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Association of Hearing Impairment With Incident Frailty and Falls in Older Adults

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Abstract

Objective—We aimed to determine whether hearing impairment (HI) in older adults is associated with the development of frailty and falls.

Method—Longitudinal analysis of observational data from the Health, Aging and Body Composition study of 2,000 participants aged 70 to 79 was conducted. Hearing was defined by the pure-tone-average of hearing thresholds at 0.5, 1, 2, and 4 kHz in the better hearing ear. Frailty was defined as a gait speed of <0.60 m/s and/or inability to rise from a chair without using arms. Falls were assessed annually by self-report.

Results—Older adults with moderate-or-greater HI had a 63% increased risk of developing frailty (adjusted hazard ratio [HR] = 1.63, 95% confidence interval [CI] = [1.26, 2.12]) compared with normal-hearing individuals. Moderate-or-greater HI was significantly associated with a greater annual percent increase in odds of falling over time (9.7%, 95% CI = [7.0, 12.4] compared with normal hearing, 4.4%, 95% CI = [2.6, 6.2]).

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Authors' Note

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Declaration of Conflicting Interests

The authors declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Dr. Lin serves as a consultant for Cochlear Americas, and is on the scientific advisory board for Pfizer and Autifony; has received an honoraria for teaching and speaking from Amplifon; and has a non-financial relationship consisting of volunteer speaking with Med-El.

Discussion—HI is independently associated with the risk of frailty in older adults and with greater odds of falling over time.

Keywords

hearing impairment; frailty; falls; older adults; Health ABC

Introduction

Frailty is a clinical syndrome in older adults characterized by decreased physiologic reserve and weakness that causes an increased vulnerability to stressors (Fried et al., 2001). Frailty prevalence ranges from 24% in community-dwelling older adults to nearly 70% in the institutionalized population, posing a significant public health problem (Gonzalez-Vaca et al., 2014; Hoover, Rotermann, Sanmartin, & Bernier, 2013). Studies have demonstrated that the burden of frailty could potentially be mitigated by physical activity, vitamin D, protein supplementation, and decreased polypharmacy (Morley et al., 2013). As the U.S. population ages, this syndrome will become increasingly prevalent, and therefore, identifying other potentially modifiable risk factors for frailty is important.

Whether hearing impairment (HI), which is highly prevalent but under-treated in older adults contributes to frailty risk, remains poorly studied (Kamil, Li, & Lin, 2014; Ng, Feng, Nyunt, Larbi, & Yap, 2014). HI has been independently associated with poorer cognitive functioning, accelerated cognitive decline, incident dementia, falls, and slower gait speed (Li, Simonsick, Ferrucci, & Lin, 2013; Lin, 2011; Lin & Ferrucci, 2012; Lin, Ferrucci, et al., 2011; Lin, Metter, et al., 2011; Lin et al., 2013). Hypothesized mechanistic pathways underlying these associations include the effects of HI on cognitive load and/or changes in brain structure as well as mediation through social isolation, loneliness, and depression (Lin et al., 2014; Mener, Betz, Genter, Chen, & Lin, 2013; Mick, Kawachi, & Lin, 2014; Peelle, Troiani, Grossman, & Wingfield, 2011).

We investigated the association of HI and frailty using data from the Health, Aging and Body Composition (Health ABC) study, a biracial cohort of 70- to 79-year-old community-dwelling older adults followed in Memphis, Tennessee, and Pittsburgh, Pennsylvania. We hypothesized that participants with HI would be more likely to develop frailty than participants with normal hearing.

Method

Study Design and Population

We analyzed data from Health ABC, a prospective, observational study of 3,075 community-dwelling older adults aged 70 to 79 years who were enrolled in 1997–1998. Participants were recruited from a random sample of Medicare enrollees residing in Memphis, Tennessee, and Pittsburgh, Pennsylvania, with the goal of investigating racial differences in aging and body composition, and thus only White and Black older adults were recruited. To be eligible for the study, participants at baseline (Year 1) had to report no

difficulty walking a quarter mile, climbing 10 steps without resting, and independently performing activities of daily living (ADLs).

