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Association Between Hearing Impairment and Self-Reported Difficulty in Physical Functioning

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Abstract

Objectives—To determine whether hearing impairment, defined using objective audiometry, is associated with multiple categories of self-reported physical functioning in a cross-sectional, nationally representative sample of older adults.

Design—Multivariate secondary analysis of cross-sectional data.

Setting—The 2005–06 and 2009–10 cycles of the National Health and Nutrition Examination Survey.

Participants—Adults aged 70 and older who completed audiometric testing (N=1,669).

Measurements—Hearing was measured using pure-tone audiometry. Physical functioning was assessed using a structured interview.

Results—In a model adjusted for age and demographic and cardiovascular risk factors, greater hearing impairment (per 25 dB hearing level (HL)) was associated with greater odds of physical disability in activities of daily living (odds ratio (OR)=1.4, 95% confidence interval (CI)=1.1–1.9), instrumental activities of daily living (OR=1.6, 95% CI=1.2–2.2), leisure and social activities (OR=1.5, 95% CI=1.1–2.0), lower extremity mobility (OR=1.4, 95% CI=1.1–1.7), general physical activities (OR=1.3, 95% CI=1.1–1.6), work limitation (OR=1.4, 95% CI=1.0–1.9), walking limitation (OR=1.6, 95% CI=1.3–2.0), and limitation due to memory or confusion (OR=1.4, 95% CI=1.1–1.8). Hearing impairment was not associated with limitations in amount or type of work done (OR=1.2, 95% CI=1.0–1.6).

Conclusion—Hearing impairment in older adults is independently associated with greater disability and limitations in multiple self-reported categories of physical functioning.

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Keywords

hearing impairment; physical functioning; older adults

Hearing impairment affects approximately 70% of older adults in the United States, and its prevalence nearly doubles with every decade of age.¹ Recent epidemiological studies have demonstrated that hearing impairment is independently associated with accelerated cognitive decline² and the risk of incident dementia in older adults.³ Effects of hearing impairment on cognitive load^{4,5} and social isolation⁶ may mediate these associations.

Similar mediating pathways may also underlie contributions of hearing impairment to poorer physical functioning in older adults. Social isolation⁷ and lack of attentional resources from cognitive load⁸ have been associated with poorer functioning in elderly adults, although prior epidemiological studies of the association of hearing impairment with physical functioning have demonstrated inconsistent results, with some studies demonstrating a positive association^{9–18} and others demonstrating no significant association.^{19–21} It is likely that differences between studies in how hearing and physical functioning were measured explain this heterogeneity in study results. (Hearing has been measured using subjective self-report^{10,12,19,21} and objective clinical audiometry^{9,13–18,20}, whereas physical functioning has been measured using activities of daily living (ADLs),^{11,12,14,17,19,21} instrumental activities of daily living (IADLs),^{10–12,19} the Sickness Impact Profile,⁹ Rosow-Breslau indices,¹⁸ and the Medical Outcomes Study 36-item Short-Form Survey.¹³) It is likely that biased or imprecise assessments of hearing thresholds would decrease the sensitivity to detect associations due to greater variance.

In the present study, cross-sectional data from a nationally representative sample of older adults in whom hearing was objectively measured using audiometry were used to perform exploratory analyses of whether hearing impairment is associated with a broad range of self-reported metrics of physical functioning and activities. These comprehensive self-reported measures of physical functioning included ADLs, IADL, and other indicators of physical functioning such as leisure and social activities, lower extremity mobility, and general physical activities.

Methods

Study Participants

The National Health and Nutrition Examination Survey (NHANES) is an ongoing series of studies that the National Center for Health Statistics conducts to assess the health, functional, and nutritional status of the civilian noninstitutionalized U.S. population. Each 2-year cross-sectional study cycle uses a complex multistage probability sampling design to survey a representative sample of the population from multiple counties across the United States, with selective oversampling of low-income individuals, racial minorities, and older adults. The sample does not include persons residing in nursing homes, members of the armed forces, institutionalized persons, or U.S. nationals living abroad. Sampling weights allow for analyses that account for the complex survey design and yield results that are

generalizable to the U.S. population. NHANES data from 2005–06 and 2009–10 were combined because these were the only 2-year cycles when hearing was measured in adults aged 70 and older. One thousand eight hundred eighty-five individuals aged 70 and older participated in the examination component of NHANES in these cycles, 1,669 (89%) of whom completed audiometric testing.

