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Association of Hearing Impairment and Mortality in Older Adults

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Background. Hearing impairment (HI) is highly prevalent in older adults and is associated with social isolation, depression, and risk of dementia. Whether HI is associated with broader downstream outcomes is unclear. We undertook this study to determine whether audiometric HI is associated with mortality in older adults.

Methods. Prospective observational data from 1,958 adults ≥70 years of age from the Health, Aging, and Body Composition Study were analyzed using Cox proportional hazards regression. Participants were followed for 8 years after audiometric examination. Mortality was adjudicated by obtaining death certificates. Hearing was defined as the pure-tone average of hearing thresholds in decibels re: hearing level (dB HL) at frequencies from 0.5 to 4 kHz. HI was defined as pure-tone average >25 dB HL in the better ear.

Results. Of the 1,146 participants with HI, 492 (42.9%) died compared with 255 (31.4%) of the 812 with normal hearing (odds ratio = 1.64, 95% CI: 1.36–1.98). After adjustment for demographics and cardiovascular risk factors, HI was associated with a 20% increased mortality risk compared with normal hearing (hazard ratio = 1.20, 95% CI: 1.03–1.41). Confirmatory analyses treating HI as a continuous predictor yielded similar results, demonstrating a nonlinear increase in mortality risk with increasing HI (hazard ratio = 1.14, 95% CI: 1.00–1.29 per 10 dB of threshold elevation up to 35 dB HL).

Conclusions. HI in older adults is associated with increased mortality, independent of demographics and cardiovascular risk factors. Further research is necessary to understand the basis of this association and whether these pathways might be amenable to hearing rehabilitation.

Key Words: Epidemiology—Longevity—Outcomes—Public health—Successful aging.

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HEARING impairment (HI) affects 16.1 million or nearly two of every three adults aged 70 and older in the United States (1). Epidemiologic studies have demonstrated that HI is independently associated with poorer hearing-related quality of life (2), depression (3), cognitive decline (4), incident dementia (5), impaired activities of daily living

(6), increased falls (7), and increased hospitalizations (8). Hypothesized mechanisms to explain these observed associations include residual confounding from shared pathologies (eg, microvascular disease), cognitive load from increased auditory central processing required to decode degraded auditory signals (9), or social isolation (10). Importantly, these mechanisms are not mutually exclusive, and multiple pathways likely coexist and contribute to poorer cognitive and social functioning in older adults with HI.

Whether HI is associated with mortality, possibly through similar pathways, is unclear. Previous studies have examined an association of HI with mortality but with inconsistent results (11–17). Most previous studies (12–15) subjectively measured hearing through self-report, and this imprecision in diagnostic assessment might have resulted in decreased sensitivity to detect associations. However, two Australian studies (16,18) determined hearing objectively through audiometric testing, with one finding an association between HI and mortality that was mediated through cognitive impairment and walking disability (16). Additionally, a study of older adults in Iceland demonstrated that HI was independently associated with increased cardiovascular mortality (17).

In the present study, we investigated whether HI defined according to World Health Organization criteria (19) was associated with mortality in a longitudinal sample of community-dwelling older adults living in the United States followed in the Health, Aging, and Body Composition study. We hypothesized that greater HI is associated with increased mortality, independent of demographics and cardiovascular risk factors.

Methods

Study Design and Population

We analyzed data from the Health, Aging, and Body Composition study, a prospective observational study that enrolled 3,075 well-functioning community-dwelling older adults aged 70–79 from 1997 to 1998 (11). Study participants were recruited from a random sample of white and black Medicare beneficiaries living in Pittsburgh, Pennsylvania and Memphis, Tennessee. Only white and black individuals were recruited because one of the original study objectives was to examine race-related differences in body composition parameters, and resources were insufficient to include other races. To be eligible, participants had to report no difficulty walking a quarter of a mile, climbing 10 steps without resting, or performing activities of daily living.

