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Research Report

Hearing Loss, Hearing Aid Use, and Depressive Symptoms in Older Adults—Findings from the Atherosclerosis Risk in Communities Neurocognitive Study (ARIC-NCS)

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Abstract

Objectives: Investigate the cross-sectional association between hearing loss (HL), hearing aid use, and depressive symptoms in community-dwelling older adults.
Method: The analytic sample consisted of 3,188 participants (age range 71–94 years) in the Atherosclerosis Risk in Communities Neurocognitive Study (ARIC-NCS). Multivariable logistic regression was used to evaluate the association of audiometric hearing status and self-reported hearing aid use with depressive symptoms (11-item Center for Epidemiologic Studies Depression scale).
Results: 4.6% of participants had depressive symptoms. Forty percent had mild HL and 27% had moderate or greater HL. In multivariable-adjusted models, mild HL was associated with 1.90 times higher odds (95% confidence interval [CI] 1.20–3.01) and moderate or greater HL with 2.42 times higher odds (95% CI 1.44–4.07) of depressive symptoms compared to normal hearing. Each 10dB increase in HL was associated with 1.30 higher odds of depressive symptoms (95% CI 1.14–1.49). Hearing aid use was not associated with depressive symptoms among those with mild (odds ratio [OR] 0.94, 95% CI 0.35–2.54) or moderate or greater (OR 1.12, 95% CI 0.60–2.11) HL.
Discussion: Older adults with HL have higher odds of depressive symptoms compared to adults with normal hearing. Future studies are needed to assess whether hearing care is protective against depressive symptoms in older adults.

Keywords: Depression, Epidemiology, Mental health, Sensory/Sensorimotor Processes

Depression is a common chronic health condition among older adults that affects 1%–5% of older adults in the United States (Fiske, Wetherell, & Gatz, 2009) and increases risk for cognitive and functional decline (Stuck et al., 1999; Yaffe et al., 1999). Hearing loss (HL) is another common condition in older adults; two-thirds of U.S. adults aged ≥70 years have clinically significant HL (Lin, Niparko, & Ferrucci, 2011). Although HL is amenable to treatment, hearing aids remain underutilized with less than 20% of adults with HL using them (Chien & Lin, 2012). Recent epidemiological evidence suggests that age-related HL is associated with negative cognitive, physical, and psychosocial health consequences (Contrera et al., 2016; Lin & Ferrucci, 2012; Livingston et al., 2017).

Older adults with HL may have difficulty communicating, especially in social environments with loud background noises (Pichora-Fuller, 2003), which could lead to social withdrawal and loneliness (Heine & Browning, 2004; Sung, Li, Blake, Betz, & Lin, 2016). Social isolation and loneliness are hypothesized potential mechanisms through which HL may be associated with depression (Kiely, Anstey, & Luszcz, 2013; Rutherford, Brewster, Golub, Kim, & Roose, 2018).

Previous epidemiological studies of objective HL and depressive symptoms in older adults have had conflicting findings. One study found that HL was associated with lower scores on the SF-36 Mental Health Index but not with depressive symptoms (Gopinath et al., 2009). However, another recent study of Hispanic Americans found that each 20 dB increase in HL was associated with 45% increase in odds of depressive symptoms (Golub et al., 2018). Other studies have found either no association between objective hearing status and depression (Mener, Betz, Genther, Chen, & Lin, 2013) or have found an association only among women (Li et al., 2014). Therefore, further investigation into the association between objective HL and depressive symptoms is needed.

We used data from the Atherosclerosis Risk in Communities Neurocognitive Study (ARIC-NCS) to examine the association between HL, hearing aid use and depressive symptoms in community-dwelling older adults. We hypothesize that objectively measured HL is independently associated with higher odds of depressive symptoms compared to normal hearing.