Audiometric Assessment

A trained examiner performed audiometry according to established NHANES protocols.²² Briefly, air conduction hearing thresholds were obtained from both ears in a sound-isolating room in the mobile examination center. Testing was conducted according to a modified Hughson-Westlake procedure using the automated testing mode of the audiometer (Interacoustics Model AD226, Interacoustics, Eden Prairie, MN) or manually, according to the testing protocol. Quality assurance and control were established through daily calibration of equipment and monitoring of ambient noise levels using a sound-level meter. As an additional quality measure, thresholds were measured twice at 1 kHz in both ears, and audiometry was repeated if there was greater than 10 dB discrepancy between the threshold measurements. Hearing ability was defined according to a speech-frequency pure tone average of thresholds at 0.5, 1, 2, and 4 kHz in the better-hearing ear, according to the definition of hearing impairment that the World Health Organization uses.²³ Thresholds of hearing impairment severity were based on American Speech-Language Hearing Association guidelines²⁴ (normal hearing <25.0 dB, mild impairment 25.0–39.9 dB, moderate impairment 40.0–69.9 dB, severe to profound impairment ≥70.0 dB).

Physical Functioning Assessment

Study personnel interviewed participants regarding their physical functioning using the Computer-Assisted Personal Interviewing system. Participants were asked a series of questions regarding any difficulties they had performing physical tasks. These physical tasks were categorized into five domains (ADLs, IADLs, leisure and social activities, lower-extremity mobility, general physical activities), as previously described.²⁵ Difficulty (yes/no) in a physical domain was defined as a response of some or more difficulty in at least one of the physical task questions within a domain.²⁵ Participants were also asked about general functional limitations in ability to work, amount and type of work performed, walking, and limitations due to confusion and memory. Limitations in these categories were defined as a response of “yes” on the survey. Survey items pertaining to these physical domains and functional limitations are summarized in Table 1.

Other Study Variables

Other covariates that could potentially confound the association between hearing impairment and physical functioning were included in this analysis. Data on demographic variables and medical history were obtained from interviews. For confidentiality purposes, the NHANES database truncates the age variable at 80. Therefore, age was treated as a categorical rather than a continuous variable in the primary analysis, with the categories 70 to 74, 75 to 79, and 80 and older. A sensitivity analysis was also conducted limiting the analytical cohort to individuals aged 70 to 79 to allow for adjustment of age as a continuous variable. Self-reported race and ethnicity was grouped as Mexican American or other

Hispanic (Hispanic), non-Hispanic white (white), non-Hispanic black (black), or other race. Education was collapsed into a three-level variable (<12th grade, high school graduate, some college or more), and household income was collapsed into a five-level variable (<\$20,000, \$20,000–44,000, \$45,000–74,000, \$75,000, refused/do not know). Variables related to medical history included hypertension, cardiovascular disease, diabetes mellitus, stroke, and smoking status (current, former, never). Hypertension was defined as having been diagnosed by a physician on at least two visits with high blood pressure or taking antihypertensive medication. Cardiovascular disease was defined as any self-reported history of congestive heart failure, coronary artery disease, angina pectoris, or myocardial infarction. Hearing aid use was defined as whether an individual reported having worn a hearing aid at least 5 hours per week in the 12 months before the interview.

Statistical Methodology

The complex sampling design was accounted for in all analyses using sample weights according to National Center for Health Statistics guidelines,²⁶ except for Table 2. The purpose of Table 2 was to provide descriptive statistics for the characteristics of the study cohort rather than nationally generalizable estimates, so weights were not used. Baseline characteristics of the study participants were compared using the Pearson chi-square test. Multivariate logistic regression was used to examine the relationship between hearing impairment as a continuous variable and physical functioning while adjusting for age and other covariates. Sensitivity analyses included restricting the analytical cohort to individuals younger than 80 (to allow for adjustment of age as a continuous variable) and excluding participants with severe hearing impairment (better-ear pure-tone average (BPTA) ≥70 dB HL). To assess effect modification according to sex and age, analyses were also conducted using a hearing impairment–sex interaction term and a hearing impairment–age interaction term, with age coded as a binary variable (<80 or ≥80). In all models, individuals with missing data accounted for less than 10% of the study population, with the exception of analyses involving IADLs, in which IADL data were missing in 267 individuals (16.0%). This high proportion of missing IADL data was due to a number of participants responding, “Do not do this activity” to questions comprising the IADL domain. All significant tests were conducted using two-sided tests with a type I error of 0.05. All analyses were conducted using Stata 11.1 (StataCorp, College Station, TX).

Results

One thousand six hundred sixty-nine participants aged 70 and older were included in this study, 529 (31.7%) of whom had normal hearing (Table 2). Of those with hearing impairment (n=1,140), 590 (51.8%) had mild hearing impairment, 518 (45.4%) had moderate hearing impairment, and 32 (2.8%) had severe to profound hearing impairment. Hearing impairment was associated with age, sex, race, education, income, hypertension, cardiovascular disease, and stroke (Table 2).

