


Hearing Loss and Physical Functioning Among Adults with Heart Failure: Data from NHANES

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Background: Hearing loss (HL) is associated with poor physical functioning among older adults, yet this association has not been examined in heart failure (HF), a disease in which both hearing loss and poor physical functioning are highly prevalent. We investigated whether this association exists in HF since HL represents a potentially modifiable risk factor for poor physical functioning.

Methods: We studied adults aged ≥ 70 years with self-reported HF in the National Health and Nutrition Examination Survey (NHANES). HL was assessed and categorized using pure-tone averages. Activities of daily living (ADLs), instrumental ADLs (IADLs), leisure and social activities (LSA), lower extremity mobility (LEM), and general physical activity (GPA) were assessed. Multiple imputation was used to examine the association.

Results: One hundred eighty-one participants comprised our population. Those with \geq moderate HL had more difficulty with ADLs (37.0% vs 24.0%, $p=0.02$), IADLs (36.0% vs 23.0%, $p=0.05$), and LEM (37.3% vs 20.0%, $p=0.009$), compared to participants with none or mild HL. In multivariable models, \geq moderate HL was significantly associated with difficulty in physical functioning across four of the five domains: ADLs: PR: 1.71 (95% CI: 1.07–2.72); IADLs: PR: 1.71 (1.24–2.34); LEM: PR: 1.51 (1.01–2.26); and GPA: PR: 1.19 (1.00–1.41).

Conclusion: Among older adults with HF, moderate or greater HL was associated with a higher prevalence of difficulty with ADLs, IADLs, and LEM, compared to mild or no HL.

Keywords: hearing loss, physical functioning, heart failure, prevalence

Background

Heart failure (HF) currently affects 6 million people in the United States, a number which is expected to rise as the population ages.¹ Adults with HF often experience decreased quality of life (QOL), especially in domains of physical functioning and vitality.^{2–6} Declining physical function may be related to the progression of HF, the aging process in general, or both. Poor physical functioning is associated with a variety of adverse outcomes including increased risk of falls, hospitalizations, morbidity, and mortality.^{7–10} Identifying modifiable risk factors for poor physical functioning in HF is important since targeted interventions have the potential to ameliorate these outcomes.

To date, only aerobic exercise has been shown to improve physical functioning among adults with HF.^{11,12} However, due to patients' severity of illness and symptoms, not all HF patients can fully engage in physical activity.¹³ One overlooked, but a potentially modifiable risk factor for poor physical functioning in HF is hearing loss. Hearing loss is associated with disability and poor physical

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functioning among older adults^{14–24} and has recently been shown to be highly prevalent among adults with HF.^{25,26} Yet the association between hearing loss and poor physical functioning among adults with HF has not been investigated.

To address this gap, and guided by the conceptual framework of Lin and Albert,²⁷ we used nationally representative data from the National Health and Nutrition Examination Survey (NHANES) to examine the association between hearing loss and physical functioning among older adults with HF.

Methods

Study Cohort

NHANES is an ongoing, cross-sectional study that assesses the health and nutritional status of the civilian noninstitutionalized US population. It utilizes a multistage probability sampling design such that national, population-level estimates can be derived. Conducted by the National Center of Health Statistics, NHANES obtains health and functional measures of participants through interviews and physical examinations continuously, releasing the collected data every 2 years.²⁸ The study was approved by the National Center for Health Statistics institutional review board, and NHANES obtained written informed consent from all participants. Additionally, the IRB at Weill Cornell deemed this exempt.

In this study, we included data from the 2005–2006 and 2009–2010 waves since during these years, objective audiometric assessments were conducted among older adults. Our study sample was comprised of adults aged 70 and older who underwent audiometric assessment and had a self-reported HF history. Like previous NHANES studies, participants were considered to have HF if they ever answered yes to, “Has a doctor ever diagnosed you with heart failure?”^{29,30}

Audiometric Assessment

Audiometric assessments were performed by a trained examiner according to the NHANES protocol.³¹ Briefly, air conduction hearing thresholds were assessed from both ears in a sound-isolating room in the NHANES mobile examination centers. Testing was done in accordance with the modified Hughson-Westlake test procedure using the automated testing mode of the audiometer (Interacoustics Model AD226) and/or manually per the testing protocol. Quality assurance and control were met through daily

calibrations of equipment and monitoring of ambient noise level. A test–retest protocol at 1 kHz threshold was used in order to ensure participant reliability.³¹ Hearing loss severity was defined according to a speech-frequency pure tone average (PTA) of thresholds at 0.5, 1, 2, and 4 kHz in the better-hearing ear, using the World Health Organization’s (WHO) guidelines.³² No hearing loss was defined as 25 dB or less; mild, 26–40 dB; moderate, 41–60 dB; severe, 61–80 dB; and profound, 81 dB or worse.³² Based on prior studies, and those which have examined the association between hearing loss and physical functioning, we further categorized hearing loss as none to mild versus moderate and greater.^{14–16,18,33–35}

