**Depression and Health-Related Quality of Life Among Older Adults with Hearing Loss in the ACHIEVE Study**

**Abstract**

Hearing loss is associated with cognitive/physical health; less is known about mental health. We investigate associations between hearing loss severity, depression, and health-related quality of life among older adults with untreated hearing loss. Data (N=948) were from The Aging and Cognitive Health Evaluation in Elders study. Hearing was measured by pure-tone average (PTA), Quick Speech-in-Noise (QuickSIN) test, and the Hearing Health Handicap Inventory for the Elderly (HHIE-S). Outcomes were validated measures of depression and health-related quality of life. Associations were assessed by negative binomial regression. Worse PTA was associated with worse physical health-related quality of life (IRR: 0.98, 95% CI: 0.96, 1.00). Better QuickSIN was associated with higher mental health-related quality of life (1.01[1.00, 1.02]). Worse HHIE-S was associated with depression (1.24[1.16, 1.33]) and worse mental (0.97[0.96, 0.98]) and physical (0.95[ 0.93, 0.96]) health-related quality of life. Further work will test the effect of hearing intervention on mental health.

**Key Words:** hearing loss, depression, mental health, epidemiology

**What this paper adds**

* There is evidence of an association between hearing loss and cognitive and physical health; this study fills a gap in the less understood area of hearing loss and mental health
* This study uniquely measures multiple dimensions of hearing allowing a comprehensive investigation of how hearing loss and its impact on activity participation are associated with mental health

**Application of study findings**

* The HHIE-S is a short questionnaire that could be useful in clinical settings to identify older adults who may struggle with mental health
* Future investigation in this clinical trial will test whether hearing intervention is efficacious for mental health and well-being

**Introduction**

Hearing loss can affect day-to-day function and lead to difficulty with communication (Dalton et al., 2003; Garstecki & Erler, 1999), social and activity limitations (Mick et al., 2014; Pronk et al., 2011; Shukla et al., 2020), loneliness (H. L. Chen, 1994; Huang et al., 2021; Shukla et al., 2020), reduced physical activity and function (Choi, Betz, Deal, et al., 2016; Martinez-Amezcua, Kuo, et al., 2021; Martinez-Amezcua, Suen, et al., 2021), and cognitive decline and dementia (Deal et al., 2016; Huang et al., 2023; Lin et al., 2011; Livingston et al., 2020). Hearing loss and the associated functional consequences of hearing loss may also impact mental health and quality of life (Dalton et al., 2003; Lawrence et al., 2020; Tseng et al., 2018).

The prevalence of hearing loss increases with age, with two thirds of older adults over 70 years having hearing loss (Goman & Lin, 2016).Hearing has multiple components. Peripheral hearing refers to the transduction and encoding of sound in the cochlea and typically measured by detection of simple pure tones in quiet (e.g., pure tone audiometry [PTA]). Speech-in-noise recognition is another component of hearing that captures the more complex and higher order auditory tasks that are important for central auditory function. Central auditory function includes both bottom-up (transmission of auditory signals to the auditory cortex) and top-down processing (cognitive function to recognize and interpret the auditory signals) (Shuai & Gong, 2014). Thirdly, the self-perceived functional, emotional, and social consequences of hearing loss are also critical components of hearing and shown to have strong associations with both mental and physical health. The Hearing Handicap Inventory for the Elderly (HHIE) and the shorter screening version (HHIE-S) are validated measures of self-perceived limitations in activity and participation due to hearing loss.

The prevalence of depression is also high among community-dwelling older adults in the United States (10%) (Cao et al., 2020) and nearly twice as high among older adults with hearing loss (19%) (Gopinath et al., 2009). Among older adults in the Atherosclerosis Risk in Communities Neurocognitive Study, moderate or greater hearing loss (PTA ≥ 40 decibels hearing level [db HL]) was associated with over 2 times higher odds of clinically significant depressive symptoms (Shukla et al., 2021). Additionally, a meta-analysis of 35 studies reported hearing loss (measured objectively in 9 of 35 of studies) was associated with 1.47 (1.31-1.65) greater odds of prevalent depression (Lawrence et al., 2020). One study in this meta-analysis assessed speech-in-noise recognition and observed no association with depression (Pronk et al., 2011) and only one study used a validated measure of the self-perceived functional, emotional, and social consequences of hearing loss (HHIE). Higher HHIE score was associated with higher odds of depressive symptoms (Saito et al., 2010).

# Further, in a systematic review of hearing loss and health-related quality of life, studies observed associations between worse objective hearing (measured by PTA) and worse mental and physical health-related quality of life (Tseng et al., 2018). Associations between worse self-reported hearing and HHIE with lower health-related quality of life (Gopinath et al., 2012). The association between speech-in-noise recognition and health-related quality of life has yet to be examined, to our knowledge, in large epidemiologic studies.

Mental health and health-related quality of life are fundamental components of health and hearing loss may be a modifiable risk factor. However, much of the prior evidence from large, epidemiologic studies is based on subjective hearing. Older adults, in particular, tend to underestimate the severity of their hearing loss, which may introduce bias in studies aiming to capture associations with objective hearing loss. Further, there are multiple components of hearing and some aspects, such as speech-in-noise recognition, are rarely included in studies of hearing loss and well-being yet may also be modifiable risk factors for poor mental health and health-related quality of life.

The objective of the current study was to investigate the cross-sectional associations between hearing loss, depressive symptomology, and health related quality of life among older adults with untreated hearing loss. We hypothesize that worse peripheral hearing is associated with greater depressive symptomology and lower health-related quality of life. A secondary objective of this study was to investigate the associations of speech-in-noise recognition and limitations in activity and participation due to hearing loss with depressive symptomology and health related quality of life. A strength of this study is the availability of multiple measures of hearing, which allows a comprehensive investigation of hearing loss and its association with well-being.

**Methods**

*Study Population*

Data come from the baseline visit (2018-2019) of the Aging and Cognitive Health Evaluation in Elders (ACHIEVE) Study (Deal et al., 2018). ACHIEVE is a randomized clinical trial designed to test the effect of hearing intervention (Arnold et al., 2022; Sanchez et al., 2020) vs. successful aging health education control intervention on cognitive decline in a multi-center sample of older adults with hearing loss (Clinicaltrials.gov Identifier: NCT03243422, IRB protocol number: IRB00008129). Additional details regarding the ACHIEVE study design were published elsewhere (Deal et al., 2018).