Audiometric testing was administered in Year 5 (2002). Various causes (missed study visit in Year 5 [$n = 508$], inability to complete hearing testing [$n = 88$], death prior to Year 5 [$n = 263$], or withdrawal from study prior to Year 5 [$n = 8$]) prevented all participants from undergoing audiometric testing. Of the 2,208 participants who underwent audiometric testing, 1,958 had no evidence of cognitive impairment (defined as Modified Mini-Mental State [3MS] examination score ≥80) (20), and these participants comprise our analytic (baseline) cohort. All participants provided written informed consent, and the institutional review boards of all sites approved this study.

Audiometry

Audiometric assessments were performed with participants seated in a sound-treated booth. Air-conduction thresholds for each ear were obtained for pure tones at octave frequencies from 0.25 to 8 kHz presented via a portable audiometer configured with TDH supra-aural earphones (MA40 Maico Diagnostics). The audiometer and examiner were located outside the booth, and the booth and audiometer met current American National Standards Institute standards (ANSI S3.1-1979; ANSI S3.6-1996). All thresholds were measured in decibels re: hearing level (dB HL). A pure-tone average (PTA) of hearing thresholds at 0.5, 1, 2, and 4 kHz was calculated for the better ear. HI was defined as PTA >25 dB HL, per the World Health Organization's definition of impairment (the level at which HI begins to impede daily communication) (19).

Mortality

Adjudicated mortality data for this cohort were available through Year 13 (2010). Information on death was obtained from family members, obituaries, and the Social Security Death Index. Deaths were confirmed by obtaining death certificates from the state offices of vital statistics or from family members.

Covariates

At enrollment, participants reported their age, sex, race, and educational history. Prespecified algorithms based on self-reported and physician diagnoses, recorded medications, and laboratory data were used to define the presence of hypertension (based on clinic measure, medications, or self-report) and diabetes mellitus (based on fasting blood glucose level, medications, or self-report) (4). Stroke history and smoking status (current, former, or never) were based on interviewer-administered questionnaires. These cardiovascular risk factors for mortality are known to be associated with HI and were included as covariates in the analytic model (21). Hearing aid use (self-report) was based on interviewer-administered questionnaires. The 3MS examination, which is a global test of cognitive functioning with components for orientation, concentration, language, praxis, and memory (20), was administered at baseline (Year 5). Scores for the 3MS range from 0 to 100, and a 3MS score <80 is considered indicative of cognitive impairment; a cut point of 80 is 91% sensitive and 97% specific for dementia (20).

Baseline physical functioning was assessed with gait speed, measured as the time to complete a 20-m straight walk in a clearly marked corridor. Depressive symptoms were assessed using the Center for Epidemiological Studies Depression (CES-D) scale (22). A score of 16 or greater on the CES-D scale suggests depressive symptoms (23).

Statistical Analyses

Baseline characteristics of participants were compared using one-way analysis of variance for continuous variables and χ^2 or Fisher's Exact Test for categorical variables. To assure that all models were run on the same cohort, 27 participants (1.4%) were excluded for missing data. The relationship between HI and mortality was analyzed using left-truncated Cox proportional hazards regression (24), which adjusts for age nonparametrically. In order to satisfy proportional hazards assumptions, baseline hazard functions were stratified by race and hypertension or tertiles of gait speed and diabetes, as appropriate for the model. The assumption of proportional hazards was evaluated using the correlation coefficient between transformed survival time and scaled Schoenfeld residuals (25). Models were sequentially adjusted for demographic characteristics (age, sex, race, education, and study site) and cardiovascular risk factors (smoking status, hypertension, diabetes, and stroke). The fully adjusted model was then additionally adjusted for physical functioning (gait speed), cognition (3MS score), depression (CES-D scale score), and hearing aid use to assess for attenuation of the association of HI with mortality. Potential nonlinear relationships between covariates and the hazard ratio (HR) were evaluated using penalized splines (26). A threshold of $p < .05$ was used to evaluate statistical significance. All analyses were conducted in R version 2.15 (27) (R Foundation for Statistical Computing, Vienna, Austria) using the Survival package (28).