Methods

Study Population

The Atherosclerosis Risk in Communities (ARIC) Study is an ongoing prospective cohort study that enrolled 15,792 participants aged 45–64 years in 1987–1989 (Visit 1). Participants were recruited using probability sampling from four communities in the United States: Jackson, Mississippi; Forsyth County, North Carolina; Minneapolis, Minnesota; and Washington County, Maryland. Participants have completed six subsequent visits over 30 years. The study design of ARIC has previously been described in detail (ARIC, 1989). An audiometric hearing assessment was introduced in Visit 6 (2016–2017). Of the original 15,792 ARIC participants, 4,003 (25.3%) attended Visit 6. Those who attended Visit 6 were more likely to be younger at Visit 1, female, white and more educated than those who did not attend Visit 6. Of the 4,003 participants who attended Visit 6, we excluded participants who were missing audiometric evaluation (n = 384), depressive symptomology outcome measure (n = 171), or covariate data (n = 241). We also excluded nonblack/nonwhite participants and blacks from Minneapolis and Washington County due to small numbers (n = 19). The analytic sample consisted of 3,188 participants (Supplementary Table 1).

Hearing Assessment

Audiometric examination was administered in clinic or at home visits by trained examiners. At clinic sites, audiometry was conducted in a soundproof booth. Air conduction thresholds in each ear were obtained using insert earphones and an Interacoustic AD629 audiometer. At home visits, ambient noise level analysis was performed prior to testing and audiometric evaluation occurred only if the ambient noise level was indicated as quiet (on a scale of quiet, moderate, and too noisy) by the portable audiometer. The portable audiometer has been validated for evaluation of HL in quiet and noisy environments (Saliba et al., 2017) and complies with the same American National Standards Institute (ANSI) criteria for testing environment, measurement techniques, and calibration standards as traditional audiometry.

A Pure-Tone Average (PTA) threshold for each ear was calculated using air conduction thresholds at 0.5, 1, 2, and 4 kHz. For primary analysis, HL was analyzed as a categorical variable, defined using clinical cut points for the better-hearing ear PTA in accordance with World Health Organization guidelines as normal hearing (<25 decibels hearing level [dB HL]), mild HL (≥25 to <40 dB HL) and moderate or greater HL (≥40 dB HL). For secondary analysis, we considered PTA in the better-hearing ear as a continuous variable, scaled by 10 dB HL.

Hearing aid use was determined using the following question: "Do you currently use a hearing aid in your right (left) ear?" Participants who answered yes for either ear were categorized as using hearing aids.

Depressive Symptomology

Depressive symptomology was measured using the 11-item Center for Epidemiologic Studies Depression scale (CES-D) (Kohout, Berkman, Evans, & Cornoni-Huntley, 1993). The CES-D is a validated (Gellis, 2010) measure of frequency of depressive symptoms in the past week, with responses scored as 0 (<1 day in the past week), 1 (1–2 days in the past week), or 2 (3–7 days in the past week) for each question. The scores are summed for a total scale score ranging from 0 to 22, with higher scores indicating greater depressive symptoms. The 11-item CES-D reflects four symptom domains: depressed affect, positive affect, somatic symptoms and interpersonal symptoms. On the 11-item CES-D scale, a score of ≥9 can identify individuals with clinically significant depressive symptoms (Kohout et al., 1993). For primary analysis, we evaluated CES-D as a binary outcome variable, with a score of ≥9 considered "positive" for depressive symptomology. We also conducted analysis with CES-D score as a continuous variable.

Covariates

Demographic variables were categorized as follows: age (≤75; 76–80; 81–85; and ≥86 years), sex (male or female), and education (less than high school, high school or General Educational Degree, or more than high school). Because race is so tightly linked to field site in ARIC, we adjusted for a categorical race-center variable (Minnesota whites, Maryland whites, North Carolina whites, North Carolina blacks, Mississippi blacks).

Smoking status was assessed through self-report and categorized as never smoker, former smoker and current smoker. Body mass index was derived from height and weight measurements. Hypertension was defined as present if systolic blood pressure >140 mmHg, diastolic BP >90 mmHg, or self-reported use of antihypertensive medications. Diabetes was considered present if one or more of the following was present: fasting blood glucose ≥126 mg/dL, nonfasting blood glucose ≥200 mg/dL, self-reported use of diabetes medication, or self-reported physician diagnosis of diabetes. History of myocardial infarction (MI) and stroke were derived from participant self-report at Visit 1 or adjudicated events thereafter. Cognition was measured using a summary variable representing general cognitive performance across 10 neurocognitive tests administered at Visit 6. Derivation of the summary variable is described in detail elsewhere (Gross et al., 2015).