The ACHIEVE participants are 977 community dwelling older adults aged 70-84 years with untreated, audiometric hearing loss (better-hearing ear PTA ≥30 and <70 dB hearing level) and without dementia (Mini-Mental State Exam [MMSE] ≥23 for those with high school degree or less, and ≥25 for those with some college education or more). Participants with self-reported difficulty in more than two activities of daily living, vision loss, or who were ineligible for hearing treatment were excluded. ACHIEVE is partially nested within the Atherosclerosis Risk in Communities (ARIC) Study with 24% of participants recruited from the ARIC Study and 75% recruited *de novo*. Participants were recruited from four communities across the United States (Forsyth County, NC; Jackson, MS; selected suburbs of Minneapolis, MN; and Washington County, MD) (Deal et al., 2018). The analytic sample includes 948 participants from the baseline visit (2018-2019); participants with missing or incomplete hearing (Quick Speech-in-Noise [QuickSIN] test: n=5, Hearing Handicap Inventory for the Elderly Screening Vesrion [HHIE-S]: n=7), health-related quality of life (n= 1), and covariate data (n=16) were excluded.

*Measures*

Depressive symptomology

Depressive symptomology was measured by the validated 11-item Center for Epidemiologic Studies Depression scale (CES-D-11) (Kohout et al., 1993). The CES-D-11 measures frequency of depressive symptoms using 11 questions about depressed and positive affect and somatic symptoms and interpersonal symptoms in the past week (less than one day in the past week [0 points], one to two days in the past week [1 point], three to seven days in the past week [2 points]). Responses were summed across questions, with higher scores indicating greater depression symptomology (score range: 0 – 22). The CES-D-11 was analyzed as a continuous score. A score of ≥ 9 on the CES-D-11 is a cut point used to determine clinically significant depressive symptoms. As only 34 participants met this criterion in this sample, CES-D-11 was not modeled as a binary measure.

Health-related quality of life

Health-related quality of life was measured by the RAND-36 Health Survey (RAND-36) (Hays & Morales, 2001). The RAND36 is a validated measure that includes 36 questions across eight domains of health: physical functioning, physical role limitations, emotional role limitations, energy/fatigue, emotional well-being, social functioning, pain, general health. For items that asked about physical health, participants were instructed to consider hearing as part of their physical health. Domain scores range from 0 to 100 with higher scores indicating better health-related quality of life. Two subscales (physical health component summary score, mental health component summary score) were also calculated using the summary component scoring algorithm (Taft et al., 2001).

Peripheral hearing

Peripheral hearing was measured by air conduction PTA. The better ear, speech-frequency PTA was measured by the average of hearing thresholds at four frequencies (0.5-4 kilohertz [kHz]). PTA was analyzed as a continuous score (per 10 decibels [dB] worse hearing level [HL], higher PTA indicates worse hearing) and as a categorical measure defined according to clinical cut points consistent with the World Health Organization: mild (20 – 34.9 dB HL), moderate or greater (≥ 35 dB HL) (Organization, 2021).

Speech-in-noise recognition

Speech-in-noise recognition was measured by the Quick Speech-in-Noise (QuickSIN) test (Killion et al., 2004). Participants were presented with a list of 6 sentences with five key “target” words per sentence. Sentences were presented at 70 dB sound pressure level in the presence of multi-talker (speech babble) background noise. With each sentence, the intensity of background noise was progressively increased in 5-dB increments so that the signal-to-noise ratio decreased with each sentence (+25 dB [first sentence] to no difference [last sentence]). Participants were asked to identify the five key words after each sentence. Two lists were presented to each participant, with the total number of key words identified in each list calculated and then averaged over the two trials (score range: 0 - 30, higher scores indicate better speech-in-noise performance). Speech-in-noise performance was analyzed as a continuous score and as a binary measure (top three quartiles vs. lowest quartile [worse]).

Limitations in activity and participation due to hearing loss

Participants’ perception of limitations in activity and participation due to hearing loss was measured by the 10-item screening version of the HHIE (HHIE-S) (Ventry & Weinstein, 1982). The HHIE-S assesses functional, social, and emotional components of hearing loss such as embarrassment, and limits on personal and social life. HHIE-S score was analyzed continuously (score range: 0 [no hearing handicap] – 40 [maximum hearing handicap]) and categorically (no hearing handicap [0-8], mild to moderate hearing handicap [10-24], severe hearing handicap [26-40]).

Covariates

Covariates include age, sex (male, female), race (White, Black/African American, Other [Asian, American Indian, Native American, Native Hawaiian, Pacific Islander]), education (elementary or some high school, completed high school or some college, Bachelor’s degree or greater), marital status (married, not married), hypertension (systolic blood pressure >=140 mm Hg or diastolic >=90 mm Hg), high cholesterol (self-reported or medication use), diabetes (self-reported or medication use), stroke or transient ischemic attack (self-reported or medication use), and study design characteristics (recruitment type [recruited from the ARIC Study or *de novo*], study site [Forsyth County, NC; Jackson, MS; selected suburbs of Minneapolis, MN; and Washington County, MD]).

***Statistical Analysis***

The distribution (frequency [proportion], mean [standard deviation]) of participant characteristics by hearing loss severity was described. The independent associations between each PTA and depressive symptomology, mental health related quality of life, and physical health-related quality of life were assessed in separate models using multivariable-adjusted negative binomial regression due to skew and overdispersion in the distribution of the dependent variables. Estimates are reported as incidence rate ratios (IRR). For depressive symptomology (higher CES-D-11 scores indicate worse depressive symptomology), IRR >1 indicates association with greater depressive symptomology and IRR <1 indicates association with less depressive symptomology. For health-related quality of life (higher RAND-36 scores indicate better health quality of life), IRR >1 indicates and association with greater health related quality of life and IRR <1 indicates association with lower health related quality of life.

In secondary analyses, associations of QuickSIN speech-in-noise recognition and HHIE-S with depressive symptomology, mental health related quality of life, and physical health-related quality of life were assessed using the same approach. Associations with each subdomain of the RAND-36 scale (physical functioning, physical role limitation, emotional role limitation, energy/fatigue, emotional well-being, social functioning, pain, general health) were also assessed. All models were adjusted for age, sex, race/ethnicity, education, marital status, hypertension, high cholesterol, diabetes, stroke, and study design characteristics. In a sensitivity analysis, associations of QuickSIN speech-in-noise recognition and HHIE-S with depressive symptomology and mental and physical component scores were additionally adjusted for PTA.

