HHS Public Access

Author manuscript

J Appl Gerontol. Author manuscript; available in PMC 2024 May 01.

Published in final edited form as:

J Appl Gerontol. 2024 May ; 43(5): 550–561. doi:10.1177/07334648231212291.

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

Alison R. Huang, PhD[a,b], **Nicholas S. Reed, AuD**[a,b], **Jennifer A. Deal, PhD**[a,b], **Michelle Arnold, AuD, PhD**[c], **Sheila Burgard, MS**[d], **Theresa Chisolm, PhD**[c], **David Couper, PhD**[d], **Nancy W. Glynn, PhD**[e], **Theresa Gmelin, MSW, MPH**[e], **Adele M. Goman, PhD**[f], **Lisa Gravens-Mueller, MS**[d], **Kathleen M. Hayden, PhD**[g], **Christine Mitchell, ScM**[a], **James S. Pankow, PhD**[h], **James Russell Pike, MBA**[a], **Jennifer A. Schrack, PhD**[a], **Victoria Sanchez, AuD, PhD**[c], **Josef Coresh, MD, PhD**[a], **Frank R. Lin, MD, PhD**[a,b],

ACHIEVE Collaborative Research Group

[a]Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

[b]Cochlear Center for Hearing and Public Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

[c]College of Science and Mathematics, University of South Florida Sarasota - Manatee, Sarasota, FL, USA

[d]Department of Biostatistics, Gillings School of Global Public Health, University of North Carolina, Chapel Hill, NC, USA

[e]Department of Epidemiology, University of Pittsburgh School of Public Health, Pittsburgh, PA, USA

[f]School of Health and Social Care, Edinburgh Napier University, UK

[g]Department of Social Sciences and Health Policy, Wake Forest University School of Medicine, Winston-Salem, NC, USA

[h]Division of Epidemiology and Community Health, University of Minnesota School of Public Health, Minneapolis, MN, USA

Abstract

Hearing loss is associated with cognitive/physical health; less is known about mental health. We investigated associations between hearing loss severity, depression, and health-related quality of life among older adults with unaided 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

Corresponding Author Alison R. Huang, PhD, 2024 Monument St., Suite B1100, Baltimore, MD 21202, ahuang31@jhu.edu.

IRB: Johns Hopkins University, IRB00008129

Conflict of Interest

All other authors report no relevant disclosures

quality of life. Associations were assessed by negative binomial regression. More severe hearing loss was associated with worse physical health-related quality of life (Ratio: 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 effects of hearing intervention on mental health.

Keywords

hearing loss; depression; mental health; epidemiology

Introduction

Hearing loss is associated with communication difficulties (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 be associated with poorer 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 is 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 (Killion et al., 2004; Smits et al., 2013). 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 (Gopinath et al., 2012; Saito et al., 2010).

The prevalence of clinically significant depressive symptomology is 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]) is associated with over 2 times higher odds of clinically significant depressive symptomology (Shukla et al., 2021). Additionally, a meta-analysis of 35 studies reports hearing loss (measured objectively in 9 of 35 of studies) is associated with 1.47 (1.31–1.65) greater odds of prevalent depressive symptoms (Lawrence et al., 2020). One study in this meta-analysis assessed speech-in-noise

recognition and observed no association with depressive symptoms (Pronk et al., 2011) and only one study used a validated measure of the self-perceived functional, emotional, and social consequences of hearing loss (The Hearing Handicap Inventory for the Elderly [HHIE]). Higher HHIE scores were 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 more severe hearing loss (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 are also observed (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.

This study investigates the cross-sectional associations between hearing loss, depressive symptomology, and health related quality of life among older adults with unaided hearing loss. We hypothesize that more severe hearing loss is associated with greater depressive symptomology and lower health-related quality of life. A secondary objective of this study is to investigate the associations of speech-in-noise recognition and the self-perceived functional, emotional, and social consequences of hearing loss (HHIE-S) 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 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 unaided, 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. Inclusion and exclusion criteria were chosen to recruit participants who were eligible for hearing treatment, not cognitively impaired, and physically capable of participating in the study.