The analytic cohort comprised 2,000 individuals who completed audiometric testing in Year 5 (2002–2003) of Health ABC. The number of participants was reduced from the original 3,075 due to participants not completing audiometric testing in Year 5 due to refusal or inability to complete audiometry ($n = 93$), death by Year 5 ($n = 263$), missed Year 5 study visit ($n = 71$), no Year 5 clinic visit ($n = 437$), and study withdrawal ($n = 8$). We excluded an additional 159 participants from the analytic cohort because of prevalent cognitive impairment in Year 1 (Modified Mini-Mental State [3MS] examination score < 80) and 44 participants due to missing frailty and covariate data in Year 1 (Teng & Chui, 1987). Compared with those excluded from the cohort, included participants were more likely to be younger, White, and from the Pittsburgh study site and less likely to be smokers at baseline with less depressive symptomatology and higher cognitive scores (data not shown). The institutional review boards for each site approved this research study, and all participants gave written informed consent.

Audiometry

Audiometry was performed with participants in a sound-attenuating booth in Year 5. Air-conduction thresholds were obtained for each ear at octave frequencies from 0.25 to 8 kHz presented via an audiometer (MA40 Maico Diagnostics) configured with TDH supra-aural earphones. All threshold measurements were recorded in decibels hearing level (dB HL). Both the booth and audiometer met American National Standards Institute criteria (ANSI S3.1–1979, ANSI S3.6–1996). A pure-tone average (PTA) of hearing thresholds at 0.5, 1, 2, and 4 kHz was calculated for the better hearing ear (normal hearing ≤ 25 dB, mild HI = 26–40 dB, moderate-or-greater HI > 40 dB; World Health Organization [WHO, n.d.]).

Frailty

Frailty was defined as a gait speed of less than 0.60 m/s and/or inability to rise from a chair without using one's arms based on a prior study by Peterson et al. (2009) using Health ABC data. This definition was modeled after Gill and colleagues' definition of physical frailty because these two metrics were the most consistently available over the study period (Gill et al., 2002; Gill, Williams, & Tinetti, 1995). Frailty data were collected in Years 1, 4, 6, 8, 10, and 11. Gait speed was measured by the time to complete a 20-m walk in a clearly marked hallway. Trained technicians determined participants' ability to stand from a standard, straight-backed 45-cm seat with folded arms. Older adults who met one positive criterion for frailty were classified as frail and those who met both criteria were severely frail.

Falls

Number of falls was determined by an interviewer-administered questionnaire on an annual basis. Participants were asked, "During the past 12 months, have you fallen and landed on the floor or ground?" If the participants answered yes, they were asked, "How many times have you fallen in the past 12 months?" The response options for number of falls included one, two or three, four or five, or six or more. We dichotomized the fall variable into no falls versus one or more falls.

Covariates

Demographic characteristics were reported at baseline (Year 1) including age, sex, race, and education. A predetermined algorithm was used to define the presence of hypertension (based on physical exam, medication, and self-reported data) and diabetes (based on laboratory, medication, and self-reported data). History of stroke, smoking, and hearing aid use were gathered by interviewer-administered questionnaire.

The 3MS examination is a comprehensive test of global cognitive functioning, which examines orientation, attention, language, praxis, and recall (Teng & Chui, 1987). This test was administered at baseline (Year 1) and scores range from 0 to 100 where a score <80 indicates cognitive impairment (Teng & Chui, 1987). Depression was also evaluated at Year 1 using the Center for Epidemiological Studies Depression (CES-D) scale (Lewinsohn, Seeley, Roberts, & Allen, 1997; Radloff, 1977).

Statistical Analyses

Baseline demographic characteristics were compared by participant hearing status using chi-square, Fisher exact test, and one-way ANOVA. The association of categorical HI and incident frailty was investigated using discrete Cox proportional hazard models. Incident frailty was defined as the development of frailty over the 10-year study period (Year 1 to Year 11). Models were adjusted for age, demographic characteristics (race, sex, education, and study site), and cardiovascular risk factors (hypertension, diabetes, stroke, and smoking history).

In secondary analyses, the association of categorical HI and falls was investigated using generalized estimating equations to account for both the fixed and random effects of the included variables and for the repeated measurement of falls over time. Models included the following variables: age, time, demographic characteristics (race, sex, education, and study site), cardiovascular risk factors at Year 1 (hypertension, diabetes, stroke, and smoking history), falls assessed annually as a binary variable (no falls vs. 1 or more falls), and two-way interactions of time and HI category. The annual percent increase in odds of having a fall over time was estimated by taking the linear combination of the coefficients associated with *time* and *HI Category* \times *Time* interaction. For analyses of HI with both frailty and falls, we also explored for possible interaction by gender through stratified analyses⁻ (Kamil et al., 2014).

