

the (causative) relationship between anatomical abnormalities and changes in renal function.

Peter W. de Leeuw, MD, PhD  
Cornelis T. Postma, MD, PhD  
Abraham A. Kroon, MD, PhD

**Author Affiliations:** Department of Medicine, University Hospital Maastricht, Maastricht, the Netherlands (Drs de Leeuw and Kroon) (p.deleeuw@maastrichtuniversity.nl); and Department of Medicine, Radboud University Nijmegen Medical Centre, Nijmegen, the Netherlands (Dr Postma).

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1. Trinquart L, Mounier-Vehier C, Sapoval M, Gagnon N, Plouin PF. Efficacy of revascularization for renal artery stenosis caused by fibromuscular dysplasia: a systematic review and meta-analysis. *Hypertension*. 2010;56(3):525-532.

## RESEARCH LETTER

### Association of Hearing Loss With Hospitalization and Burden of Disease in Older Adults

**To the Editor:** Hearing loss (HL) is a chronic condition that affects nearly 2 of every 3 adults aged 70 years or older in the United States.<sup>1</sup> Hearing loss has broader implications for older adults, being independently associated with poorer cognitive<sup>2</sup> and physical functioning.<sup>3</sup>

The association of HL with other health economic outcomes, such as health care use, is unstudied. We investigated the association of HL with hospitalization and burden of disease in a nationally representative study of adults aged 70 years or older.

**Methods.** We analyzed combined data from the 2005-2006 and 2009-2010 cycles of the National Health and Nutrition Examination Survey (NHANES), an ongoing epidemiological study designed to assess the health and functional status of the civilian, noninstitutionalized US population.<sup>4</sup> Air-conduction pure-tone audiometry was administered to all individuals aged 70 years or older, according to established NHANES protocols.

Hearing was defined per the World Health Organization<sup>5</sup> as the average of hearing thresholds (in decibels) at speech frequencies (0.5-4 kHz) in the better-hearing ear (range: 0-100 dB). Data on hospitalizations (during the previous 12 months) and on burden of disease (during the previous 30 days) were gathered through computer-assisted or interviewer-administered questionnaires. Hospitalization was defined as any hospitalization (yes or no) and number of hospitalizations (0, 1, or >1 times). Burden of disease was defined as self-reported number of days of poor physical health, poor mental health, and inactivity due to health (0-10 or >10 days).<sup>4</sup>

Data were analyzed using stepwise multivariable logistic and ordinal logistic regression models to investigate the association of HL as a continuous variable (per 25 dB) with hospitalization and burden of disease, adjusting for demographic characteristics and cardiovascular risk factors. We accounted for the complex sampling design using sample

**Table 1.** Demographic Characteristics of Participants Aged 70 Years or Older With Audiometric Testing From National Health and Nutrition Examination Surveys in 2005-2006 and 2009-2010<sup>a</sup>

Characteristic	Normal Hearing (n = 529)	Hearing Loss <sup>b</sup> (n = 1140)	P Value <sup>c</sup>
Age group, y			
70-74	289 (54.6)	319 (30.0)	<.001
75-79	138 (26.1)	283 (24.8)	
≥80	102 (19.3)	538 (47.2)	
Degree of hearing loss <sup>d</sup>			
Mild		590 (51.8)	
Moderate		446 (39.1)	
Severe		97 (8.5)	
Profound		7 (0.6)	
Any hospitalization	99 (18.7)	271 (23.8)	.02
No. of hospitalizations, mean (95% CI)	1.27 (1.13-1.41)	1.52 (1.40-1.64)	.03
Days of poor health, mean (95% CI)			
Physical	4.48 (3.69-5.26)	4.98 (4.39-5.56)	.33
Mental	2.49 (1.90-3.08)	2.23 (1.99-2.64)	.46
Days inactive due to health, mean (95% CI)	1.91 (1.36-2.46)	2.33 (1.90-2.76)	.26
Male sex	217 (41.0)	631 (55.4)	<.001
Race <sup>e</sup>			
White	327 (61.8)	859 (75.3)	<.001
Black	117 (22.1)	117 (10.3)	
Hispanic	68 (12.9)	131 (11.5)	
Other	17 (3.2)	33 (2.9)	
Education			
<12th grade	161 (30.4)	428 (37.5)	.003
High school graduate	128 (24.2)	300 (26.3)	
≥Some college	239 (45.2)	410 (36.0)	
Refused or not known	1 (0.2)	2 (0.2)	
Household annual income, US \$			
<20 000	129 (24.4)	353 (31.1)	.002
20 000-44 999	176 (33.3)	406 (35.8)	
≥45 000	185 (35.0)	301 (26.5)	
Refused or not known	39 (7.4)	75 (6.6)	
Hypertension	353 (66.9)	703 (61.9)	.05
Diabetes mellitus	113 (21.4)	247 (21.7)	.89
Stroke	38 (7.2)	130 (11.4)	.008
Cardiovascular disease <sup>f</sup>	103 (19.5)	307 (27.0)	.001
Smoking history			
Current	258 (48.8)	534 (46.8)	.24
Former	226 (42.7)	529 (46.4)	
Never	45 (8.5)	77 (6.8)	
Type of health insurance			
Private only	11 (2.1)	16 (1.4)	.67
Medicare only	223 (42.2)	460 (40.4)	
Private and Medicare	283 (53.5)	630 (55.3)	
Other	3 (0.6)	13 (1.1)	

<sup>a</sup>Demographic characteristics are unweighted to give descriptive statistics on the characteristics of the study cohort rather than nationally generalizable estimates. Data are expressed as number (percentage) unless otherwise indicated.