ACHIEVE is partially nested within the Atherosclerosis Risk in Communities (ARIC) Study with 24.5% of participants recruited from the ARIC Study and 75.5% newly recruited from the surrounding communities (*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 psychometrically validated 11-item Center for Epidemiologic Studies Depression scale (CES-D-11) (Cronbach's alpha: 0.76) (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 (Hays & Morales, 2001). The RAND36 is a psychometrically validated measure that includes 36 questions about eight domains of health using a past 4 weeks' interval: physical functioning, physical role limitations, emotional role limitations, energy/fatigue, emotional well-being, social functioning, pain, general health (Cronbach's alpha > 0.73 for all domains) (Brazier et al., 1992). 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 calculated using the summary component scoring algorithm (Taft et al., 2001).

Pure tone average—The ability to detect sound was measured by the air-conduction speech-frequency PTA in the better hearing ear. PTA was measured by the average of hearing thresholds at four frequencies (0.5, 1, 2, 4 kilohertz [kHz]). Hearing assessment was

conducted in a single-walled, 7×7 sound attenuating WhisperRoom by a study audiologist. 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) (World Health Organization, 2021).

Speech-in-noise recognition—Speech-in-noise recognition was measured by the Quick Speech-in-Noise (QuickSIN) test (Killion et al., 2004) in a single-walled, 7×7 sound attenuating WhisperRoom by a study audiologist. 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]).

Self-perceived functional, emotional, and social consequences of hearing loss—Self-perceived functional, emotional, and social consequences of hearing loss was measured by the 10-item screening version of the HHIE (HHIE-S) (Cronbach's alpha: 0.87) (Lichtenstein et al., 1988; 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 hearing measure 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 (depressive symptomology: positive skew [mean > median], mental and physical health-related quality of life: negative skew [mean < median]) and overdispersion (variance > mean) in the distribution of the dependent variables. Estimates are reported as ratios. For depressive symptomology (higher CES-D-11 scores indicate worse depressive symptomology), ratio >1 indicates association with greater depressive symptomology and ratio <1 indicates association with less depressive symptomology. For health-related quality of life (higher RAND-36 scores indicate better health quality of life), ratio >1 indicates and association with greater health related quality of life and ratio <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, 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

The mean age of the sample was 76.8 (4.0) years. Participants were 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 2). 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).

More severe hearing loss was associated with lower (worse) physical health component scores (per 10 dB higher PTA: Ratio: 0.98, 95% CI: 0.96,1.00) (Table 4). When PTA was modeled as a binary measure, estimates suggested lower (worse) physical health component scores among those with moderate or greater hearing loss (vs. mild hearing loss [reference]) but estimates were not statistically significant. Associations with depressive symptomology (Table 3) and mental health component score (Table 4) were similar between those with moderate or greater vs. mild hearing loss.

Greater speech-in-noise recognition was associated with higher (better) mental health component score (per 5 unit higher QuickSIN score: Ratio: 1.01, 95% CI: 1.00, 1.02) (Table 4). When QuickSIN speech-in-noise recognition was modeled as a binary measure, estimates suggested higher (better) 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 with depressive symptomology and physical health component score were similar by QuickSIN speech-in-noise recognition score (Tables 3 and 4).

Greater functional, social, and emotional impacts of hearing loss (HHIE-S score) was associated with greater depressive symptomology score (per 10 units higher HHIE-S score: Ratio: 1.24, 95% CI: 1.16, 1.33). Higher HHIE-S score was also associated with lower (worse) mental (per 10 units higher HHIE-S score: Ratio: 0.97, 95% CI: 0.96,0.98) and physical health component scores (per 10 units higher HHIE-S score: Ratio: 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 3 and 4).

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

This study investigated, among older adults with unaided hearing loss, the cross-sectional associations of hearing loss severity, speech-in-noise recognition, and HHIE with depressive symptomology over the past week and health related quality of life over the past month. Greater hearing loss severity (i.e., higher PTA) was cross-sectionally associated with worse physical health quality of life. Better speech-in-noise recognition was associated with higher mental health quality of life. Associations with depressive symptomology were similar between mild and moderate or greater hearing loss as well as by level of speech-in-

noise recognition. Greater self-perceived functional, emotional, and social consequences of hearing loss was associated with greater depressive symptomology and poorer health-related quality of life. Collectively, these results suggest hearing loss is an important part of 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 unaided 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 (and compare to participants with normal hearing) as analytic approaches and interpretations differ. 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 unaided hearing loss, do not have dementia, are primarily White (87.7%) or Black (11.6%), and were recruited from specific geographical areas.