In sensitivity analyses, HI was treated as a continuous variable in both primary and secondary analyses. In further tests, 3MS and CES-D were included in fully adjusted models to examine for mediation. The fully adjusted model was additionally adjusted for hearing aid use to assess for attenuation of the associations of HI with incident frailty, and HI and falls among those with moderate-or-greater HI. Statistical significance was evaluated by a threshold of a two-tailed $p < .05$ and all analyses were conducted in R version 2.15 (R Foundation for Statistical Computing, Vienna, Austria) using the Survival package.

Results

At baseline, participants with moderate-or-greater HI were more likely to be older, male, White, and a current or former smoker (Table 1). There were no significant differences in education, frailty, or history of hypertension, stroke or diabetes at baseline. In the analytic cohort of 2,000, there were 35 (1.75%) frail participants at baseline (Year 1) and 631 (31.6%) participants who developed frailty over the 10-year study period (Table 1). In all, 1,599 (80.0%) participants experienced at least one fall during the study period.

In participants without prevalent frailty at baseline, we investigated the association of HI with incident frailty using discrete Cox proportional hazards models adjusted for age, demographic characteristics (race, sex, education, and study site), and cardiovascular risk factors (hypertension, diabetes, stroke, and smoking history; Table 2). We observed that persons with moderate-or-greater HI had a 63% (adjusted hazard ratio [HR] = 1.63, 95% confidence interval [CI] = [1.26, 2.12]) increased risk of incident frailty compared with normal-hearing older adults. When stratified by sex, moderate-or-greater HI was significantly associated with incident frailty in both men (adjusted HR = 1.60, 95% CI = [1.09, 2.34]) and women (adjusted HR = 1.63, 95% CI = [1.11, 2.39]). Analyses treating HI as a continuous variable yielded similar results. We observed that greater loss (per 10 dB) was associated with an 11% (adjusted HR = 1.11, 95% CI = [1.03, 1.19]) increased risk of incident frailty. Analyses including cognitive status (3MS) and depressive scores (CES-D) in the model demonstrated results that were substantively unchanged (cf. Table 2, data not shown). Among participants with moderate-or-greater HI, hearing aid use was not significantly associated with decreased frailty risk (adjusted HR = 0.81, 95% CI = [0.54, 1.21]).

In secondary analyses, we investigated the association of HI with the annual percent increase in odds of falls over follow-up using models adjusted for age, demographic characteristics (race, sex, education, and study site), and cardiovascular risk factors (hypertension, diabetes, stroke, and smoking; Table 3). Among all participants, we observed, on average, that individuals with normal hearing, mild HI, and moderate-or-greater HI, respectively, had a 4.4% (95% CI = [2.6, 6.2]), 6.3% (95% CI = [4.4, 8.2]), and 9.7% (95% CI = [7.0, 12.4]) annual increase in odds of having a fall over follow-up. Compared with those with normal hearing, individuals with a moderate-or-greater HI had a significantly greater percent annual increase in the odds of falls over time (9.7% vs. 4.4%, $p = .001$). Analyses stratified by sex demonstrated that moderate-or-greater HI was associated with a greater percent increase in odds of falls over time (compared with normal hearing) in women (11.6% vs. 3.5%, $p < .001$) than men (8.5% vs. 6.4%, $p = .41$), but this difference was not significant ($p = .07$). Results from analyses incorporating hearing as a continuous variable were similar. Among all participants, greater HI (per 10 dB) was associated with a 3.8% (95% CI = [1.7, 5.9], $p < .001$) annual percent increase in odds of having a fall over time. Among those with moderate-or-greater HI, rates of increase in odds of having a fall over time did not differ between individuals who did ($n = 137$) and did not report ($n = 270$) using a hearing aid (7.4%, 95% CI = [3.2, 11.8] vs. 11.0%, 95% CI = [7.5, 14.2], $p = .22$).

