994). Methods for screening for hearing loss in older adults. *American Journal of the Medical Sciences, 307*(1), 40–42.

McHugh, M. L. (2012). Interrater reliability: The kappa statistic. *Biochemia Medica, 22*(3), 276–282.

Menkin, J. A., Guan, S. A., Araiza, D., Reyes, C. E., Trejo, L., Choi, S. E., Willis, P., Kotick, J., Jimenez, E., Ma, S., McCreath, H., Chang, E., Witarama, T., & Sarkisian, C. A. (2017). Racial/ethnic differences in expectations regarding aging among older adults. *The Gerontologist, 57*(Suppl. 2), S138–S148.

Mick, P., Foley, D., Lin, F., & Pichora-Fuller, M. K. (2018). Hearing difficulty is associated with injuries requiring medical care. *Ear and Hearing, 39*(4), 631–644.

Moscicki, E. K., Elkins, E. F., Baum, H. M., & McNamara, P. M. (1985). Hearing loss in the elderly: An epidemiologic study of the Framingham Heart Study cohort. *Ear and Hearing, 6*(4), 184–190.

National Hispanic Council on Aging. (2017). *Breaking stigmas, creating awareness, and increasing age-sensitive education are three key elements to improve the lives Alzheimer's patients and their caregivers*. Retrieved from http://www.nhcoa.org/breaking-stigmas-creating-awareness-and-increasing-age-sensitive-education-are-three-key-elements-to-improve-the-lives-alzheimers-patients-and-their-caregivers/

Newman, C. W., & Sandridge, S. A. (2004). Hearing loss is often undiscovered, but screening is easy. *Cleveland Clinic Journal of Medicine, 71*(3), 225–232.

Nieman, C. L., Marrone, N., Szanton, S. L., Thorpe, R. J., Jr., & Lin, F. R. (2016). Racial/ethnic and socioeconomic disparities in hearing health care among older Americans. *Journal of Aging and Health, 28*(1), 68–94.

Nondahl, D. M., Cruickshanks, K. J., Wiley, T. L., Tweed, T. S., Klein, R., & Klein, B. E. (1998). Accuracy of self-reported hearing loss. *Audiology, 37*(5), 295–301.

Pinder, R. J., Ferguson, J., & Møller, H. (2016). Minority ethnicity patient satisfaction and experience: Results of the National Cancer Patient Experience Survey in England. *British Medical Journal, 6*(6), e011938.

Rawool, V. W., & Keihl, J. M. (2008). Perception of hearing status, communication, and hearing aids among socially active older individuals. *Journal of Otolaryngology, 37*(1), 27–42.

Reuben, D. B., Herr, K. A., Pacala, J. T., Pollock, B. G., Potter, J. F., & Semla, T. P. (2017). *Geriatrics at your fingertips* (19th ed.). AGS.

Saunders, G. H., Frederick, M. T., Silverman, S. C., Penman, T., Gardner, A., Chisolm, T. H., Escabi, C. D., Oree, P. H., Westermann, L. C., Sanchez, V. A., & Arnold, M. L. (2018). Hearing screening in the community. *Journal of the American Academy of Audiology, 30*(2), 145–152.

Sever, J. C., Jr., Harry, D. A., & Rittenhouse, T. S. (1989). Using a self-assessment questionnaire to identify probable hearing loss among older adults. *Perceptual and Motor Skills, 69*(2), 511–514.

Sindhusake, D., Mitchell, P., Smith, W., Golding, M., Newall, P., Hartley, D., & Rubin, G. (2001). Validation of self-reported hearing loss. The Blue Mountains hearing study. *International Journal of Epidemiology, 30*(6), 1371–1378.

Torre, P., III, Moyer, C. J., & Haro, N. R. (2006). The accuracy of self-reported hearing loss in older Latino-American adults. *International Journal of Audiology, 45*(10), 559–562.

Turner, R. G., & Nielsen, D. W. (1984). Application of clinical decision analysis to audiological tests. *Ear and Hearing, 5*(3), 125–133.

Turner, R. G., Shepard, N. T., & Frazer, G. J. (1984). Clinical performance of audiological and related diagnostic tests. *Ear and Hearing, 5*(4), 187–194.

U.S. Census Bureau. (2010). *2010 Census Summary File 1*. Retrieved from https://www.census.gov/prod/cen2010/doc/sf1.pdf

U.S. Census Bureau. (2017). *World population review: Nogales, Arizona*. Retrieved from http://worldpopulationreview.com/us-cities/nogales-az-population/

U.S. Census Bureau. (2018). *The population 65 years and older in the United States: 2016*. Retrieved from https://www.census.gov/content/dam/Census/library/publications/2018/acs/ACS-38.pdf

Ventry, I. M., & Weinstein, B. E. (1983). Identification of elderly people with hearing problems. *ASHA, 25*(7), 37–42.

Wang, D., Zhuang, Y., Wu, Y., Ma, H., Peng, Y., Xu, H., Zhang, B., Zhang, L., Lei, S. Yang, L. & Xu, L. (2019). Analysis of

influential factors of self-reported hearing loss deviation in young adults. *Journal of Public Health,* 1–7.

Watson, C. S., Kidd, G. R., Miller, J. D., Smits, C., & Hume, L. E. (2012). Telephone screening tests for functionally impaired hearing: Current use in seven countries and development of a US version. *Journal of the American Academy of Audiology, 23*(10)*,* 757–767.

Widen, J. E., Folsom, R. C., Cone-Wesson, B., Carty, L., Dunnell, J. J., Koebsell, K., Levi, A., Mancl, L., Ohlrich, B.,Trouba, S., Gorga, M. P., Sininger, Y. S., Vohr, B. R., & Norton, S. J. (2000). Identification of neonatal hearing impairment: Hearing status at 8 to 12 months corrected age using a visual reinforcement audiometry protocol. *Ear and Hearing, 21*(5), 471–487.

Williams-Sanchez, V., McArdle, R. A., Wilson, R. H., Kidd, G. R., Watson, C. S., & Bourne, A. L. (2014). Validation of a screening test of auditory function using the telephone. *Journal of the American Academy of Audiology, 25*(10), 937–951.

Yeung, J. C., Heley, S., Beauregard, Y., Champagne, S., & Bromwich, M. A. (2015). Self-administered hearing loss screening using an interactive, tablet play audiometer with ear bud headphones. *International Journal of Pediatric Otorhinolaryngology, 79*(8), 1248–1252.