In a model adjusted for age and demographic and cardiovascular risk factors, a 25-dB difference in hearing threshold was associated with greater odds of poorer ADL functioning (OR=1.4, 95% CI=1.1–1.9; p=.01), IADL functioning (OR=1.6, 95% CI=1.2–2.2; p=.003,

leisure and social activities (OR=1.5, 95% CI=1.1–2.0; $p=.01$), lower extremity mobility (OR=1.4, 95% CI=1.1–1.7; $p=.005$, and general physical activities (OR=1.3, 95% CI=1.1–1.6; $p=.02$). For functional limitations, a 25-dB difference in hearing threshold was associated with greater odds of work limitation (OR=1.4, 95% CI=1.0–1.9; $p=.03$), walking limitation (OR=1.6, 95% CI=1.3–2.0; $p<.001$), and limitation due to memory or confusion (OR=1.4, 95% CI=1.1–1.8; $p=.01$) (Figure 1). Hearing impairment was not associated with limitations in amount or type of work done (OR=1.2, 95% CI=1.0–1.6; $p=.11$).

A sensitivity analysis restricting the analytical cohort to individuals younger than 80 (to allow for adjustment of age as a continuous covariate) did not substantially change the results (data not shown) from those shown in Figure 1, with the exception of wider CIs being observed for work limitations (OR=1.4, 95% CI=0.9–2.1; $p=.17$) and memory and confusion limitations (OR=1.2, 95% CI=0.9–1.7; $p=.20$). An additional sensitivity analysis excluding participants with severe hearing impairment (BPTA ≥ 70 dB HL) also yielded results similar to those shown in Figure 1 (data not shown), with the exception of wider CIs being observed for general physical activities (OR=1.3, 95% CI=1.0–1.6; $p=.10$) and work limitations (OR=1.3, 95% CI=0.9–1.8; $p=.17$).

Effect modification was also investigated according to sex and age. Sex did not significantly moderate the relationship between hearing and any of the outcome variables except amount or type of work done and limitations due to confusion and memory. Men had greater odds of limitation in the former category ($p=.02$), and women had greater limitation in the latter category ($p=.04$). Age did not significantly moderate the association between hearing impairment and physical functioning in any of the categories. Finally, the association between hearing aid use and physical functioning was also investigated. In individuals with hearing impairment (BPTA ≥ 25 dB HL), hearing aid use was not significantly associated with any of the domains of physical functioning (data not shown) except for greater odds of having ADL impairments (OR=2.2, 95% CI 1.2–3.9).

Discussion

In this nationally representative study of adults aged 70 and older, greater hearing impairment was independently associated with poorer functioning in multiple self-reported measures including ADLs, IADLs, leisure and social activities, lower extremity mobility, general physical activities, work limitation, walking limitation, and limitations due to confusion and memory. These results were robust to adjustment for multiple confounders and in sensitivity analyses excluding individuals with severe hearing impairment or aged 80 and older. A 25 dB difference in hearing thresholds (equivalent to the magnitude of difference between normal hearing and mild hearing impairment) was associated with 60% greater odds of having self-reported IADL impairments, 50% greater odds of impairments in leisure and social activities, and 62% greater odds of walking limitations.

These findings are consistent with prior research demonstrating significant associations between hearing impairment and ADL, IADL^{10–12,17} and other measures of physical functioning.^{9,12,13,15,18} In contrast, several studies have found no association between hearing impairment and functioning or functional decline.^{19–21} One study that used

longitudinal data from NHANES I and the NHANES Epidemiologic Follow-up Study found that hearing impairment at baseline was predictive of poorer Rosow-Breslau functional indices but not ADLs or IADLs after 10 years, although the cohort in this study was younger, and hearing impairment was defined using a cutoff of 40 rather than 25 dB. The measurement and definition of hearing impairment varied considerably in prior studies. Several studies relied on self-report or other subjective tests to measure hearing,^{10–12,19,21} whereas those that used pure-tone audiometry used varying audiometric definitions of hearing impairment and testing environments.^{9,13–18,20} With the exception of two studies,^{18,21} prior reports were conducted in study populations in which results may not be generalizable. The strengths of the current study are that the results are based on a nationally representative sample, and a standardized audiometric testing protocol using a definition of hearing impairment that the World Health Organization²³ provided was applied to all individuals. Physical functioning was also assessed using a broad range of functional metrics not limited to ADLs and IADLs. Several explanations could account for the observed association between hearing impairment and physical functioning. First, poor verbal reception resulting from hearing impairment may have interfered with participants' understanding of the questionnaire items, but it is likely that this would lead to a nondifferential bias rather than a specific bias toward a positive association. The results were also not sensitive to exclusion of individuals with severe hearing impairment from the analytical cohort. Second, a shared impairment of the cochlear and vestibular sense organs, given their common location in the inner ear,²⁷ could contribute to impaired balance and poorer physical functioning, although a previous analysis demonstrated associations between hearing impairment and falls that were robust to adjustment for vestibular function.²⁸ Third, pure-tone audiometry has been found to be weakly associated with cardiovascular risk factors,^{29,30} and underlying microvascular disease or another common pathologic process may contribute to hearing impairment and poorer physical functioning. Nevertheless, the current results demonstrate an association between hearing impairment and physical functioning even after adjustment for multiple cardiovascular risk factors.