The current study suggests that older adults with mild hearing loss may experience depressive symptoms similarly to those with moderate or greater hearing loss. 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). Some studies including participants with the full range of hearing did not observe significant associations between PTA and depression symptomology (Kiely et al., 2013; Mener et al., 2013; Mick & Pichora-Fuller, 2016) while others observe associations in specific subgroups (e.g. older women (Li et al., 2014; Scinicariello et al., 2019), Hispanic older adults (Golub et al., 2019)) (Lawrence et al., 2020). 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 unaided 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. These domains include physical functioning, emotional role limitations, and social functioning, concurrent with findings from 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 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 unaided 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).

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. This study is cross-sectional and the directionality of the association as well as

persistence or specific patterns of depression symptomology and health-related quality of life over time could not be established. This study does, however, set 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 unaided 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). An increased clinical awareness of mental health considerations among older adults with hearing loss or those who self-report poor functional, emotional, and social consequences of hearing loss is needed. Similarly, greater awareness among mental health professionals of the link between hearing loss and mental health may aid in care and treatment decisions. The HHIE-S (Ventry & Weinstein, 1982) is a short and easily administered questionnaire that could have greater utility in audiological as well as primary and mental health care settings to quickly identify hearing concerns potentially linked to mental health concerns.

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 hearing loss may have varying levels of HHIE-S scores based on the hearing-related demands of the environments in which they navigate. Greater accessibility for individuals with hearing loss 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 the ability to detect sound 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. 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. The ACHIEVE study (Clinicaltrials.gov Identifier: NCT03243422) will test the effect of hearing intervention (vs. a successful aging health education control) on depressive symptomology and health related quality of life as pre-specified exploratory outcomes.

In conclusion, in a sample of older adults with unaided hearing loss, worse 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 self-perceived functional, emotional, and social consequences of hearing loss was associated with both depressive symptomology and health-related quality of life. Future work may assess potential mediators and moderations of this association and whether hearing intervention may be efficacious for reducing depressive symptomology and improving health-related quality of life among older adults with hearing loss.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements and Funders

Members of the ACHIEVE Collaborative Research Group are listed at achievestudy.org.

The Aging and Cognitive Health Evaluation in Elders (ACHIEVE) Study is supported by the National Institute on Aging (NIA) R01AG055426 and R01AG060502 with previous pilot study support from the NIA R34AG046548 and the Eleanor Schwartz Charitable Foundation, in collaboration with the Atherosclerosis Risk in Communities (ARIC) Study, supported by National Heart, Lung, and Blood Institute contracts (HHSN268201700001I, HHSN268201700002I, HHSN268201700003I, HHSN268201700005I, HHSN268201700004I). Neurocognitive data is collected by 2U01HL096812, 2U01HL096814, 2U01HL096899, 2U01HL096902, 2U01HL096917 from the NIH (NHLBI, NINDS, NIA and NIDCD), and with previous brain MRI examinations funded by R01HL70825 from the NHLBI. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

The investigators thank the staff and participants of the ACHIEVE and ARIC studies for their important contributions and dedication to the study. The investigators also thank Sonova/Phonak for in-kind donation of hearing technologies and training support of audiologists for the ACHIEVE study.

Dr. Reed reported serving on the scientific advisory boards of Neosensory.

Dr. Lin reported being a consultant to Frequency Therapeutics and Apple and being the director of a research center funded in part by a philanthropic gift from Cochlear Ltd to the Johns Hopkins Bloomberg School of Public Health. Dr. Lin is also a board member of the nonprofit Access HEARS.

Dr. Sanchez reported industry funding related to consulting or research support from Otonomy Inc., Autifony Therapeutics Ltd., Boehringer Ingelheim, Frequency Therapeutics Ltd., Pipeline Therapeutics, Aerin Medical, Oticon Medical, Helen of Troy Ltd., Sonova Holding AG, and Phonak USA.