Physical Functioning

Physical functioning was assessed during the in-home interview using a Computer-Assisted Personal Interviewing system. Participants were asked about their ability to perform physical activities without the use of special equipment. Nineteen physical activities were assessed, subcategorized into five main domains: (1) activities of daily living (ADLs) (getting in and out of bed, eating, dressing yourself); (2) instrumental ADLs (IADLs) (managing money, performing house chores, preparing meals); (3) leisure and social activities (LSA) (going to the movies, attending social events, performing leisure activity at home); (4) lower extremity mobility (LEM) (walking a quarter mile, walking up to 10 steps, walking between rooms on the same floor); and (5) general physical activity (GPA) (lifting or carrying heavy objects, reaching up overhead, grasping/holding small objects, standing for long periods, sitting for long periods). The five physical functioning domains and the individual items which comprise them are summarized in Table 1. Participant responses were categorized as “no difficulty,” “some difficulty,” “much difficulty,” or “unable to do.” A limitation was considered as having some or more difficulty in one or more physical tasks in a given domain as previously described.^{36–40}

Covariates

Demographic data included self-reported age, which we categorized as 70–79, 80+, gender (M/F), race/ethnicity, which we categorized as Non-Hispanic white, or Non-Hispanic black, Hispanic, education level categorized as < high school, completed high school, and college, income, which we categorized as <20,000, ≥20,000, and marital status which we categorized as married/living with a partner, or widowed/separated/divorced.

Table 1 Five Physical Functioning Domains in NHANES

Physical Functioning Domains	Physical Tasks Comprising Each Domain
Activities of daily living (ADLs)	Getting in and out of bed Eating Dressing yourself
Instrumental activities of daily living (IADLs)	Managing money Performing house chores Preparing meals
Leisure and social activities (LSA)	Going to the movies Attending social events Performing leisure activity at home
Lower extremity mobility (LEM)	Walking one-quarter of a mile Walking up 10 steps Walking between rooms on the same floor
General physical activities (GPA)	Lifting or carrying heavy objects Reaching up overhead Grasping/holding small objects Standing for long periods Sitting for long periods

Participants were classified as having coronary heart disease (CHD) if they had a self-reported previous diagnosis of CHD, or if they reported a history of angina or myocardial infarction. The presence of diabetes was determined if participants had a self-reported previous diagnosis of diabetes, if they were taking medication for diabetes, if they had a 2-hrs fasting glucose concentration of 126 mg/dL or greater, or if they had a hemoglobin a1c of 6.5% or greater. Participants were classified as having hypertension if they reported a history of high blood pressure, were taking a prescription medication for high blood pressure or, if during the examination in the MEC, the mean of four blood pressure measurements was more than 140 mmHg (systolic) or more than 90 mmHg (diastolic). Stroke history was ascertained by self-report of a physician diagnosis. Finally, smoking history was categorized as never/former or current.

Statistical Analysis

NHANES examination weights were used to determine national estimates.²⁸ Differences between participant characteristics by HF status were determined with Chi-square tests for categorical variables and t-tests for continuous variables. The association between hearing loss severity and the physical functioning outcomes was determined

using multiple imputation to adjust for demographic and other clinical covariates. For all models, prevalence ratios (PRs) and their corresponding 95% confidence intervals (CIs) were calculated. Associations were considered to be statistically significant at $p < 0.05$. STATA procedures for complex survey design were used for all analyses (StataCorp LP, College Station, TX).

Results

Overall, 1972 participants 70 years of age and older underwent audiometric assessment in the 2005–2006 and 2009–2010 waves of NHANES. Of these, the 181 who had HF comprised our study sample. The prevalence of hearing loss was high, with 39.4% (95% CI, 31.8–47.6) having mild hearing loss and 39.0% (95% CI, 31.0–47.7) having moderate or greater hearing loss.