Hearing impairment could also be associated with physical functioning through mechanistic pathways involving cognitive load and social isolation. Age-related hearing impairment leads to impaired neural encoding of sounds by the cochlea, and the cognitive resources required for processing of degraded sound signals may place a load on the listener's cognitive and attentional resources,^{4,5} both of which are important determinants of physical mobility and functioning.^{32,33} Consistent with this hypothesis, hearing impairment has been associated with poorer performance on tests of executive function requiring attentional resources,³¹ which are necessary for maintaining postural control and balance³² and predict gait speed declines in older adults.³³ Communication impairments due to hearing impairment may also contribute to social isolation and loneliness in older adults,^{12,34} which in turn could mediate the association with poorer physical functioning.^{35,36}

It was found that hearing aid use was not significantly associated with any domains of physical functioning except for greater odds of ADL impairments. The basis of this association is unclear but may be due to a greater likelihood of Medicaid eligibility in individuals with ADL impairments. Many state Medicaid programs provide benefits for hearing aids, in contrast to the federal Medicare program.³⁷ Because the data are cross-

sectional, the direction of this observed association cannot be established (whether hearing aid use is a marker of incipient ADL difficulty or vice versa). Ultimately, investigating whether rehabilitative hearing treatments could affect physical functioning will require a randomized clinical trial.

This study has several limitations. First, the pathways underlying the observed associations between hearing impairment and physical functioning cannot be determined. Although there is unlikely to be reverse causation (poor physical functioning leading to hearing impairment), it is likely that there is some degree of residual confounding by other medical or environmental factors (e.g., inflammation, mitochondrial aging). Established confounders for hearing impairment and physical functioning were adjusted for in the models, and multiple pathways (e.g., shared pathology, cognitive load, social isolation) could contribute synergistically to poorer physical functioning. Second, although data from NHANES is understood to be representative of the U.S. population, individuals who are institutionalized (e.g., older adults in nursing homes) are specifically excluded from the NHANES cohort. The association between hearing impairment and physical functioning could be expected to be even stronger in these institutionalized individuals who are excluded. Third, results from the two functional limitation categories regarding ability to work and amount or type of work done may not be relevant to some individuals in the study population who may no longer be working. Fourth, the analyses are also based on cross-sectional data and may thus be subject to bias according to cohort effects or interindividual heterogeneity in participant characteristics. Further prospective research will be needed to determine whether hearing impairment is associated with accelerated declines in physical functioning over. Specifically, longitudinal studies using objective physical performance measurements may help clarify the temporal relationship between hearing impairment and functional parameters such as gait speed and balance.

Physical functioning is a critical determinant of overall health and vitality in older adults. Given the high prevalence of hearing impairment in elderly adults and the increasing proportion of older adults in the general population, clarifying the role of hearing impairment as a potentially modifiable risk factor for poorer physical functioning is a public health priority. Further research is needed to investigate the basis of the observed association between hearing impairment and physical disability, as well as to determine whether hearing rehabilitative therapies could help mitigate declines in physical functioning.

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Figure 1.

Adjusted odds ratios (adjusted for age, sex, race, education, income, hypertension, cardiovascular disease, stroke, diabetes, and smoking status) of disabilities and functional limitations per 25-dB difference in hearing level (hearing defined according to the speech-frequency pure tone average of hearing thresholds at 0.5, 1, 2, and 4 kHz in the better ear). Error bars indicate 95% confidence intervals.