References

Almeida OP (2014). Prevention of depression in older age. Maturitas, 79(2), 136–141. [PubMed: 24713453]

Arnold ML, Haley W, Lin FR, Faucette S, Sherry L, Higuchi K, Witherell K, Anderson E, Reed NS, & Chisolm TH (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. [PubMed: 34533430]

Brazier JE, Harper R, Jones NM, O'cathain A, Thomas KJ, Usherwood T, & Westlake L. (1992). Validating the SF-36 health survey questionnaire: New outcome measure for primary care. British Medical Journal, 305(6846), 160–164. [PubMed: 1285753]

Campos J, Ramkhalawansingh R, & Pichora-Fuller MK (2018). Hearing, self-motion perception, mobility, and aging. Hearing Research, 369, 42–55. [PubMed: 29661612]

Cao C, Hu L, Xu T, Liu Q, Koyanagi A, Yang L, Carvalho AF, Cavazos-Rehg PA, & Smith L. (2020). Prevalence, correlates and misperception of depression symptoms in the United States, NHANES 2015–2018. Journal of Affective Disorders, 269, 51–57. [PubMed: 32217343]

Chen DS, Betz J, Yaffe K, Ayonayon HN, Kritchevsky S, Martin KR, Harris TB, 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 HL (1994). Hearing in the elderly: Relation of hearing loss, loneliness, and self-esteem. Journal of Gerontological Nursing, 20(6), 22–28. [PubMed: 8006351]

Chew HS, & Yeak S. (2010). Quality of life in patients with untreated age-related hearing loss. The Journal of Laryngology & Otology, 124(8), 835–841. [PubMed: 20403224]

Chisolm TH, Johnson CE, Danhauer JL, Portz LJ, Abrams HB, Lesner S, McCarthy PA, & Newman CW (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. [PubMed: 17402301]

Choi JS, Betz J, Deal J, Contrera KJ, Genther DJ, Chen DS, Gispen FE, & Lin FR (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. [PubMed: 26553723]

Choi JS, Betz J, Li L, Blake CR, Sung YK, Contrera KJ, & Lin FR (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. [PubMed: 27258813]

Clarke PJ, Ailshire JA, Nieuwenhuijsen ER, & de Kleijn–de Vrankrijker MW (2011). Participation among adults with disability: The role of the urban environment. Social Science & Medicine, 72(10), 1674–1684. [PubMed: 21514024]

Contrera KJ, Betz J, Li L, Blake CR, Sung YK, Choi JS, & Lin FR (2016). Quality of life after intervention with a cochlear implant or hearing aid. The Laryngoscope, 126(9), 2110–2115. [PubMed: 26775283]

Cuijpers P, Beekman AT, & Reynolds CF (2012). Preventing depression: A global priority. Jama, 307(10), 1033–1034. [PubMed: 22416097]

Dalton DS, Cruickshanks KJ, Klein BE, Klein R, Wiley TL, & Nondahl DM (2003). The impact of hearing loss on quality of life in older adults. The Gerontologist, 43(5), 661–668. [PubMed: 14570962]

Dawes P, Cruickshanks KJ, Fischer ME, Klein BE, Klein R, & Nondahl DM (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. [PubMed: 26140300]

Deal JA, Betz J, Yaffe K, Harris T, Purchase-Helzner E, Satterfield S, Pratt S, Govil N, Simonsick EM, Lin FR, & 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. 10.1093/gerona/glw069

Deal JA, Goman AM, Albert MS, Arnold ML, Burgard S, Chisolm T, Couper D, Glynn NW, Gmelin T, & Hayden KM (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. [PubMed: 30364572]

Garstecki DC, & Erler SF (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 JS, Brewster KK, Brickman AM, Ciarleglio AJ, Kim AH, Luchsinger JA, & Rutherford BR (2019). Association of audiometric age-related hearing loss with depressive symptoms among Hispanic individuals. JAMA Otolaryngology–Head & Neck Surgery, 145(2), 132–139. [PubMed: 30520955]

Goman AM, & Lin FR (2016). Prevalence of hearing loss by severity in the United States. American Journal of Public Health, 106(10), 1820–1822. [PubMed: 27552261]

Gopinath B, Schneider J, Hickson L, McMahon CM, Burlutsky G, Leeder SR, & 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. [PubMed: 22521684]

Gopinath B, Wang JJ, Schneider J, Burlutsky G, Snowdon J, McMahon CM, Leeder SR, & 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. [PubMed: 19570163]