The characteristics of HF participants by hearing loss severity are shown in Table 2. Overall, 48.8% (95% CI, 38.7–59.0) were 80 years or older, 53.3% (95% CI, 46.5–60.0) were female, and 85.0% (95% CI, 79.0–89.5) were non-Hispanic White. The overall prevalence of cardiovascular risk factors was high; a total of 58.0% (95% CI, 48.5–66.9) of participants had CHD and 70.6% (95% CI, 63.0–77.2) had hypertension. Compared to those with none or mild hearing loss, participants with moderate or greater hearing loss were older, less educated, of lower socioeconomic status, and were more often widowed, divorced or separated. In terms of cardiovascular risk factors, CHD was more prevalent among those with moderate or greater hearing loss.

Participants with moderate or greater hearing loss had significantly more difficulty with ADLs (37.0% vs 24.0%, $p=0.02$), IADLs (36.0% vs 23.0%, $p=0.05$), and LEM (37.0% vs 20.0%, $p=0.009$), compared to those with less severe hearing loss (Table 3).

Table 4 shows the associations between the severity of hearing loss and the five physical functioning outcomes. In unadjusted models, moderate or greater hearing loss was associated with a significantly higher prevalence of difficulty in physical functioning across four of the five domains: ADLs (PR, 1.82; 95% CI, 1.13–2.93), IADLs (PR, 1.56; 95% CI, 1.09–2.22), LEM (PR, 1.39; 95% CI, 1.08–1.80), and GPA (PR, 1.19; 95% CI, 1.02–1.38) (Table 4, Model 1). An association between moderate or greater hearing loss and difficulty with LSA was also seen (PR, 1.35; 95% CI, 0.97–1.88); however, it did not reach statistical significance.

Table 2 Characteristics of the Heart Failure Population from the 2005–2006 and 2009–2010 National Health and Nutrition Examination Survey (NHANES)^a, by Hearing Loss Severity

Characteristics	Prevalence % (95% Confidence Interval)		
	Overall ^b	None/Mild	Moderate or Greater
Age group, years			
70–79	51.2 (41.0–61.3)	70.2 (55.4–81.8)	30.1 (15.8–49.6)
80+	48.8 (38.7–59.0)	29.8 (18.3–44.6)	69.9 (50.4–84.2)
Gender			
Male	46.7 (40.0–53.5)	47.6 (37.9–57.5)	46.9 (34.3–59.8)
Female	53.3 (46.5–60.0)	52.4 (42.5–62.1)	53.1 (40.2–65.7)
Race/ethnicity			
Hispanic	4.8 (2.1–9.2)	7.1 (3.3–14.9)	0.80 (0.1–6.0)
Non-Hispanic white	85.0 (79.0–89.5)	80.4 (71.1–87.3)	96.3 (89.3–98.8)
Non-Hispanic black	10.2 (7.0–14.9)	12.5 (7.5–19.9)	2.9 (0.8–9.9)
Education Level			
<High school	30.9 (24.9–37.7)	26.6 (18.4–36.9)	35.4 (22.6–50.6)
High school	33.2 (25.4–42.0)	39.3 (28.3–51.5)	34.7 (22.4–49.5)
College or higher	35.9 (26.5–46.6)	34.1 (23.2–46.9)	30.0 (18.6–44.6)
Income			
≥20,000	70.8 (63.6–77.0)	75.0 (63.7–83.8)	67.5 (50.8–80.7)
<20,000	29.2 (23.0–36.4)	25.0 (16.3–36.3)	32.5 (19.3–49.2)
Marital Status			
Married/living with partner	50.3 (38.5–62.1)	64.1 (50.2–76.0)	37.1 (20.3–57.7)
Widowed, separated, or divorced	49.7 (37.9–61.6)	35.9 (24.0–49.8)	62.9 (42.3–79.7)
Coronary heart disease	58.0 (48.5–66.9)	53.3 (36.8–69.1)	65.6 (48.7–79.3)
Diabetes	39.7 (31.6–48.4)	46.0 (32.1–60.6)	36.5 (25.7–48.8)
Hypertension	70.6 (63.0–77.2)	75.5 (64.2–84.1)	68.0 (54.6–79.0)
Stroke	24.7 (17.0–34.3)	25.7 (14.9–40.5)	22.0 (15.1–30.8)
Smoking Status			
Never/former	91.8 (86.1–95.3)	88.3 (79.3–93.7)	97.2 (91.2–99.1)
Current	8.2 (4.7–13.9)	11.7 (6.3–20.7)	2.8 (0.9–8.8)

Notes: Overall, 1972 participants underwent audiometric assessments, of which 181 had HF. ^aPrevalence estimates were computed using Mobile Examination Center examination weights to provide estimates for the total US population and are age standardized to the US 2010 Census population. ^bMissing data included: level of education (0.50%), income (3.35%), marital status (0.2%), CHD (0.66%), hypertension (0.35%), smoking (48.5%), stroke (0.41%).