The primary estimands for inference in this study were the differences in depressive symptomology, physical health related quality of life, and mental health related quality of life from the fully adjusted models for continuously modeled PTA. Analyses were conducted with Stata 17 (StataCorp, 2021).

**Results**

Overall, participants were a mean of 76.8 (4.0) years, 53.9% female, 87.7% White, and 53.4% had a Bachelor’s degree or higher (Table 1). Participants had mild (28.9%) or moderate or greater (71.1%) hearing loss (Table 1). Mean CES-D-11 score was 2.5 (Standard Deviation [SD]: 2.5). Mean RAND-36 mental health component score was 56.3 (SD: 6.6) and mean RAND-36 physical health component score was 44.8 (SD: 9.8) (Table 2). Strength of the correlation between hearing measures was moderate to high (PTA and QuickSIN: r = -0.55, PTA and HHIE-S: 0.29, QuickSIN and HHIE-S: -0.24).

Every 10 dB worse hearing (measured by PTA) was associated with lower physical health component scores (per 10 dB worse PTA: IRR: 0.98, 95% CI: 0.96,1.00) (Table 3). When PTA was modeled as a binary measure, estimates suggested lower physical health component scores among those with moderate or greater hearing loss (vs. mild hearing loss [reference]) but estimates were not statistically significant. Statistically significant associations were not observed between PTA, depressive symptomology (Table 2), and mental health component score (Table 3).

Every 5 unit better QuickSIN speech-in-noise recognition was associated with higher mental health component score (per 5 unit better QuickSIN performance: IRR: 1.01, 95% CI: 1.00, 1.02) (Table 3). When QuickSIN speech-in-noise recognition was modeled as a binary measure, estimates suggested higher mental health component score among participants scoring in the top 3 quartiles of QuickSIN speech-in-noise recognition (vs. lowest quartile [reference]) but were not statistically significant. Associations were not observed between QuickSIN speech-in-noise recognition, depressive symptomology, and physical health component score (Tables 2 and 3).

Every 10 unit worse HHIE-S score was associated with greater depressive symptomology score (per 10 units worse HHIE-S score: IRR: 1.24, 95% CI: 1.16, 1.33). Higher HHIE-S score was also associated with lower mental (per 10 units worse HHIE-S score: IRR: 0.97, 95% CI: 0.96,0.98) and physical health component scores (per 10 units worse HHIE-S score: IRR: 0.95, 95% CI: 0.93,0.96), but HHIE-S and RAND-36 likely measure similar constructs. Findings were consistent when HHIE-S was modeled categorically (Tables 2 and 3).

Associations between hearing (PTA, QuickSIN speech-in-noise recognition, HHIE-S) and each of the 8 subdomains of the RAND-36 Health Survey were also assessed (Table 4, Supplementary Table 1). Every 10 dB worse PTA (per 10 dB worse PTA) was associated with 4% lower scores in physical functioning (IRR: 0.96, 95% CI: 0.93,0.99) and 3% lower scores in social functioning (IRR: 0.97, 95% CI: 0.95,0.99). Higher QuickSIN speech-in-noise recognition (per 5 unit better QuickSIN performance) was associated with higher scores in energy (IRR: 1.02, 95% CI: 1.00, 1.05) and higher social functioning score (IRR: 1.02, 95% CI: 1.01,1.04). Interestingly, greater HHIE-S (per 10 unit worse HHIE-S score) was associated with lower scores in all 8 subdomains (physical functioning: IRR: 0.93, 95% CI: 0.91,0.95, physical role limitation: IRR: 0.84, 95% CI: 0.78,0.90, emotional role limitation: IRR: 0.94, 95% CI: 0.91,0.97, energy/fatigue: IRR: 0.92, 95% CI: 0.90, 0.94, emotional well-being: IRR: 0.96, 95% CI: 0.95,0.97, social functioning: IRR: 0.93, 95% CI: 0.91, 0.94, pain: IRR: 0.95, 95% CI: 0.93,0.97, general health:IRR: 0.94, 95% CI: 0.93,0.96).

In a sensitivity analysis, associations of QuickSIN speech-in-noise recognition and HHIE-S with depressive symptomology and mental and physical component summary scores were additionally adjusted for PTA. Estimates were similar in magnitude as estimates produced in the primary analysis (Supplemental Tables 2 and 3).

**Discussion**

In a sample of older adults with untreated hearing loss, greater hearing loss severity (i.e., poorer PTA) was associated with worse physical health quality of life. Better speech-in-noise recognition was associated with higher mental health quality of life. Neither hearing loss nor speech-in-noise recognition were associated with depressive symptomology. Greater limitations in activity and participation due to hearing loss was associated with greater depressive symptomology and poorer health-related quality of life. Collectively, these results suggest greater severity of hearing loss is important to health-related quality of life.

To our knowledge, no other studies have investigated hearing loss *severity*, depressive symptomology, and health-related quality of life in a sample of only older adults with untreated hearing loss. Thus, findings from the current study add to the literature by allowing investigation across levels of hearing loss but are difficult to compare to findings from studies that include participants across the full range of hearing as analytic approaches and interpretations differ. The current study assesses changes in depressive symptomology and health-related quality of life by hearing loss *severity* while studies including participants across the full range of hearing typically compare participants with hearing loss to those with normal hearing. Differences in findings between the current study and prior studies may also be attributed to differences in measurement of exposures and outcomes and other differences in sample characteristics. Notably, ACHIEVE is a clinical trial and participants who elect to participate may have lower depressive symptomology (only 4% meet criteria for clinical depressive symptomology [CES-D-11 score >= 9]) than participants from other observational studies. Participants in ACHIEVE also have untreated hearing loss, do not have dementia, are primarily non-Hispanic White (87.7%) or Black (11.6%), and were recruited from specific geographical areas.

Prior evidence of the association between objective hearing and depressive symptomology, conducted in samples including participants with the full range of hearing, is mixed (Lawrence et al., 2020). Several studies did not observe significant associations between PTA and depression symptomology (Kiely et al., 2013; Mener et al., 2013; Mick & Pichora-Fuller, 2016) while some studies observe associations in specific subgroups (e.g. older women (Li et al., 2014; Scinicariello et al., 2019), Hispanic older adults (Golub et al., 2019)). In the ARIC Study, of which 24% of participants in the current study are co-enrolled, moderate or greater hearing loss (PTA ≥ 40 db HL) was associated with over 2 times higher odds of depressive symptoms compared to normal hearing (Shukla et al., 2021). Prior investigations of HHIE, speech-in-noise recognition, and depressive symptomology are limited. In a cohort of community dwelling, older adults in Japan, greater HHIE-S score was associated with nearly 2.5 times higher odds of depressive symptoms, independent of PTA, over 3 years (Saito et al., 2010). In addition, one study investigating speech-in-noise recognition found no association with depression symptomology (Pronk et al., 2011).