Results

In our study population of 1,958 older adults, 492 (42.9%) of the 1,146 with HI (PTA >25 dB HL in the better ear) died compared with 255 (31.4%) of the 812 with normal hearing (odds ratio = 1.64, 95% CI: 1.36–1.98). At baseline, participants with HI were more likely to be older, white, male, have a history of smoking and stroke, and have a lower 3MS score (Table 1). There were no differences in education, history of hypertension or diabetes, gait speed, or CES-D score.

We investigated the association of HI with mortality using Cox proportional hazards models, sequentially adjusted for demographics and cardiovascular risk factors (Table 2). In the model adjusted for age, race, and hypertension, HI was associated with a 34% increased risk of mortality compared with normal hearing (HR = 1.34, 95% CI: 1.15–1.56). After further adjustment for other demographic characteristics (sex, education, and study site) and cardiovascular risk

Table 1. Demographic and Clinical Characteristics of the Study Cohort by Hearing Impairment Status*

Characteristic	Normal Hearing (n = 812)	Hearing Impairment (n = 1,146)	p Value
Age, mean (*SD*), y	76.8 (2.7)	77.9 (2.8)	<.001
Race			
Black	340 (41.9)	293 (25.6)	<.001
White	472 (58.0)	863 (74.3)	
Male	304 (37.4)	632 (55.1)	<.001
Education			
<12th grade	130 (16.0)	204 (17.8)	.47
High school graduate	274 (33.7)	394 (34.4)	
Some college or greater	408 (50.2)	548 (47.8)	
Site			
Memphis	342 (42.1)	556 (48.5)	.006
Pittsburgh	470 (57.9)	590 (51.5)	
Smoking			
Current	42 (5.2)	68 (5.9)	.002
Former	366 (45.1)	599 (52.3)	
Never	409 (49.8)	483 (41.8)	
Hypertension	631 (77.7)	879 (76.7)	.62
Diabetes	136 (16.7)	220 (19.2)	.172
Stroke	55 (6.8)	108 (9.4)	.038
Hearing aid use	5 (0.6)	250 (21.8)	<.001
Pure-tone average, mean (*SD*), dB HL	18.1 ± (5.0)	38.7 ± (10.8)	<.001
3MS examination, mean (*SD*)	93.2 ± (5.1)	92.4 ± (5.3)	<.001
Gait speed, mean (*SD*), m/s	1.1 ± (0.2)	1.1 ± (0.2)	.128
CES-D scale score, mean (*SD*)	4.7 ± (4.1)	4.8 ± (4.2)	.71

Notes: 3MS = Modified Mini-Mental State; CES-D = Center for Epidemiological Studies Depression.

*All values are expressed as No. (%) of participants unless otherwise indicated. Hearing impairment is defined as pure-tone average >25 dB HL at 0.5–4 kHz in the better ear.

Table 2. Risk of Mortality for Individuals With Hearing Impairment* Compared With Normal Hearing

Model†	Hazard Ratio	95% CI	p Value
Sequentially adjusted model			
Base model (adjusted for age, hypertension, race)	1.34	1.15–1.56	<.001
Base model + demographic factors	1.24	1.06–1.46	.007
Base model + demographic factors + cardiovascular risk factors	1.20	1.03–1.41	.022
Adjustment for potential mediating factors			
Full model‡ + gait speed	1.15	0.98–1.35	.091
Full model‡ + 3MS examination score	1.13	0.97–1.33	.120
Full model‡ + CES-D scale score	1.20	1.03–1.41	.023

Notes: 3MS = Modified Mini-Mental State; CES-D = Center for Epidemiologic Studies Depression.

*Hearing impairment is defined as pure-tone average >25 dB HL at 0.5–4 kHz in the better ear.

†Demographic factors include race, sex, education, and study site. Cardiovascular risk factors include hypertension, diabetes, stroke, and smoking.

‡Full model adjusted for all demographics and cardiovascular risk factors.

factors (diabetes, stroke, and smoking), HI was associated with a 20% increased risk of mortality compared with normal hearing (HR = 1.20, 95% CI: 1.03–1.41).