Table 1
National Health and Nutrition Examination Survey Questionnaire Items Comprising
Physical Domains and Functional Limitations As Described Previously²⁵

Measure of Disability	Survey Items	Possible Responses
Physical domain		
Activities of daily living	By yourself and without using any special equipment, how much difficulty do you have... Getting in and out of bed Eating Dressing yourself	No difficulty, some difficulty, much difficulty, unable to do, do not do this activity
Instrumental activities of daily living	By yourself and without using any special equipment, how much difficulty do you have... Managing money Performing house chores Preparing meals	No difficulty, some difficulty, much difficulty, unable to do, do not do this activity
Leisure and social activities	By yourself and without using any special equipment, how much difficulty do you have... Going to the movies Attending social events Performing leisure activity at home	No difficulty, some difficulty, much difficulty, unable to do, do not do this activity
Lower extremity mobility	By yourself and without using any special equipment, how much difficulty do you have... Walking one-quarter of a mile Walking up 10 steps Stopping, kneeling, crouching Walking between rooms on the same floor Standing up from an armless chair	No difficulty, some difficulty, much difficulty, unable to do, do not do this activity
General physical activities	By yourself and without using any special equipment, how much difficulty do you have... Lifting or carrying heavy objects Reaching up overhead Grasping/holding small objects Standing for long periods Sitting for long periods	No difficulty, some difficulty, much difficulty, unable to do, do not do this activity
Functional limitations		
Ability to work	Does a physical, mental, or emotional problem now keep you from working at a job or business?	Yes, no
Amount and type of work	Are you limited in the kind or amount of work you can do because of a physical, mental, or emotional problem?	Yes, no
Walking	Because of a health problem, do you have difficulty walking without using any special equipment?	Yes, no
Memory and confusion	Are you limited in any way because of difficulty remembering or because you experience periods of confusion?	Yes, no

^a Difficulty (yes/no) in a physical domain was defined as a response of some difficulty or more in at least one of the physical task questions within a domain.

Table 2
Demographic Characteristics of Participants Aged 70 and Older with Audiometric Testing, National Health and Nutrition Examination Survey, 2005–06 and 2009–10

Characteristic	Normal Hearing, n=529 (32%)	Hearing Impairment, n=1,140 (68%)	P-Value
	n (%)		
Age			<.001
70–74	289 (55)	319 (30)	
75–79	138 (26)	283 (25)	
80	102 (19)	538 (47)	
Male	217 (41)	631 (55)	<.001
Race			<.001
White	327 (62)	859 (75)	
Black	117 (22)	117 (10)	
Hispanic	68 (13)	131 (12)	
Other	17 (3)	33 (3)	
Education			.001
<12 th grade	161 (30)	428 (38)	
High school graduate	128 (24)	300 (26)	
Some college or more	239 (45)	410 (36)	
Income, \$			.004
<20,000	129 (24)	353 (31)	
20,000–44,999	176 (33)	406 (36)	
45,000–74,999	114 (22)	182 (16)	
75,000	71 (13)	119 (10)	
Refused or do not know	39 (7)	75 (7)	
Hypertension	353 (67)	703 (62)	.050
Cardiovascular disease ^a	103 (17)	307 (27)	.001
Stroke	38 (7)	130 (11)	.008
Diabetes mellitus	113 (21)	247 (22)	.890
Smoking			.240
Never	258 (49)	534 (47)	
Former	226 (43)	529 (46)	
Current	45 (9)	77 (7)	
Degree of hearing impairment			
Mild	-	590 (52)	
Moderate	-	518 (45)	
Severe to profound	-	32 (3)	
Hearing aid use	1 (0)	198 (17)	<.001
Physical function difficulty ^b			
Activities of daily living	93 (18)	272 (24)	.004
Instrumental activities of daily living	103 (19)	261 (23)	.020

Characteristic	Normal Hearing, n=529 (32%)	Hearing Impairment, n=1,140 (68%)	P-Value
	n (%)		
Leisure and social activities	95 (18)	249 (22)	.030
Lower extremity mobility	261 (49)	718 (63)	<.001
General physical activities	260 (49)	630 (55)	.004
Work limitation	82 (15.5)	229 (20.1)	.020
Limitation in amount or type of work	172 (32.5)	451 (39.6)	.006
Walking limitation	85 (16.1)	285 (25.0)	<.001
Memory and confusion limitation	60 (11.3)	178 (15.6)	.020

Hearing impairment is defined as a speech-frequency pure-tone average of hearing thresholds at 0.5, 1, 2, and 4 kilohertz in the better hearing ear of 25 dB of hearing loss or greater.

^a Self-reported history of congestive heart failure, coronary artery disease, angina pectoris, or myocardial infarction

^b Some difficulty or more in at least one of the physical task questions within a domain. Presence of a functional limitation (work, amount or type of work, walking, memory, and confusion) was defined as a response of “yes” in a category.