For health-related quality of life, Chew et al. found, among older adults with untreated hearing loss, PTA was not associated with mental or physical health related quality of life or any subdomains of quality of life (measured by the Short Form-36 Health Survey, SF-36) (Chew & Yeak, 2010). Findings from Chew et al. are in contrast to findings from the current study potentially due to differences in study population (participants were younger [50 years and older] and recruited from an audiology clinic). Worse PTA among older adults in Beaver Dam, WI was associated with lower mental and physical health summary scores and lower scores on six of the eight domains of quality of life, including physical functioning, emotional role limitations, and social functioning as also observed in the current study (Dalton et al., 2003).

The association between PTA and physical health related quality of life observed in the current study may be explained by reduced physical activity (Martinez-Amezcua et al., 2022; Martinez-Amezcua, Suen, et al., 2021), lower physical function (D. S. Chen et al., 2015; Martinez-Amezcua, Kuo, et al., 2021), and impaired perception of environment auditory cues, which can affect balance (Campos et al., 2018), in older adults with hearing loss. Further, in this study, greater speech-in-noise recognition was associated with greater mental, but not physical, health quality of life. This component of hearing is important for communication and particularly important for many social settings where background noise is high (e.g., restaurants). Those with greater speech-in-noise recognition may be less likely to withdraw from conversational settings and more likely to maintain robust social connections and engagement activities that maintain mental health related quality of life. Additionally, observed associations between greater speech-in-noise recognition and higher energy (less fatigue) may reflect the impact of cognitive load. Cognitive load refers to the greater cognitive resources needed to process speech and sound in the presence of hearing loss and low speech-in-noise recognition; high cognitive load can lead to greater feelings of fatigue.

While self-perceived limitations in activity and participation due to hearing loss (measured by HHIE-S) was consistently associated with health-related quality life, these measures likely reflect similar constructs. Observed associations may suggest, however, that the self-perceived functional and emotional consequences of hearing loss could be an important component of overall health-related quality of life among older adults with untreated hearing loss. HHIE was a stronger predictor than PTA of the multiple components of quality life among older adults in the Blue Mountains Hearing Study (Gopinath et al., 2012). Similarly, among older adults in Beaver Dam, Wisconsin, HHIE was associated with lower SF-36 mental and physical health component summary scores as well as lower scores in all quality of life subdomains (Dalton et al., 2003).

Interestingly, the social functioning subdomain was the only subdomain associated with all three measures of hearing (PTA, QuickSIN speech-in-noise recognition, HHIE-S). These findings are consistent with a growing body of research demonstrating greater loneliness and social isolation among older adults with hearing loss (Huang et al., 2021; Mick et al., 2014; Shukla et al., 2020; Sung et al., 2016). Older adults with greater hearing loss may have more difficulty communicating (Pichora-Fuller et al., 2016) and withdraw from engaging with friends and family (Mick et al., 2014; Pichora-Fuller et al., 2015), particularly in situations where background noise is high, which can lead to greater social isolation and loneliness, components of quality of life and risk factors for depression. Hearing loss has been linked to greater social and emotional loneliness, reduced social support, and reduced engagement in social activities (Pronk et al., 2011; Shukla et al., 2020). Perceived functional and emotional impacts of hearing loss may also reflect confidence and perceived capacity to engage with others and participate in activities that contribute to positive mood and greater quality of life.

*Limitations*

This study presents the baseline associations between hearing loss, depressive symptomology, and health related quality of life among participants in the ACHIEVE Study. While the study is cross-sectional and the directionality of the association cannot be established, this study sets the stage for future longitudinal investigations of this association with continued follow-up of ACHIEVE participants. Additionally, as all participants had hearing loss, this study was able to compare associations of hearing loss, depressive symptoms, and health related quality of life within levels of hearing loss, however comparisons between those with hearing loss vs. normal hearing could not be made. Given the moderate sample size, this study fills a gap in the literature by allowing investigation of differences in depression and health related quality of life by hearing loss severity. Finally, participants had untreated hearing loss and were recruited from four communities in the U.S. Generalizability to the broader population of older adults of different races, ethnicities, education levels, geographic areas, as well as to older adults with treated hearing loss in the U.S. may be limited.

*Implications*

Mental health and well-being are critical components of health in older adults. Identifying older adults with higher risk for depression and poor health related quality of life who may benefit from prevention intervention is important for maintaining mental health and potentially reducing risk for downstream poor health outcomes (Almeida, 2014; Cuijpers et al., 2012). In older adults with hearing loss, findings from the current study suggest that HHIE-S is strongly associated with depressive symptoms as well as health-related quality of life. The HHIE-S (Ventry & Weinstein, 1982) is a short and easily administered questionnaire that could have greater utility in a variety of health care settings to quickly identify older adults to consider for depression screening and potential follow-up care.

Further, greater HHIE-S scores reflect the perceived functional challenges associated, in part, with hearing loss but also with challenges attributed to hearing loss-related stigma (Wallhagen, 2010) and low hearing accessibility, or lack thereof, in one’s environment (Clarke et al., 2011; Jaiswal et al., 2020). Older adults with the same severity of peripheral hearing loss may have varying levels of HHIE-S scores based on the hearing-related demands of the environments in which they navigate. Greater low hearing accessibility in the built environment (e.g. noisy restaurants, retail settings) and work to destigmatize hearing loss can lower barriers of engagement in social and public spaces, potentially alleviating perceived functional and emotional impacts of hearing loss, and improve mental health and well-being.

Additionally, among older adults with hearing loss, hearing treatment has been shown to benefit not only peripheral hearing but perceived hearing handicap as well (Dawes et al., 2015) and may serve as an effective intervention for reducing risk for depression and poor health related quality of life as well. Some observational studies suggested hearing aid use and treatment was associated with reduced odds of both major depressive disorder and depressive symptomology (Choi, Betz, Li, et al., 2016; Mahmoudi et al., 2019; Mener et al., 2013) as well as improved quality of life (Chisolm et al., 2007; Contrera et al., 2016; Mondelli & de Souza, 2012). Evidence of hearing treatment effect from randomized controlled trials is, however, lacking. Once completed, the ACHIEVE Study (Clinicaltrials.gov Identifier: NCT03243422) will test the effect of hearing intervention (vs. a successful aging health education control intervention) on cognitive change over three years (primary outcome). Depressive symptomology and health related quality of life will also be investigated as pre-specified exploratory outcomes.