Confirmatory analysis treating HI as a continuous predictor variable yielded similar results. In the fully adjusted model, greater HI was nonlinearly associated with an increased risk of mortality. The hazard of mortality became greater than 1 at approximately 25 dB HL and continued to increase until approximately 35–40 dB HL, thereafter plateauing at higher levels of HI (HR = 1.14, 95% CI: 1.00–1.29 per 10 dB of threshold elevation up to 35 dB HL; Figure 1).

We then explored whether the association of HI and mortality was attenuated after controlling for factors (physical function [gait speed], cognition [3MS], and depression [CES-D]) that might mediate this association (Table 2). Each variable was added individually to the fully adjusted model. The association of HI with mortality was slightly attenuated by adjustment for gait speed (HR = 1.15, 95% CI: 0.98–1.35) and cognition (HR = 1.13, 95% CI: 0.97–1.33) but was not attenuated by adjustment for depression (HR = 1.20, 95% CI: 1.03–1.41).

We included hearing aid use as a covariate in the fully adjusted models to investigate whether this was associated with reduced mortality risk. Hearing aid use was not significantly associated with a lower risk of mortality (HR = 0.85, 95% CI: 0.68–1.06).

Discussion

Our results demonstrate that HI, as measured through objective audiometric testing, is associated with an increased risk of mortality in community-dwelling older adults (aged 70–79 at study enrollment) in the United States, independent of demographic characteristics and cardiovascular risk factors. Compared with those with normal hearing, older individuals with HI had a 20% increased risk of mortality, and this association was robust to adjustment for multiple confounders. Interestingly, we observed a nonlinear association between HI and mortality in which the risk of increased mortality only became evident for PTAs >25 dB HL (the average threshold level at which HI begins to impede everyday communication) (19).

Two previous Australian studies examined the association of audiometric HI with mortality. One study of adults aged 70 and older found an association between HI and mortality after adjusting for demographic characteristics, but this association disappeared after adjusting for various health factors (comorbidity, self-reported health status, and medications) (18). A second study of adults aged 50 and older used structural equation modeling and found an association between HI and mortality that was mediated through cognitive impairment and walking disability (16). A study from Iceland of adults aged 67 and older found an association between objective HI and increased cardiovascular mortality but not with all-cause mortality (17). Additional studies have examined the association of HI with mortality using subjective measures of HI and have produced inconsistent results; Ostbye and coworkers (15) and Barnett and Franks (14) examined adults aged 65 and older and 19 and older, respectively, and demonstrated positive associations for all participants, whereas Appollonio and coworkers (12) and Lam and coworkers (13) examined adults aged 70–75 and 18 and older, respectively, and demonstrated positive associations only for men and non-black subgroups, respectively. Our results are consistent with the Australian study by Karpa and coworkers (16), demonstrating an independent association of audiometric HI with mortality.

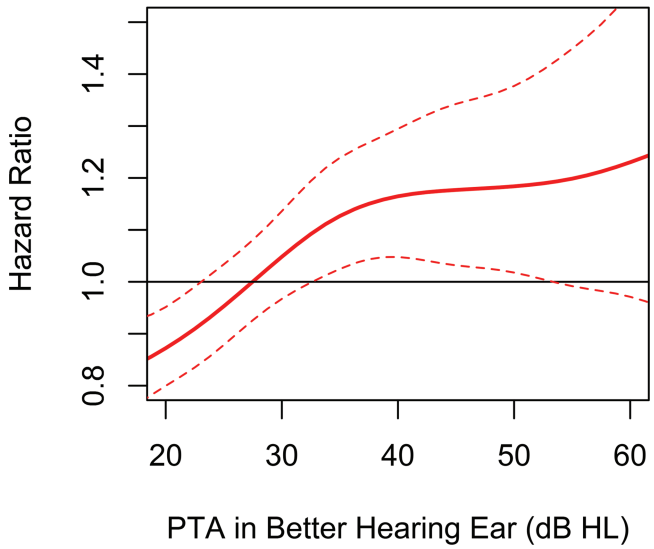

Figure 1. Risk of mortality by baseline hearing loss in fully adjusted model. Hearing impairment is defined as pure-tone average >25 dB HL at 0.5–4 kHz in the better ear. The solid line indicates the hazard ratio of mortality by degree of hearing loss, and the dotted lines represent the 95% CI for the hazard ratio. dB = decibels; HL = hearing level; PTA = pure-tone average.