Statistical Analysis

Baseline demographic and clinical characteristics were compared using Pearson's chi-squared tests or ANOVA. The relationship between HL and depressive symptoms was analyzed using multivariable logistic regression. Models were adjusted for demographic and clinical characteristics. Our final model included age as both a nominal categorical variable as well as a continuous variable to account for any residual confounding by age. To assess the association of hearing aid use and depressive symptoms, we restricted our analysis to those who had HL and examined the association using multivariable logistic regression models separately for those who have mild HL (n = 1,265) and for those who have moderate or greater HL (n = 853). All analyses were performed using Stata version 15 (StataCorp LLC, College Station, TX).

Results

The mean age of the study population was 79.1 years (standard deviation 4.6). Overall, 39.7% had mild HL and 26.8% had moderate or greater HL (Table 1). Participants with HL were more likely to be older, male, white, have less education, have a history of stroke and MI, have lower cognition scores, and use hearing aids than those with normal hearing (Table 1). The overall prevalence of depressive symptoms (CES-D ≥ 9) was 4.6%.

In unadjusted analyses, mild HL (odds ratio [OR] 1.73, 95% confidence interval [CI] 1.12–2.66) and moderate or greater HL (OR 2.06, 95% CI 1.31–3.24) were associated with higher odds of depressive symptoms compared to normal hearing (Table 2). In fully-adjusted analyses, effect estimates remained significant for both mild HL (OR 1.90, 95% CI 1.20–3.01) and moderate or greater HL (OR 2.42, 95% CI 1.44–4.07; Table 2).

Each 10 dB increase in PTA was associated with a 1.24 (95% CI 1.11–1.39) times increase in odds of depressive symptoms in unadjusted analysis and with a 1.30 (95% CI 1.14–1.49) times increase in odds of depressive symptoms in fully-adjusted analysis. When considering CES-D score as a continuous outcome variable, each 10dB increase in PTA was associated with a 0.11 (95% CI 0.04–0.19) increase in CES-D score.

Overall, 11.7% of participants with mild HL and 54.9% of participants with moderate or greater HL reported hearing aid use (Table 1). Among participants with HL, we found no statistically significant difference in depressive symptoms among participants who did and did not use hearing aids in unadjusted or adjusted models (Table 3).

Discussion

In this study of 3,188 older adults aged 71–94 years, objectively measured HL was associated with higher odds of depressive symptoms, independent of demographics, cardiovascular risk factors, and cognition. Those with mild and moderate or greater HL had 1.9 and 2.4 times higher odds of depressive symptoms, respectively. Each 10 dB increase in PTA was associated with 1.3 times higher odds of depressive symptoms. Among participants with HL, hearing aid users did not have decreased odds of depressive symptoms compared to hearing aid nonusers.

Our findings are consistent with the previous studies that have found an association between objective HL and depressive symptoms in older adults (Golub et al., 2018, Gopinath et al., 2009). However, other epidemiological studies have found no association between audiometric hearing and depressive symptoms (Mener et al., 2013). The prevalence of depressive symptoms in our study population was lower than what has been reported in other studies of community-dwelling older adults (Blazer, 2003; Gopinath et al., 2009). This may reflect the fact that our study sample consists of participants who have completed several visits of an ongoing study and may be otherwise healthier and less likely to have depressive symptoms than the general population.

The observed cross-sectional association might be a result of unmeasured factors that may cause both HL and depressive symptoms. However, HL and depressive symptoms could plausibly be mechanistically linked through social isolation and loneliness. Older adults with HL may be more socially isolated and lonely (Heine & Browning, 2004; Mick, Kawachi, & Lin, 2014; Sung et al., 2016),

Table 1. Baseline Characteristics of the Study Population by Hearing Status[a]