Discussion

Our results demonstrate that moderate-or-greater HI, as measured by objective audiometric testing, is associated with an increased risk of developing frailty in high-functioning, community-dwelling older adults, independent of age, demographic characteristics, and cardiovascular risk factors. Compared with those with normal hearing, older adults with moderate-or-greater HI had a 63% increased risk of frailty. In further analyses, we observed that individuals with moderate-or-greater HI had more than twice the rate of increase in odds of falling over time compared with individuals with normal hearing (9.7% vs. 4.4% annual increase in odds of falls). Among those with moderate-or-greater HI, hearing aid use was not found to modify the risk of frailty or falls.

Our results are consistent with prior epidemiologic studies that have investigated the association of HI with frailty and physical functioning. A study by Ng et al. (2014) found that presence of HI helped to predict frailty in a cross-sectional cohort. Another cross-sectional study found an association between subjective HI and frailty in older women only (Kamil et al., 2014). In general, our results are consistent with the literature on the association of hearing with physical functioning as well as with prior work investigating the association of hearing with falls (Li et al., 2013; Lin & Ferrucci, 2012; Strawbridge, Wallhagen, Shema, & Kaplan, 2000; Viljanen, Kaprio, Pykko, Sorri, Koskenvuo, & Rantanen, 2009; Viljanen, Kaprio, Pykko, Sorri, Pajala, et al., 2009). Strengths of our current study include use of a community-based cohort of older adults, audiometric assessments of hearing using a definition of hearing loss adopted by the WHO, and objective measures of physical functioning and frailty.

Multiple mechanisms could underlie an association between HI and frailty. Frailty is a state of decreased resilience characterized by increased susceptibility to stressors such as infection and trauma and can contribute to poor health outcomes such as falls, difficulty carrying out ADLs, hospitalization, institutionalization, and death (Bandein-Roche et al., 2006; Ensrud et al., 2007; Fried, Ferrucci, Darer, Williamson, & Anderson, 2004). The relationship between frailty, disability, and comorbidity is complex and overlapping (Fried et al., 2004). Shared pathological pathways (e.g., systemic inflammation, neurodegeneration, microvascular disease) could contribute to both greater HI and onset of frailty (Dinarello, Simon, & van der Meer, 2012; Gates, Cobb, D'Agostino, & Wolf, 1993; Goldstein & Wolfe, 2013; Liew et al., 2007). Alternatively, a study by Fried et al. (2009) found that older adults having a greater number of abnormal physiological systems had a greater likelihood of developing frailty. Although hearing was not considered in their analyses, the contribution of HI to frailty could plausibly be mediated through depression (Bonnet et al., 2005; Mener et al., 2013; Roshanaei-Moghaddam, Katon, & Russo, 2009; Walston et al., 2006; Win et al., 2011), social isolation, and cognitive impairment (Avila-Funes et al., 2009; Etgen et al., 2010; Jacobs, Cohen, Ein-Mor, Maaravi, & Stessman, 2011; Yogev-Seligmann, Hausdorff, & Giladi, 2008).

We also observed that HI was strongly associated with a greater increase in the odds of falling over time in older women. A number of studies have found that HI increases the risk of falling, including a meta-analysis that found a 21% increased odds of falling among those

with HI (Deandrea et al., 2010; Kulmala et al., 2009; Pluijm et al., 2006; Tromp, Smit, Deeg, Bouter, & Lips, 1998). There are multiple mechanisms by which HI could influence falls including shared pathological pathways (e.g., co-morbid vestibular dysfunction, cerebrovascular disease; Agrawal, Carey, Della Santina, Schubert, & Minor, 2009; Gates et al., 1993; Zuniga et al., 2012) or through decreased awareness of the auditory environment. Attentional resources are also essential for maintaining postural control and balance (Viljanen, Kaprio, Pyykko, Sorri, Pajala, et al., 2009; Woollacott & Shumway-Cook, 2002), and postural balance in older adults is markedly affected by the performance of concurrent cognitive tasks that utilize attentional resources. Decrements in attentional and cognitive resources imposed by hearing loss (Bandeem-Roche et al., 2006; Lopez et al., 2011; Purchase-Helzner et al., 2004) may therefore impair the maintenance of postural balance in real-world situations and increase the risk of falling. Interestingly, the association between HI and falls was greater in women than men. Speculatively, this observation may be related to women being more likely to report a fall, experience fall-related injury, and suffer functional decline following a fall (Centers for Disease Control and Prevention, 2008; Stel, Smit, Pluijm, & Lips, 2004; Stevens et al., 2012).