Abbreviation: PTAR, pure tone audiometry range.

After adjustment for age, socio-demographic characteristics, and clinical comorbidities, the association between hearing loss severity and difficulty in physical functioning remained significant (Table 4, Model 3). In this fully adjusted model, moderate or greater hearing loss was associated with a significantly higher prevalence of difficulty with ADLs (aPR, 1.78; 95% CI, 1.07–2.94), IADLs (aPR, 1.91; 95% CI, 1.34–2.73), LSA (aPR, 1.52; 95% CI, 1.01–2.30), LEM (aPR, 1.58; 95% CI, 1.16–2.13), and GPA (aPR, 1.22; 95% CI, 1.04–1.42). In this fully adjusted model, no participant characteristics were independently

associated with difficulty in physical functioning across the domains.

Discussion

In this nationally representative study of older adults with HF, we found that hearing loss severity was associated with greater difficulty with physical functioning in the following domains including activities of daily living (ADLs), instrumental ADLs, leisure and social activity (LSA), lower extremity mobility (LEM), and general physical activity (GPA). These associations

Table 3 Hearing Loss Severity and Difficulty with Physical Functioning Domains Among Participants with Heart Failure

Hearing Loss (HL)		Difficulty with Physical Functioning		
		No (N, %)	Yes (N, %)	P-value
Activities of daily living (ADLs)		94	86	
Mean (SD)		36.7 (14.2)	42.1 (15.3)	0.03
Severity of HL	None	18 (19%)	9 (10%)	0.02
	Mild	38 (40%)	20 (23%)	
	Moderate/Severe/Profound	23 (24%)	32 (37%)	
Instrumental ADLs (IADLs)		75	99	
Mean (SD)		36.9 (15.3)	40.4 (14.1)	0.17
Severity of HL	None	14 (19%)	13 (13%)	0.05
	Mild	31 (41%)	26 (26%)	
	Moderate/Severe/Profound	17 (23%)	36 (36%)	
Lower extremity mobility (LEM)		70	110	
Mean (SD)		36.8 (13.4)	40.5 (15.6)	0.15
Severity of HL	None	10 (14%)	17 (15%)	0.009
	Mild	31 (44%)	27 (24%)	
	Moderate/Severe/Profound	14 (20%)	41 (37%)	
Leisure and social activities (LSA)		91	89	
Mean (SD)		37.7 (14.8)	40.6 (14.9)	0.24
Severity of HL	None	18 (20%)	9 (10%)	0.19
	Mild	31 (34%)	27 (30%)	
	Moderate/Severe/Profound	25 (27%)	30 (34%)	
General physical activities (GPA)		34	146	
Mean (SD)		37.9 (13.9)	39.4 (15.1)	0.63
Severity of HL	None	5 (14.7%)	22 (15.1%)	0.09
	Mild	17 (50.0%)	41 (28.1%)	
	Moderate/Severe/Profound	7 (20.6%)	48 (32.9%)	

Notes: Hearing loss was defined by pure tone audiometric range (PTAR). Difficulty (yes/no) in physical domain defines as a response of some difficulty or more in at least one of the physical task questions within a domain. Missing hearing data per physical functioning domain: ADLs (22.1%), Instrumental ADLs (20.4%), LEM (22.1%), Leisure and Social (22.1%), General Physical Activities (22.1%).

Abbreviation: SD, standard deviation.

persisted after adjustment for age, demographics, and clinical variables.

While the association between hearing loss and poor physical functioning has been established among older adults and older adults with cardiovascular disease (CVD) and CVD risk factors,^{16–26,41,42} this study is the first to investigate this association in HF, a chronic disease characterized by high prevalence of physical, cognitive, and sensory deficits.^{2–4,6,43–45} This association, however, may be of particular importance in HF. A recent study by Gorodeski et al (2018) recommends that older adults with

HF be cared for using a domain framework that includes regular assessment of medical issues, mind and emotion, physical function, and social environment.⁵ This work posits that HF patients have many geriatric conditions that require screening and treatment. For example, physical functioning assessments should encompass a review of ADLs/IADLS, gait speed, and frailty to determine patients' risk for falls, hospitalizations, and mortality.^{7–10} Our findings add to this framework by suggesting that hearing loss be considered in the care of HF patients, and in particular, those with poor physical functioning.