Variable	Total	No HL	Mild HL	Moderate or greater HL	
Total Sample (*n*, %)	3,188	1,070 (33.6)	1,265 (39.7)	853 (26.8)	*p* value[b]
Age (years, %)					
71–75	810 (25.4)	386 (47.7)	319 (39.4)	105 (12.9)	<.001
76–80	1,275 (40.0)	484 (38.0)	506 (39.7)	285 (22.4)	
81–85	754 (23.7)	166 (22.0)	312 (41.4)	276 (36.6)	
86–94	349 (11.0)	34 (9.7)	128 (36.7)	187 (53.6)	
Female, *n*, %	1,882 (59.0)	779 (41.4)	729 (38.7)	374 (19.9)	<.001
Black, *n*, %	710 (22.3)	360 (50.7)	251 (35.4)	99 (13.9)	<.001
Education, *n*, %					
<High school	368 (11.5)	104 (28.2)	138 (37.5)	126 (34.2)	<.001
High school/GED	1,311 (41.1)	406 (31.0)	527 (40.2)	378 (28.8)	
>High school	1,509 (47.3)	560 (37.1)	600 (39.8)	349 (23.1)	
BMI (kg/m^2), mean, *SD*	28.4 (5.4)	28.5 (5.5)	28.6 (5.5)	27.9 (4.9)	.008
Smoking status, *n*, %					
Current	228 (7.2)	81 (35.5)	81 (35.5)	66 (28.9)	.040
Former	1,494 (46.9)	463 (31.0)	625 (41.8)	406 (27.2)	
Never	1,466 (46.0)	526 (35.9)	559 (38.1)	381 (26.0)	
Diabetes, %	1,057 (33.2)	342 (32.4)	433 (41.0)	282 (26.7)	.510
Hypertension, %	2,531 (79.4)	861 (34.0)	989 (39.1)	681 (26.9)	.370
History of MI, %	302 (9.5)	87 (28.8)	107 (35.4)	108 (35.7)	.001
History of stroke, %	453 (14.2)	138 (30.5)	168 (37.0)	147 (32.5)	.012
[b]Cognitive factor score (*SD*)	−0.11 (0.88)	0.10 (0.86)	−0.01(0.85)	−0.16 (0.82)	<.001
Hearing aid use, %	630 (19.8)	14 (2.2)	148 (23.5)	468 (74.2)	<.001
Depressive symptoms (CES-D ≥ 9)	147 (4.6)	32 (21.8)	64 (43.5)	51 (34.7)	.005

Note: BMI = Body mass index; GED = General educational development; HL = Hearing loss; MI = Myocardial infarction; SD = Standard deviation.
[a]Hearing status defined using WHO criteria pure-tone averages (PTA) of thresholds at 0.5, 1, 2, and 4 kHz frequencies in the better hearing ear. Categorized using PTA as normal (<25dB), mild hearing loss (≥25 to <40 dB) and moderate or greater hearing loss (≥40 dB).
[b]*p* values for Pearson's chi-squared tests for categorical variables and analysis of variance for continuous variables.
[c]Cognitive factor score is a summary score representing performance across all Visit 6 neurocognitive tests with units in standard deviations.

Table 2. Odds Ratio of Depressive Symptoms in Those with Hearing Loss Compared to Normal Hearing

	Odds of CES-D score ≥ 9					
	Mild hearing loss[a]	95% CI	*p*	Moderate or greater hearing loss[a]	95% CI	*p*
Base (hearing only)	1.73	1.12–2.66	.013	2.06	1.31–3.24	.002
Base + Demographics[b]	2.05	1.31–3.21	.002	2.73	1.65–4.52	<.001
Base + Demographics + Cardiovascular risk factors[c]	2.03	1.29–3.19	.002	2.64	1.58–4.42	<.001
Base + Demographics + Cardiovascular + Cognition[d]	1.90	1.20–3.01	.006	2.42	1.44–4.07	.001

Note: CES-D = Center for Epidemiological Studies Depression scale; CI = Confidence interval.
[a]Hearing status defined using pure-tone averages (PTA) at 0.5, 1, 2 and 4 kHz frequencies in the better hearing ear. Categorized using PTA as normal (<25 dB), mild hearing loss (≥25 to <40 dB) and moderate/severe hearing loss (≥40 dB).
[b]Demographics include age, sex, race-center, and education.
[c]Cardiovascular risk factors include BMI, smoking status, hypertension, diabetes, history of myocardial infarction, and history of stroke.
[d]Cognition factor score is a summary score representing performance across all Visit 6 neurocognitive tests.

which could in turn lead to depressive symptoms. One study of dual sensory (vision and hearing) loss found that social engagement partially explained the association between sensory impairment and depressive symptoms (Kiely et al., 2013). Future studies within the ARIC cohort could examine social support and loneliness as mediators of the association between HL and depressive symptoms.