Our study has limitations. We cannot determine the mechanistic pathways through which HI is associated with frailty and falls. Another limitation is that audiometric assessments were taken 4 years after baseline enrollment rather than at baseline or assessed longitudinally. However, it is unlikely that this limitation would substantively bias the results given that age-related HI progresses slowly at a rate of approximately 1 to 2 dB per year (Pedersen, Rosenhall, & Moller, 1989, 1991), and hearing was conservatively defined using the better hearing ear. There is also no physiologic basis to expect that frailty would affect peripheral hearing thresholds as measured by audiometry (reverse causation). We also cannot exclude residual confounding by unmeasured biological or environmental factors that could contribute to HI, frailty, and falls. However, we adjusted for recognized major risk factors for HI, frailty, and falls in our statistical models (e.g., cardiovascular risk factors, diabetes, smoking, age). Importantly, the hypothesized pathways (e.g., cognitive load, shared pathology, social isolation) underlying the observed associations are not mutually exclusive and multiple pathways could synergistically contribute to frailty and falls in older adults with HI. Finally, we note that different definitions of frailty exist and that using a different definition could affect analytic results. A priori, we used a definition modeled after Gill and colleagues because metrics of gait speed and chair stands were the most consistently available over the study period (Gill et al., 2002; Gill et al., 1995), and this approach has been used in a prior study of frailty in Health ABC (Peterson et al., 2009). However, we understand this definition is limited by a narrow view of frailty.

In summary, our results demonstrate that moderate-or-greater HI is associated with increased risk of developing frailty over time, independent of age, demographic characteristics, and cardiovascular risk factors. We also found that HI was associated with an increased annual risk of falling. Future research is needed to determine the underlying mechanistic pathways of these associations and whether hearing loss treatments could influence these pathways.

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Table 1

Demographic and Clinical Characteristics of the Study Cohort by Hearing Status.

Characteristic	Normal hearing (<i>n</i> = 832)	Mild HI (<i>n</i> = 761)	Moderate-or-greater HI (<i>n</i> = 407)	<i>p</i>
Age, <i>M</i> (<i>SD</i>)	73.3 (2.7)	74.1 (2.7)	74.8 (2.9)	<.001
Sex, <i>n</i> (%)				
Male	306 (36.8)	372 (48.9)	264 (64.9)	<.001
Female	526 (63.2)	389 (51.1)	143 (35.1)	
Race, <i>n</i> (%)				
Black	360 (43.3)	227 (29.8)	88 (21.6)	<.001
White	472 (56.7)	534 (70.2)	319 (78.4)	
Education, <i>n</i> (%)				
<HS	143 (17.2)	125 (16.4)	94 (23.1)	.06
HS	278 (33.4)	266 (35.0)	129 (31.7)	
Some college or greater	411 (49.4)	370 (48.6)	184 (45.2)	
Site, <i>n</i> (%)				
Memphis	358 (43.0)	362 (47.6)	215 (52.8)	.004
Pittsburgh	474 (57.0)	399 (52.4)	192 (47.2)	
Smoking, <i>n</i> (%)				
Current	65 (7.8)	48 (6.3)	38 (9.3)	<.001
Former	343 (41.2)	377 (49.5)	216 (53.1)	
Never	424 (51.0)	336 (44.2)	153 (37.6)	
Hypertension, <i>n</i> (%)				
Yes	527 (63.3)	467 (61.4)	248 (60.9)	.62
No	305 (36.7)	294 (38.6)	159 (39.1)	
Diabetes, <i>n</i> (%)				
Yes	120 (14.4)	128 (16.8)	80 (19.7)	.06
No	712 (85.6)	633 (83.2)	327 (80.3)	
Stroke, <i>n</i> (%)				
Yes	12 (1.4)	20 (2.6)	5 (1.2)	.14
No	820 (98.6)	741 (97.4)	402 (98.8)	
Hearing aid use, <i>n</i> (%)				
Yes	5 (0.6)	40 (5.3)	137 (33.7)	<.001
No	827 (99.4)	721 (94.7)	270 (66.3)	
3MS, <i>M</i> (<i>SD</i>)	92.8 (5.1)	92.7 (5.0)	92 (5.0)	.01
CES-D scale score, <i>M</i> (<i>SD</i>)	4.3 (4.7)	4.4 (5.5)	4.8 (5.2)	.25
Frailty at baseline (Year 1), <i>n</i> (%) ^a				
Not frail	821 (98.7)	746 (98.0)	398 (97.8)	.40
Frail	11 (1.3)	15 (2.0)	8 (2.0)	
Severely frail	0 (0.0)	0 (0.0)	1 (0.2)	
Frailty at end of study period (Year 10), <i>n</i> (%) ^b				
Not frail	593 (71.3)	526 (69.1)	250 (61.4)	.002
Frail or severely frail	239 (28.7)	235 (30.9)	157 (38.6)	