Hays RD, & Morales LS (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 AR, Deal JA, Rebok GW, Pinto JM, Waite L, & Lin FR (2021). Hearing impairment and loneliness in older adults in the United States. Journal of Applied Gerontology, 40(10), 1366–1371. [PubMed: 32749194]

Huang AR, Jiang K, Lin FR, Deal JA, & Reed NS (2023). Hearing Loss and Dementia Prevalence in Older Adults in the US. JAMA, 329(2), 171–173. [PubMed: 36625819]

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 KM, Anstey KJ, & Luszcz MA (2013). Dual sensory loss and depressive symptoms: The importance of hearing, daily functioning, and activity engagement. Frontiers in Human Neuroscience, 7, 837. [PubMed: 24379769]

Killion MC, Niquette PA, Gudmundsen GI, Revit LJ, & 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. [PubMed: 15532670]

Kohout FJ, Berkman LF, Evans DA, & Cornoni-Huntley J. (1993). Two shorter forms of the CES-D depression symptoms index. Journal of Aging and Health, 5(2), 179–193. [PubMed: 10125443]

Lawrence BJ, Jayakody DM, Bennett RJ, Eikelboom RH, Gasson N, & Friedland PL (2020). Hearing loss and depression in older adults: A systematic review and meta-analysis. The Gerontologist, 60(3), e137–e154. [PubMed: 30835787]

Li C-M, Zhang X, Hoffman HJ, Cotch MF, Themann CL, & Wilson MR (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. [PubMed: 24604103]

Lichtenstein MJ, Bess FH, & Logan SA (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. [PubMed: 3169401]

Lin FR, Metter EJ, O'Brien RJ, Resnick SM, Zonderman AB, & Ferrucci L. (2011). Hearing loss and incident dementia. Archives of Neurology, 68(2), 214–220. [PubMed: 21320988]

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 MM, 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. [PubMed: 31486068]

Martinez-Amezcua P, Dooley EE, Reed NS, Powell D, Hornikel B, Golub JS, Gabriel KP, & 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. [PubMed: 35302630]

Martinez-Amezcua P, Kuo P-L, Reed NS, Simonsick EM, Agrawal Y, Lin FR, Deal JA, Ferrucci L, & Schrack JA (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 JJ, Lin F, Schrack JA, & Deal JA (2021). Hearing impairment and objectively measured physical activity: A systematic review. Journal of the American Geriatrics Society.

Mener DJ, Betz J, Genther DJ, Chen D, & Lin FR (2013). Hearing loss and depression in older adults. Journal of the American Geriatrics Society, 61(9), 1627. [PubMed: 24028365]

Mick P, Kawachi I, & Lin FR (2014). The association between hearing loss and social isolation in older adults. Otolaryngology–Head and Neck Surgery, 150(3), 378–384. [PubMed: 24384545]

Mick P, & Pichora-Fuller MK (2016). Is hearing loss associated with poorer health in older adults who might benefit from hearing screening? Ear and Hearing, 37(3), e194–e201. [PubMed: 26825862]

Mondelli MFCG, & de Souza PJS (2012). Quality of life in elderly adults before and after hearing aid fitting. Brazilian Journal of Otorhinolaryngology, 78(3), 49–56. [PubMed: 22714847]

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

Pichora-Fuller MK, Kramer SE, Eckert MA, Edwards B, Hornsby BW, Humes LE, Lemke U, Lunner T, Matthen M, & Mackersie CL (2016). Hearing impairment and cognitive energy: The framework for understanding effortful listening (FUEL). Ear and Hearing, 37, 5S–27S. [PubMed: 27355771]

Pichora-Fuller MK, 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. [PubMed: 27516713]

Pronk M, Deeg DJH, Smits C, Tilburg TG van Kuik DJ, Festen JM, & Kramer SE (2011). Prospective effects of hearing status on loneliness and depression in older persons: Identification of subgroups. International Journal of Audiology, 50(12), 887–896. 10.3109/14992027.2011.599871 [PubMed: 21929374]

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. [PubMed: 20002512]

Sanchez VA, Arnold ML, Reed NS, Oree PH, Matthews CR, Eddins AC, Lin FR, & Chisolm TH (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. [PubMed: 32251012]

Scinicariello F, Przybyla J, Carroll Y, Eichwald J, Decker J, & Breysse PN (2019). Age and sex differences in hearing loss association with depressive symptoms: Analyses of NHANES 2011–2012. Psychological Medicine, 49(6), 962–968. [PubMed: 29909806]

Shuai L, & Gong T. (2014). Temporal relation between top-down and bottom-up processing in lexical tone perception. Frontiers in Behavioral Neuroscience, 8, 97. [PubMed: 24723863]

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

Shukla A, Reed NS, Armstrong NM, Lin FR, Deal JA, & Goman AM (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.