In conclusion, in a sample of older adults with untreated hearing loss, worse peripheral hearing was associated with worse physical health-related quality of life. Speech-in-noise recognition was associated with mental health-related quality of life and limitations in activity and participation due to hearing loss was associated with both depressive symptomology and health-related quality of life. Once completed with three years of follow-up, the ACHIEVE Study will test whether hearing intervention is efficacious for reducing depressive symptomology and increased health-related quality of life among older adults with untreated hearing loss.

Table 1: Participant characteristics by hearing level (N=948), Aging and Cognitive Health Evaluation in Elders (ACHIEVE) Study, 2018-2019

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Total** | **Mild Hearing Lossc** | **Moderate or Greater**  **Hearing Lossc** |
|  | N=948 | N=274 | N=674 |
| **Age, mean (SD)** | 76.8 (4.0) | 75.9 (3.9) | 77.1 (3.9) |
| **Sex, n (%)** |  |  |  |
| Female | 511 (53.9) | 162 (59.1) | 349 (51.8) |
| **Race, n (%)** |  |  |  |
| White | 831 (87.7) | 246 (89.8) | 585 (86.8) |
| Black/African American | 110 (11.6) | 27 (9.9) | 83 (12.3) |
| Other a | 7 (0.7) | 1 (0.4) | 6 (0.9) |
| **Education, n (%)** |  |  |  |
| Some High School or Elementary | 35 (3.7) | 8 (2.9) | 27 (4.0) |
| High School Diploma or Some College | 407 (42.9) | 100 (36.5) | 307 (45.5) |
| Bachelor Degree or Higher | 506 (53.4) | 166 (60.6) | 340 (50.4) |
| **Marital status, n (%)** |  |  |  |
| Married | 584 (61.6) | 180 (65.7) | 404 (59.9) |
| Not married | 364 (38.4) | 94 (34.3) | 270 (40.1) |
| **Hypertension, n (%)** | 636 (67.1) | 174 (63.5) | 462 (68.5) |
| **High cholesterol, n (%)** | 571 (60.2) | 163 (59.5) | 408 (60.5) |
| **Diabetes, n (%)** | 190 (20.0) | 44 (16.1) | 146 (21.7) |
| **Stroke, n (%)** | 79 ( 8.3) | 16 ( 5.8) | 63 ( 9.3) |
| **Pure-tone average, mean (SD)** | 39.4 (6.8) | 32.2 (1.5) | 42.3 (5.9) |
| **Recruitment type, n (%)** |  |  |  |
| ARICb | 232 (24.5) | 68 (24.8) | 164 (24.3) |
| De novo | 716 (75.5) | 206 (75.2) | 510 (75.7) |
| **Study** **site, n (%)** |  |  |  |
| Forsyth County, NC | 234 (24.7) | 70 (25.5) | 164 (24.3) |
| Jackson, MS | 235 (24.8) | 58 (21.2) | 177 (26.3) |
| Minneapolis, MN | 228 (24.1) | 69 (25.2) | 159 (23.6) |
| Washington County, MD | 251 (26.5) | 77 (28.1) | 174 (25.8) |
| **Pure tone average, mean (SD)** | 39.4 (6.8) | 32.2 (1.5) | 42.3 (5.9) |
| **Quick Speech-in-Noise (QuickSIN) Score, mean (SD)** | 18.4 (5.2) | 21.3 (3.0) | 17.2 (5.5) |
| **Hearing Handicap Inventory for the** **Elderly (HHIE-S)** | 15.3 (9.7) | 12.6 (8.8) | 16.3 (9.8) |
| **Depressive symptoms, mean (SD)** | 2.5(2.5) | 2.3 (2.4) | 2.5 (2.5) |
| **Mental Health-Related Quality of Life, mean (SD)** | 56.3 (6.6) | 56.2 (6.3) | 56.3 (6.8) |
| **Physical Health-Related Quality of Life, mean (SD)** | 44.8 (9.8) | 46.0 (9.4) | 44.3 (9.9) |

Notes:

aOther race includes Asian (n=6), American Indian, Native American, Native Hawaiian, Pacific Islander (n=3)

bARIC: Atherosclerosis Risk in Communities Study

**c**Mild hearing loss: four-frequency pure-tone average 20-34.9 dB HL, Moderate or greater hearing loss: four-frequency pure-tone average 35 dB HL

Table 2: Association between PTA, QuickSIN speech-in-noise recognition, and HHIE-S and depression symptomology (N=948), Aging and Cognitive Health Evaluation in Elders (ACHIEVE) Study, 2018-2019

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Depression Symptomology** | | |
|  | **Mean(SD)** | **IRR** | **95% CI** |
| **Pure-Tone Average (PTA)** |  |  |  |
| Mild Hearing Impairment | 2.3 (2.4) | Ref. | Ref. |
| Moderate Hearing Impairment | 2.5 (2.5) | 1.01 | 0.88,1.17 |
| Per 10-dB worse PTA |  | 1.03 | 0.93,1.13 |
| **Quick Speech-in-Noise (QuickSIN) Recognition** |  |  |  |
| Lowest quartile (worse function) | 2.5 (2.7) | Ref. | Ref. |
| Top 3 quartiles | 2.4 (2.4) | 1.02 | 0.88,1.19 |
| Per 5-unit better QuickSIN performance |  | 0.98 | 0.92,1.05 |
| **Hearing Handicap Inventory for the Elderly (HHIE-S)** |  |  |  |
| None | 2.1 (2.4) | Ref. | Ref. |
| Mild/Moderate | 2.3 (2.2) | 1.12 | 0.96,1.30 |
| Severe | 3.7 (3.1) | 1.76 | 1.46,2.12 |
| Per 10-unit worse HHIE-S |  | 1.24 | 1.16,1.33 |

Notes:

Abbreviations: SD: Standard Deviation, CI: Confidence Interval

Models adjusted for age, sex, race, education, marital status, hypertension, high cholesterol, diabetes, stroke, use of prescription medication for depression, and study design characteristics.