There are multiple theoretical mechanisms through which HI could be associated with mortality. Shared pathologic processes such as mitochondrial dysfunction (29), generalized inflammation (30), or microvascular disease (31,32) could potentially contribute to both poorer hearing and mortality risk. These factors would not necessarily be accounted for in the demographic characteristics and cardiovascular risk factors adjusted for in our models, and thus, residual confounding cannot be excluded.

The association of HI with mortality could also be mediated through the effects of HI on cognitive decline/dementia (5), depression (33), and walking speed (34), all of which have been associated with increased mortality risk (16,35–39). Indeed, a previous analysis from Australia using structural equation modeling demonstrated that HI was associated with mortality through the mediating pathways of walking disability and cognitive functioning (16). Our results demonstrating attenuation of the association of HI and mortality after adjustment for gait speed and cognition are consistent with these previous findings.

Finally, HI also could be associated with mortality through impairment of social engagement and attendant social isolation and loneliness. Impairments in communication associated with HI can lead to social isolation and loneliness in older adults (6), and social isolation has been strongly associated with increased mortality in multiple studies (10,40,41). Social isolation likely exerts effects on poorer health and increased mortality risk through multiple pathways, including health behavioral (eg, decreased adherence to medical treatment, poorer diet, and increased rate of smoking), psychological (eg, self-esteem, self-efficacy, coping, and depression), and physiological pathways (eg, hypothalamic-pituitary-adrenal axis activation, immune system dysfunction, and increased cardiovascular reactivity). Importantly, these hypothesized mechanisms are not mutually exclusive, and multiple pathways likely coexist and contribute to increased mortality risk in older adults with HI.

HI exhibited a nonlinear association with mortality when examined as a continuous variable. The increased mortality risk only became evident at PTAs >25 dB HL. Interestingly, 25 dB HL (the point at which HI begins to impede daily communication) (19) also was the level at which the risk of incident dementia began to increase in another epidemiologic study (5). The mortality risk increased until approximately 40 dB HL and thereafter plateaued, possibly indicating no further increased risk of mortality with greater HI. This finding could be related to the level of conversational speech, insofar as people with PTAs ≥40 dB HL in the better ear would miss the majority of conversational speech sounds if not using amplification (19), and the functional consequence of additional HI in the absence of amplification might be relatively small.

In the present study, self-reported hearing aid use was not associated with a significant reduction in the risk of mortality. However, key variables (eg, type of hearing aid used, hours worn per day, number of years used, and use of other communicative strategies) that would affect the success of hearing rehabilitation and subsequently affect any observed associations were not available. Therefore, whether hearing rehabilitation could affect mortality risk among older adults with HI remains uncertain and requires further study.

A key limitation of the present study is that we cannot determine the mechanistic basis for the observed association between HI and mortality. Although these results suggest that cognitive function and gait speed might mediate this association, as demonstrated in a prior study (16), this hypothesis is speculative at present and will require further investigation. Another limitation of this study is that HI was only measured at one time point, and information is not available on the duration and trajectory of HI before or after this single assessment. However, it is unlikely that this limitation would lead to a differential bias in the results.

Strengths of the current study are that the results are based on a cohort of community-dwelling older adults and that standardized audiometric assessments of hearing using a definition of HI adopted by the World Health Organization (19) were used. Additionally, our models were adjusted for multiple potential confounders and accounted for the nonlinear effects of age.

In conclusion, our results demonstrate that HI in older adults is associated with increased mortality, independent of demographic characteristics and cardiovascular risk factors. Future research should work to further elucidate the pathways responsible for this association and to determine whether these pathways might be amenable to hearing rehabilitative therapies.

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