Table 4 Association Between Severity of Hearing Loss and Difficulty in Physical Functioning Among Adults with HF Using Multiple Imputation

Physical Functioning Domain	Model 1	Model 2	Model 3
	PR [95% CI]	PR [95% CI]	PR [95% CI]
Activities of daily living (ADLs)	1.82 [1.13, 2.93]	1.74 [1.18, 2.57]	1.71 [1.07, 2.72]
Instrumental ADLs (IADLs)	1.56 [1.09, 2.23]	1.64 [1.26, 2.15]	1.71 [1.24, 2.34]
Leisure and social activities	1.35 [0.97, 1.88]	1.47 [1.01, 2.14]	1.51 [1.01, 2.26]
Lower extremity mobility	1.39 [1.08, 1.80]	1.49 [1.10, 2.02]	1.50 [1.11, 2.03]
General physical activities	1.19 [1.02, 1.38]	1.17 [0.98, 1.39]	1.19 [1.00, 1.41]

Notes: Model 1 – Crude. Model 2 – Demographics (Age, Race, Gender, Education, Income, Marital Status). Model 3 – Model 2 + Coronary heart disease, stroke, diabetes, hypertension, smoking.

Abbreviations: PR, prevalence ratio; CI, confidence interval.

While the underlying mechanism between hearing loss and physical functioning is not well understood in HF, several possible explanations exist. First, individuals with HF share many CVD risk factors that are associated with hearing loss, including hypertension, CHD, diabetes, and smoking.^{46–52} CVD and its risk factors cause microvascular ischemia leading to ciliary damage that results in hearing loss as well as poor health and function.^{49,50,53,54} The common location of cochlear and vestibular function in conjunction with concurrent neuronal degeneration, given cardiovascular risk factors such as diabetes, could explain the association between hearing loss and physical function as the balance is crucial for physical functioning.⁵⁵ Secondly, ototoxic medications such as loop diuretics and aspirin are commonly used in HF patients and could contribute to hearing loss. Third, it has been suggested that hearing loss could also worsen physical functioning through increased cognitive load and decreased executive function.^{56,57} Thus, less cognitive reserve may remain for gait and balance which directly impact physical functioning.^{58–61} Finally, hearing loss often results in communication barriers which have been shown to increase the risk of social isolation.^{18,62,63} Social isolation affects health care and social communication, impacting an individual's ability to do physical activities and manage their health conditions effectively. Given the cross-sectional nature of this study, additional prospective research is needed to better elucidate the underlying pathway.

Beyond additional research in this area, our findings suggest that increased awareness of hearing loss among HF patients and its possible deleterious on physical functioning is warranted. Among those with established or worsening physical functioning, inpatient and outpatient healthcare providers might consider screening HF patients for hearing deficits during medical encounters. Second,

among those with suspected hearing loss, referral to an audiologist and otolaryngologist may be appropriate. Finally, since effective strategies exist which can mitigate the effects of hearing loss, providers ought to familiarize themselves with hearing aid options and refer patients when appropriate.

Strengths and Limitations

Our study has several strengths. First, we use a comprehensive battery of physical functioning domains which have been well accepted in the literature.^{36–40} Second, NHANES is a nationally representative cohort that utilizes objective audiometric assessments and a standard definition of hearing loss according to the World Health Organization's (WHO) guidelines.³² We also note a few limitations. Although we found a strong association between hearing loss severity and poor physical functioning in HF, casual inferences cannot be made. Additionally, NHANES is a nationally representative cohort of the US population, it does not include adults who reside in nursing homes or rehab centers, which are relevant to HF patients. Lastly, although our study used objective audiometric data, HF status and physical functioning data were obtained through self-report.

Conclusion

Our findings suggest that hearing loss severity among older adults with HF is associated with a higher prevalence of difficulty in physical functioning across several domains. Increased awareness of this association is needed among healthcare providers. Additional observational research is needed to further investigate the association and underlying mechanism between hearing loss and physical functioning in HF. If an association between hearing loss and physical

functioning among adults with HF existed, interventions to mitigate hearing loss may be warranted.

Abbreviations

HL, Hearing loss; HF, Heart failure; NHANES, National Health and Nutrition Examination Survey; ADLs, Activities of daily living; IADLs, Instrumental ADLs; LSA, Leisure and social activities; LEM, Lower extremity mobility; GPA, General physical activity; CHD, Coronary heart disease; CVD, Cardiovascular disease.

Impact Statement

We certify that this work is novel clinical research. The association between hearing loss and physical functioning among adults with heart failure and has not previously been investigated.

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