Table 3: Association between PTA, QuickSIN speech-in-noise recognition, and HHIE-S and health-related quality of life (N=948), Aging and Cognitive Health Evaluation in Elders (ACHIEVE) Study, 2018-2019

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Mental Health-Related**  **Quality of Life** | | | **Physical Health-Related**  **Quality of Life** | | |
|  | **Mean (SD)** | **IRR** | **95% CI** | **Mean (SD)** | **IRR** | **95% CI** |
| **Pure Tone Average (PTA)** |  |  |  |  |  |  |
| Mild Hearing Impairment | 56.2 (6.3) | Ref. | Ref. | 46.0 (9.4) | Ref. | Ref. |
| Moderate Hearing Impairment | 56.3 (6.8) | 1.00 | 0.98,1.02 | 44.3 (9.9) | 0.98 | 0.95,1.01 |
| Per 10-dB worse PTA |  | 0.99 | 0.98,1.01 |  | 0.98 | 0.96,1.00 |
| **Quick Speech-in-Noise (QuickSIN) Understanding** |  |  |  |  |  |  |
| Lowest quartile (worse function) | 55.5 (7.5) | Ref. | Ref. | 43.3 (10.4) | Ref. | Ref. |
| Top 3 quartiles | 56.5 (6.3) | 1.02 | 1.00,1.04 | 45.3 (9.5) | 1.02 | 0.99,1.05 |
| Per 5-unit better QuickSIN performance |  | 1.01 | 1.00,1.02 |  | 1.01 | 0.99,1.02 |
| **Hearing Handicap Inventory for the Elderly (HHIE-S)** |  |  |  |  |  |  |
| None | 58.1 (5.0) | Ref. | Ref. | 47.0 (8.7) | Ref. | Ref. |
| Mild/Moderate | 56.4 (6.1) | 0.97 | 0.95,0.99 | 45.0 (9.3) | 0.94 | 0.91,0.97 |
| Severe | 52.8 (8.9) | 0.91 | 0.88,0.93 | 40.7 (11.2) | 0.88 | 0.84,0.92 |
| Per 10-unit worse HHIE-S |  | 0.97 | 0.96,0.98 |  | 0.95 | 0.93,0.96 |

Notes:

Abbreviations: SD: Standard Deviation, CI: Confidence Interval

Models adjusted for age, sex, race, education, marital status, hypertension, high cholesterol, diabetes, stroke, use of prescription medication for depression, and study design characteristics

Table 4: Association of PTA, QuickSIN speech-in-noise recognition, and HHIE-S with health-related quality of life subscales (N=948), Aging and Cognitive Health Evaluation in Elders (ACHIEVE) Study, 2018-2019

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Physical functioning** | **Physical role limitation** | **Emotional role limitation** | **Energy/**  **Fatigue** | **Emotional well-being** | **Social functioning** | **Pain** | **General Health** |
|  | **IRR**  95% CI | **IRR**  95% CI | **IRR**  95% CI | **IRR**  95% CI | **IRR**  95% CI | **IRR**  95% CI | **IRR**  95% CI | **IRR**  95% CI |
| **Pure-Tone Average (PTA)** |  |  |  |  |  |  |  |  |
| Per 10-dB worse PTA | 0.96 | 0.94 | 0.98 | 0.98 | 0.99 | 0.97 | 0.98 | 0.98 |
|  | 0.93, 0.99 | 0.85, 1.04 | 0.94, 1.02 | 0.95, 1.01 | 0.98,1.01 | 0.95, 0.99 | 0.94, 1.01 | 0.96, 1.01 |
| **Quick Speech-in-Noise (QuickSIN)**  **Understanding** |  |  |  |  |  |  |  |  |
| Per 5-unit better QuickSIN performance | 1.01 | 1.02 | 1.01 | 1.02 | 1.01 | 1.02 | 1.00 | 1.02 |
|  | 0.99, 1.04 | 0.95, 1.09 | 0.98, 1.03 | 1.00, 1.05 | 1.00, 1.02 | 1.01, 1.04 | 0.98, 1.03 | 1.00, 1.03 |
| **Hearing Handicap Inventory for the Elderly (HHIE-S)** |  |  |  |  |  |  |  |  |
| Per 10-unit worse  HHIE-S | 0.93 | 0.84 | 0.94 | 0.92 | 0.96 | 0.93 | 0.95 | 0.94 |
|  | 0.91, 0.95 | 0.78, 0.90 | 0.91, 0.97 | 0.90, 0.94 | 0.95, 0.97 | 0.91, 0.94 | 0.93, 0.97 | 0.93, 0.96 |

Notes:

Abbreviations: SD: Standard Deviation, CI: Confidence Interval

Subdomain scores of the 36-Item RAND Health Survey range from 0-100 with higher scores indication better health outcomes

Models adjusted for age, sex, race, education, marital status, hypertension, high cholesterol, diabetes, stroke, use of prescription medication for depression, and study design characteristics.

**References**

Almeida, O. P. (2014). Prevention of depression in older age. *Maturitas*, *79*(2), 136–141.

Arnold, M. L., Haley, W., Lin, F. R., Faucette, S., Sherry, L., Higuchi, K., Witherell, K., Anderson, E., Reed, N. S., & Chisolm, T. H. (2022). Development, assessment, and monitoring of audiologic treatment fidelity in the aging and cognitive health evaluation in elders (ACHIEVE) randomised controlled trial. *International Journal of Audiology*, *61*(9), 720–730.

Campos, J., Ramkhalawansingh, R., & Pichora-Fuller, M. K. (2018). Hearing, self-motion perception, mobility, and aging. *Hearing Research*, *369*, 42–55.

Cao, C., Hu, L., Xu, T., Liu, Q., Koyanagi, A., Yang, L., Carvalho, A. F., Cavazos-Rehg, P. A., & Smith, L. (2020). Prevalence, correlates and misperception of depression symptoms in the United States, NHANES 2015–2018. *Journal of Affective Disorders*, *269*, 51–57.

Chen, D. S., Betz, J., Yaffe, K., Ayonayon, H. N., Kritchevsky, S., Martin, K. R., Harris, T. B., Purchase-Helzner, E., Satterfield, S., & Xue, Q.-L. (2015). Association of hearing impairment with declines in physical functioning and the risk of disability in older adults. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences*, *70*(5), 654–661.

Chen, H. L. (1994). Hearing in the elderly: Relation of hearing loss, loneliness, and self-esteem. *Journal of Gerontological Nursing*, *20*(6), 22–28.

Chew, H. S., & Yeak, S. (2010). Quality of life in patients with untreated age-related hearing loss. *The Journal of Laryngology & Otology*, *124*(8), 835–841.