Table 3. Odds Ratio of Depressive Symptoms Among Hearing Aid Users Compared to Nonhearing Aid Users Within Each Hearing Loss Category (mild hearing loss, moderate or greater hearing loss)

	Odds of CES-D score ≥ 9					
	Mild HL[a] (*N* = 1,265)	95% CI	*p*	Moderate or greater HL[b] (*N* = 853)	95% CI	*p*
Base (hearing only)	0.63	0.25–1.59	.33	0.85	0.48–1.50	.57
Base + Demographics[c]	0.90	0.35–2.35	.83	1.06	0.58–1.95	.85
Base + Demographics + Cardiovascular risk factors[d]	0.81	0.30–2.16	.67	1.06	0.57–1.98	.86
Base + Demographics + Cardiovascular + Cognition[d]	0.94	0.35–2.54	.89	1.12	0.60–2.11	.72

Note: CES-D = Center for Epidemiological Studies Depression scale; CI = Confidence interval; HL = Hearing loss.

[a,b]Hearing status defined using pure-tone averages (PTA) at 0.5, 1, 2, and 4 kHz frequencies in the better hearing ear. Categorized using PTA as normal (<25 dB), mild hearing loss (≥25 to <40 dB) and moderate/severe hearing loss (≥40 dB).

[c]Demographics include age, sex, race-center, and education.

[d]Cardiovascular risk factors include body mass index, smoking status, hypertension, diabetes, history of myocardial infarction, and history of stroke.

[d]Cognition factor score is a summary score representing performance across all Visit 6 neurocognitive tests.

Hearing aids have been found to be protective against depressive symptoms in older adults in previous studies (Acar, Yurekli, Babademez, Karabulut, & Karasen, 2011, Mener et al., 2013). In the present study, we found no significant associations between hearing aid use and depressive symptoms. However, there are several factors related to hearing aid use, such as frequency of use and perceived benefit by the user that were not included in our binary characterization of hearing aid use. The lack of data on these important factors limits our ability to fully examine the role of hearing aids in decreasing depressive symptoms in older adults with HL.

Due to the cross-sectional nature of our analysis, we cannot determine the direction of the observed association between HL and depressive symptoms, although there is a lack of biological plausibility to suggest that depressive symptoms may cause HL. Our study population comprised of participants who attended Visit 6 of the ARIC study who may represent a healthier subset of the original ARIC cohort recruited at baseline (*N* = 15,792). We used depressive symptoms rather than clinical depression as our outcome measure. However, even in the absence of clinically diagnosed major depressive disorder, depressive symptoms measured using validated scales can lead to negative health consequences in older adults (Schulz et al., 2000).

Despite these limitations, some important conclusions emerge. In this large cross-sectional study, we found higher odds of depressive symptoms in older adults with HL compared to adults with normal hearing. Further research should explore whether HL is differentially associated with different symptom domains measured as part of the CES-D. Whether hearing aids reduce the prevalence of depressive symptomology in older adults with HL remains unclear. Population-based prospective studies with rigorous methodology to account for selection factors related to hearing aid use will be needed to evaluate if treatment can reduce depressive symptoms in older adults.

Supplementary Material

Supplementary data is available at *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences* online.

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Conflict of Interest

FRL is a board member of the nonprofit organization Access HEARS. FRL reports prior consultant or speaker

fees from Triton Hearing, Boehringer Ingelheim, Cochlear Ltd, and Caption Call. AMG reports prior consultant or speaker fees from Cochlear Ltd. NSR serves on the scientific advisory board (nonfinancial) for Clearwater Clinical and is a consultant for Helen of Troy.

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