Characteristic	Normal hearing (<i>n</i> = 832)	Mild HI (<i>n</i> = 761)	Moderate-or-greater HI (<i>n</i> = 407)	<i>p</i>
Falls at end of study period (Year 10), <i>n</i> (%) ^{<i>b</i>}				
No falls	190 (22.8)	134 (17.6)	77 (18.9)	.03
Falls	642 (77.2)	627 (82.4)	330 (81.1)	

Note. Percentages are column percentages. Normal-hearing PTA = 25dB in the better hearing ear; mild HI PTA = 26–40 dB; moderate-or-greater HI PTA > 40 dB. HI = hearing impairment; 3MS = Modified Mini-Mental State Examination; CES-D = Center for Epidemiological Studies Depression; PTA = pure-tone average.

^{*a*}The *p* value presented is the comparison for any frailty.

^{*b*}All demographic and clinical characteristics were taken at baseline (Year 1) except for frailty at end of the 10-year study period and falls at the end of the 10-year study period.

Table 2

Association of Mild and Moderate-or-Greater HI With Risk of Incident Frailty Compared With Normal Hearing.

Model	Incident frailty			
	Mild HI		Moderate-or-greater HI	
	Hazard ratio (95% CI)	<i>p</i>	Hazard ratio (95% CI)	<i>p</i>
All (<i>n</i> = 2,000)	1.12 [0.90, 1.39]	.32	1.63 [1.26, 2.12]	<.001
Men (<i>n</i> = 942)	1.18 [0.81, 1.71]	.39	1.60 [1.09, 2.34]	.02
Women (<i>n</i> = 1,058)	1.09 [0.83, 1.42]	.55	1.63 [1.11, 2.39]	.01

Note. Normal-hearing PTA \leq 25 dB in the better hearing ear; mild HI PTA = 26–40 dB; moderate-or-greater HI PTA > 40 dB. Models were adjusted for age, demographic factors (race, sex, education, and study site), and cardiovascular risk factors (hypertension, diabetes, stroke, and smoking history). HI = hearing impairment; CI = confidence interval; PTA = pure-tone average.

Table 3

Association of HI With Annual Percent Increase in Odds of Falls Over Time.

Model	Annual percent increase in odds of falls over time					
	Normal hearing		Mild HI		Moderate-or-greater HI	
	% increase in odds (95% CI)	<i>p</i>	% increase in odds (95% CI)	<i>p</i>	% increase in odds (95% CI)	<i>p</i>
All (<i>n</i> = 2,000)	4.4 [2.6, 6.2]	<.001	6.3 [4.4, 8.2]	<.001	9.7 [7.0, 12.4]	<.001
	<i>p</i> = .17		<i>p</i> = .001			
Men (<i>n</i> = 942)	6.4 [3.0, 9.9]	<.001	8.6 [5.7, 11.5]	<.001	8.5 [5.1, 12.0]	<.001
	<i>p</i> = .35		<i>p</i> = .41			
Women (<i>n</i> = 1,058)	3.5 [1.4, 5.6]	.001	4.4 [2.0, 6.9]	<.001	11.6 [7.5, 16.0]	<.001
	<i>p</i> = .58		<i>p</i> < .001			

Note. Normal-hearing PTA ≤ 25 dB in the better hearing ear; mild HI PTA = 26–40 dB; moderate-or-greater HI PTA > 40 dB. Falls was defined as a binary variable (no falls vs. 1 or more falls). Models were adjusted for age, demographic factors (race, sex, education, and study site), and cardiovascular risk factors (hypertension, diabetes, stroke, and smoking history). HI = hearing impairment; CI = confidence interval; PTA = pure-tone average.

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