Chisolm, T. H., Johnson, C. E., Danhauer, J. L., Portz, L. J., Abrams, H. B., Lesner, S., McCarthy, P. A., & Newman, C. W. (2007). A systematic review of health-related quality of life and hearing aids: Final report of the American Academy of Audiology Task Force on the Health-Related Quality of Life Benefits of Amplification in Adults. *Journal of the American Academy of Audiology*, *18*(02), 151–183.

Choi, J. S., Betz, J., Deal, J., Contrera, K. J., Genther, D. J., Chen, D. S., Gispen, F. E., & Lin, F. R. (2016). A comparison of self-report and audiometric measures of hearing and their associations with functional outcomes in older adults. *Journal of Aging and Health*, *28*(5), 890–910.

Choi, J. S., Betz, J., Li, L., Blake, C. R., Sung, Y. K., Contrera, K. J., & Lin, F. R. (2016). Association of using hearing aids or cochlear implants with changes in depressive symptoms in older adults. *JAMA Otolaryngology–Head & Neck Surgery*, *142*(7), 652–657.

Clarke, P. J., Ailshire, J. A., Nieuwenhuijsen, E. R., & de Kleijn–de Vrankrijker, M. W. (2011). Participation among adults with disability: The role of the urban environment. *Social Science & Medicine*, *72*(10), 1674–1684.

Contrera, K. J., Betz, J., Li, L., Blake, C. R., Sung, Y. K., Choi, J. S., & Lin, F. R. (2016). Quality of life after intervention with a cochlear implant or hearing aid. *The Laryngoscope*, *126*(9), 2110–2115.

Cuijpers, P., Beekman, A. T., & Reynolds, C. F. (2012). Preventing depression: A global priority. *Jama*, *307*(10), 1033–1034.

Dalton, D. S., Cruickshanks, K. J., Klein, B. E., Klein, R., Wiley, T. L., & Nondahl, D. M. (2003). The impact of hearing loss on quality of life in older adults. *The Gerontologist*, *43*(5), 661–668.

Dawes, P., Cruickshanks, K. J., Fischer, M. E., Klein, B. E., Klein, R., & Nondahl, D. M. (2015). Hearing-aid use and long-term health outcomes: Hearing handicap, mental health, social engagement, cognitive function, physical health, and mortality. *International Journal of Audiology*, *54*(11), 838–844.

Deal, J. A., Betz, J., Yaffe, K., Harris, T., Purchase-Helzner, E., Satterfield, S., Pratt, S., Govil, N., Simonsick, E. M., Lin, F. R., & for the Health ABC Study Group. (2016). Hearing Impairment and Incident Dementia and Cognitive Decline in Older Adults: The Health ABC Study. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, glw069. https://doi.org/10.1093/gerona/glw069

Deal, J. A., Goman, A. M., Albert, M. S., Arnold, M. L., Burgard, S., Chisolm, T., Couper, D., Glynn, N. W., Gmelin, T., & Hayden, K. M. (2018). Hearing treatment for reducing cognitive decline: Design and methods of the Aging and Cognitive Health Evaluation in Elders randomized controlled trial. *Alzheimer’s & Dementia: Translational Research & Clinical Interventions*, *4*, 499–507.

Garstecki, D. C., & Erler, S. F. (1999). Older adult performance on the communication profile for the hearing impaired: Gender difference. *Journal of Speech, Language, and Hearing Research*, *42*(4), 785–796.

Golub, J. S., Brewster, K. K., Brickman, A. M., Ciarleglio, A. J., Kim, A. H., Luchsinger, J. A., & Rutherford, B. R. (2019). Association of audiometric age-related hearing loss with depressive symptoms among Hispanic individuals. *JAMA Otolaryngology–Head & Neck Surgery*, *145*(2), 132–139.

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.

Gopinath, B., Schneider, J., Hickson, L., McMahon, C. M., Burlutsky, G., Leeder, S. R., & Mitchell, P. (2012). Hearing handicap, rather than measured hearing impairment, predicts poorer quality of life over 10 years in older adults. *Maturitas*, *72*(2), 146–151.

Gopinath, B., Wang, J. J., Schneider, J., Burlutsky, G., Snowdon, J., McMahon, C. M., Leeder, S. R., & Mitchell, P. (2009). Depressive symptoms in older adults with hearing impairments: The Blue Mountains Study. *Journal of the American Geriatrics Society*, *57*(7), 1306–1308.

Hays, R. D., & Morales, L. S. (2001). *The RAND-36 Measure of Health-Related Quality of Life*. The Finnish Medical Society Duodecim. https://www.rand.org/pubs/reprints/RP971.html

Huang, A. R., Deal, J. A., Rebok, G. W., Pinto, J. M., Waite, L., & Lin, F. R. (2021). Hearing impairment and loneliness in older adults in the United States. *Journal of Applied Gerontology*, *40*(10), 1366–1371.

Huang, A. R., Jiang, K., Lin, F. R., Deal, J. A., & Reed, N. S. (2023). Hearing Loss and Dementia Prevalence in Older Adults in the US. *JAMA*, *329*(2), 171–173.

Jaiswal, A., Fraser, S., & Wittich, W. (2020). Barriers and facilitators that influence social participation in older adults with dual sensory impairment. *Frontiers in Education*, *5*, 127.

Kiely, K. M., Anstey, K. J., & Luszcz, M. A. (2013). Dual sensory loss and depressive symptoms: The importance of hearing, daily functioning, and activity engagement. *Frontiers in Human Neuroscience*, *7*, 837.

Killion, M. C., Niquette, P. A., Gudmundsen, G. I., Revit, L. J., & Banerjee, S. (2004). Development of a quick speech-in-noise test for measuring signal-to-noise ratio loss in normal-hearing and hearing-impaired listeners. *The Journal of the Acoustical Society of America*, *116*(4), 2395–2405.

Kohout, F. J., Berkman, L. F., Evans, D. A., & Cornoni-Huntley, J. (1993). Two shorter forms of the CES-D depression symptoms index. *Journal of Aging and Health*, *5*(2), 179–193.

Lawrence, B. J., Jayakody, D. M., Bennett, R. J., Eikelboom, R. H., Gasson, N., & Friedland, P. L. (2020). Hearing loss and depression in older adults: A systematic review and meta-analysis. *The Gerontologist*, *60*(3), e137–e154.

Li, C.-M., Zhang, X., Hoffman, H. J., Cotch, M. F., Themann, C. L., & Wilson, M. R. (2014). Hearing impairment associated with depression in US adults, National Health and Nutrition Examination Survey 2005-2010. *JAMA Otolaryngology–Head & Neck Surgery*, *140*(4), 293–302.