Smits C, Theo Goverts S, & Festen JM (2013). The digits-in-noise test: Assessing auditory speech recognition abilities in noise. The Journal of the Acoustical Society of America, 133(3), 1693–1706. [PubMed: 23464039]

StataCorp. (2021). Stata Statistical Software: Release 17 [Computer software]. StataCorp LLC.

Sung Y, Li L, Blake C, Betz J, & Lin FR (2016). Association of hearing loss and loneliness in older adults. Journal of Aging and Health, 28(6), 979–994. [PubMed: 26597841]

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. [PubMed: 11763202]

Tseng Y-C, Liu SH-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. [PubMed: 29404924]

Ventry IM, & Weinstein BE (1982). The hearing handicap inventory for the elderly: A new tool. Ear and Hearing, 3(3), 128–134. [PubMed: 7095321]

Wallhagen MI (2010). The stigma of hearing loss. The Gerontologist, 50(1), 66–75. [PubMed: 19592638]

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 for identifying 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

Table 1:

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

	Total N=948	Mild Hearing Loss[c] N=274	Moderate or Greater Hearing Loss[c] 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)
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)
Recruitment type, n (%)			
ARIC[b]	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)

Notes:

[a] Other race includes Asian (n=6), American Indian, Native American, Native Hawaiian, Pacific Islander (n=3)

[b] ARIC: 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:

Hearing characteristics, depressive symptoms, and health-related quality of life by hearing level (N=948), Aging and Cognitive Health Evaluation in Elders (ACHIEVE) Study, 2018–2019

	Total N=948	Mild Hearing Loss[a] N=274	Moderate or Greater Hearing Loss[a] N=674
Hearing Characteristics			
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 (CESD-11)[c], mean (SD)	2.5 (2.5)	2.3 (2.4)	2.5 (2.5)
Health-Related Quality of Life (RAND36) [d]			
Physical Functioning, mean (SD)	75.3 (22.0)	78.6 (20.2)	74.0 (22.5)
Physical Role Limitations, mean (SD)	71.1 (37.1)	74.9 (36.1)	69.5 (37.4)
Emotional Role Limitations, mean (SD)	90.5 (23.6)	92.1 (21.5)	89.9 (24.4)
Energy/Fatigue, mean (SD)	63.7 (18.8)	64.6 (18.9)	63.3 (18.7)
Emotional Well-being, mean (SD)	85.5 (12.0)	85.2 (11.0)	85.6 (12.4)
Social Functioning, mean (SD)	87.8 (18.3)	89.6 (16.1)	87.1 (19.1)
Pain, mean (SD)	73.4 (22.6)	73.6 (21.7)	73.4 (23.0)
General Health, mean (SD)	69.5 (17.4)	70.9 (16.9)	68.9 (17.6)
Mental Health-Related Quality of Life Component Score, mean (SD)	56.3 (6.6)	56.2 (6.3)	56.3 (6.8)
Physical Health-Related Quality of Life Component Score, mean (SD)	44.8 (9.8)	46.0 (9.4)	44.3 (9.9)

Notes:

[a] 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

[b] QuickSIN score range: 0 – 30; HHIE-S score range: 0 – 40

[c] CESD-11 score range: 0 – 22

[d] RAND36 domain and component score ranges: 0 −100

Table 3:

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)	**Ratio**	**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 4:

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)	**Ratio**	**95% CI**	**Mean (SD)**	**Ratio**	**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 5:

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
	Ratio 95% CI	Ratio 95% CI	Ratio 95% CI	Ratio 95% CI	Ratio 95% CI	Ratio 95% CI	Ratio 95% CI	Ratio 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.