Lin, F. R., Metter, E. J., O’Brien, R. J., Resnick, S. M., Zonderman, A. B., & Ferrucci, L. (2011). Hearing loss and incident dementia. *Archives of Neurology*, *68*(2), 214–220.

Livingston, G., Huntley, J., Sommerlad, A., Ames, D., Ballard, C., Banerjee, S., Brayne, C., Burns, A., Cohen-Mansfield, J., & Cooper, C. (2020). Dementia prevention, intervention, and care: 2020 report of the Lancet Commission. *The Lancet*, *396*(10248), 413–446.

Mahmoudi, E., Basu, T., Langa, K., McKee, M. M., Zazove, P., Alexander, N., & Kamdar, N. (2019). Can hearing aids delay time to diagnosis of dementia, depression, or falls in older adults? *Journal of the American Geriatrics Society*, *67*(11), 2362–2369.

Martinez-Amezcua, P., Dooley, E. E., Reed, N. S., Powell, D., Hornikel, B., Golub, J. S., Gabriel, K. P., & Palta, P. (2022). Association of Hearing Impairment and 24-Hour Total Movement Activity in a Representative Sample of US Adults. *JAMA Network Open*, *5*(3), e222983–e222983.

Martinez-Amezcua, P., Kuo, P.-L., Reed, N. S., Simonsick, E. M., Agrawal, Y., Lin, F. R., Deal, J. A., Ferrucci, L., & Schrack, J. A. (2021). Association of hearing impairment with higher level physical functioning and walking endurance: Results from the Baltimore Longitudinal Study of Aging (BLSA). *The Journals of Gerontology: Series A*.

Martinez-Amezcua, P., Suen, J. J., Lin, F., Schrack, J. A., & Deal, J. A. (2021). Hearing impairment and objectively measured physical activity: A systematic review. *Journal of the American Geriatrics Society*.

Mener, D. J., Betz, J., Genther, D. J., Chen, D., & Lin, F. R. (2013). Hearing loss and depression in older adults. *Journal of the American Geriatrics Society*, *61*(9), 1627.

Mick, P., Kawachi, I., & Lin, F. R. (2014). The association between hearing loss and social isolation in older adults. *Otolaryngology–Head and Neck Surgery*, *150*(3), 378–384.

Mick, P., & Pichora-Fuller, M. K. (2016). Is hearing loss associated with poorer health in older adults who might benefit from hearing screening? *Ear and Hearing*, *37*(3), e194–e201.

Mondelli, M. F. C. G., & de Souza, P. J. S. (2012). Quality of life in elderly adults before and after hearing aid fitting. *Brazilian Journal of Otorhinolaryngology*, *78*(3), 49–56.

Organization, W. H. (2021). *World report on hearing*.

Pichora-Fuller, M. K., Kramer, S. E., Eckert, M. A., Edwards, B., Hornsby, B. W., Humes, L. E., Lemke, U., Lunner, T., Matthen, M., & Mackersie, C. L. (2016). Hearing impairment and cognitive energy: The framework for understanding effortful listening (FUEL). *Ear and Hearing*, *37*, 5S-27S.

Pichora-Fuller, M. K., Mick, P., & Reed, M. (2015). Hearing, cognition, and healthy aging: Social and public health implications of the links between age-related declines in hearing and cognition. *Seminars in Hearing*, *36*(03), 122–139.

Pronk, M., Deeg, D. J. H., Smits, C., Tilburg, T. G. van, Kuik, D. J., Festen, J. M., & Kramer, S. E. (2011). Prospective effects of hearing status on loneliness and depression in older persons: Identification of subgroups. *International Journal of Audiology*, *50*(12), 887–896. https://doi.org/10.3109/14992027.2011.599871

Saito, H., Nishiwaki, Y., Michikawa, T., Kikuchi, Y., Mizutari, K., Takebayashi, T., & Ogawa, K. (2010). Hearing handicap predicts the development of depressive symptoms after 3 years in older community‐dwelling Japanese. *Journal of the American Geriatrics Society*, *58*(1), 93–97.

Sanchez, V. A., Arnold, M. L., Reed, N. S., Oree, P. H., Matthews, C. R., Eddins, A. C., Lin, F. R., & Chisolm, T. H. (2020). The Hearing Intervention for the Aging and Cognitive Health Evaluation in Elders randomized control trial: Manualization and feasibility study. *Ear and Hearing*, *41*(5), 1333–1348.

Scinicariello, F., Przybyla, J., Carroll, Y., Eichwald, J., Decker, J., & Breysse, P. N. (2019). Age and sex differences in hearing loss association with depressive symptoms: Analyses of NHANES 2011–2012. *Psychological Medicine*, *49*(6), 962–968.

Shuai, L., & Gong, T. (2014). Temporal relation between top-down and bottom-up processing in lexical tone perception. *Frontiers in Behavioral Neuroscience*, *8*, 97.

Shukla, A., Harper, M., Pedersen, E., Goman, A., Suen, J. J., Price, C., Applebaum, J., Hoyer, M., Lin, F. R., & Reed, N. S. (2020). Hearing Loss, Loneliness, and Social Isolation: A Systematic Review. *Otolaryngology–Head and Neck Surgery*, 0194599820910377.

Shukla, A., Reed, N. S., Armstrong, N. M., Lin, F. R., Deal, J. A., & Goman, A. M. (2021). Hearing loss, hearing aid use, and depressive symptoms in older adults—Findings from the atherosclerosis risk in communities neurocognitive study (ARIC-NCS). *The Journals of Gerontology: Series B*, *76*(3), 518–523.

StataCorp. (2021). *Stata Statistical Software: Release 17*. StataCorp LLC.

Sung, Y., Li, L., Blake, C., Betz, J., & Lin, F. R. (2016). Association of hearing loss and loneliness in older adults. *Journal of Aging and Health*, *28*(6), 979–994.

Taft, C., Karlsson, J., & Sullivan, M. (2001). Do SF-36 summary component scores accurately summarize subscale scores? *Quality of Life Research*, *10*(5), 395–404.

Tseng, Y.-C., Liu, S. H.-Y., Lou, M.-F., & Huang, G.-S. (2018). Quality of life in older adults with sensory impairments: A systematic review. *Quality of Life Research*, *27*(8), 1957–1971.

Ventry, I. M., & Weinstein, B. E. (1982). The hearing handicap inventory for the elderly: A new tool. *Ear and Hearing*, *3*(3), 128–134.

Wallhagen, M. I. (2010). The stigma of hearing loss. *The Gerontologist*, *50*(1), 66–75.