<sup>b</sup>Defined as the average of hearing thresholds (0.5-4 kHz) in the better hearing ear of 25 dB or greater.

<sup>c</sup>For binary and categorical variables, the  $\chi^2$  test was used; for continuous variables, the 2-sample *t* test was used to evaluate for differences.

<sup>d</sup>Defined by the average of hearing thresholds (0.5-4 kHz) in the better hearing ear: mild, 25 to 39 dB; moderate, 40 to 59 dB; severe, 60 to 84 dB; profound, 85 dB or greater.

<sup>e</sup>Based on self-report by the study participant.

<sup>f</sup>Includes any or all of the following: history of myocardial infarction, history of angina, diagnosis of coronary artery disease, diagnosis of congestive heart failure.

**Table 2.** Association of Hearing Loss With Any Hospitalization, Number of Hospitalizations, and Burden of Disease in the Previous 12 Months From National Health and Nutrition Examination Surveys in 2005-2006 and 2009-2010

	Base Model <sup>a</sup>			Base Model + Demographic Factors <sup>b</sup>			Base Model + Demographic Factors + Cardiovascular Risk Factors <sup>c</sup>		
	No. <sup>d</sup>	OR (95% CI)	P Value	No. <sup>d</sup>	OR (95% CI)	P Value	No. <sup>d</sup>	OR (95% CI)	P Value
Hospitalizations in past 12 mo									
Any (yes or no)	1666	1.33 (1.08-1.65)	.008	1658	1.34 (1.09-1.65)	.006	1646	1.32 (1.07-1.63)	.01
No. of hospitalizations (0, 1, >1)	1666	1.36 (1.10-1.67) <sup>e</sup>	.005	1661	1.36 (1.11-1.68) <sup>e</sup>	.005	1649	1.35 (1.09-1.68) <sup>e</sup>	.007
Self-reported disease burden for >10 d in past 30 d									
Poor physical health	1570	1.32 (1.06-1.64)	.02	1562	1.35 (1.06-1.73)	.02	1552	1.36 (1.06-1.74)	.02
Poor mental health	1568	1.25 (0.97-1.61)	.09	1560	1.54 (1.19-1.99)	.002	1550	1.57 (1.20-2.06)	.002
Inactivity due to health	1570	1.09 (0.72-1.67)	.66	1562	1.04 (0.68-1.58)	.87	1552	1.02 (0.67-1.56)	.93

Abbreviation: OR, odds ratio.

<sup>a</sup> Consisted of hearing loss per 25 dB and age. Hearing loss was defined by the average of hearing thresholds (0.5-4 kHz) in the better hearing ear. Age was adjusted for as a categorical variable (70-74, 75-79, ≥80 years). The National Health and Nutrition Examination Surveys report individuals aged 80 years or older as 80 years to ensure participant confidentiality.

<sup>b</sup> Demographic factors include sex, race, level of education, and annual household income.

<sup>c</sup> Cardiovascular risk factors include hypertension, stroke, diabetes mellitus, and cardiovascular disease (myocardial infarction, coronary artery disease, angina, congestive heart failure), smoking history (current, former, never).

<sup>d</sup> Number of individuals included in each model. Individuals with missing data for a given model were excluded from that model. For analyses of hospitalization, missing data comprised less than 1.1% of the data set, and for burden of disease, missing data comprised less than 7.1% of the data set.

<sup>e</sup> The OR represents the odds of the next higher categorical number of hospitalizations.

weights according to National Center for Health Statistics guidelines.

Data were analyzed using Stata version 11 (StataCorp). A 2-sided threshold of  $P < .05$  was used to evaluate statistical significance. The NHANES protocol was reviewed and approved by the National Center for Health Statistics's institutional review board and informed written consent was obtained from all participants.

**Results.** Compared with individuals with normal hearing ( $n=529$ ), individuals with HL ( $n=1140$ ) were more likely to be older (mean age: 74.7 vs 77.0 years;  $P < .001$ ), male, white, less educated, in lower income households, have a positive history for cardiovascular risk factors, have a history of hospitalization in the past year (18.7% vs 23.8%;  $P = .02$ ), and have more hospitalizations (1.27 [95% CI, 1.13-1.41] vs 1.52 [95% CI, 1.40-1.64];  $P = .03$ ) (TABLE 1).

Fully adjusted models accounting for demographic and cardiovascular risk factors demonstrated that HL (per 25 dB) was significantly associated with any hospitalization (odds ratio [OR], 1.32 [95% CI, 1.07-1.63]), number of hospitalizations (OR, 1.35 [95% CI, 1.09-1.68]), more than 10 days of self-reported poor physical health (OR, 1.36 [95% CI, 1.06-1.74]), and more than 10 days of self-reported poor mental health (OR, 1.57 [95% CI, 1.20-2.06]) (TABLE 2). Hearing loss was not associated with days of self-reported inactivity due to health.

**Discussion.** For adults aged 70 years or older, HL was independently associated with hospitalization and poorer self-reported health over the past 12 months. This is, to our

knowledge, the first nationally representative study to demonstrate that HL is independently associated with increased health care use and burden of disease among older adults. Pathways through which HL would contribute to the odds of hospitalization and poorer self-reported health include effects of HL on social isolation,<sup>6</sup> health-related oral literacy, and cognitive decline.<sup>2</sup>

Alternatively, residual confounding by unmeasured factors not accounted for in our analyses (eg, subclinical microvascular disease) could also underlie the observed associations. A principal limitation of this cross-sectional study is that we cannot determine the temporal course and mechanisms through which hearing loss could be associated with hospitalization and burden of disease.

Future economic analyses may need to take into account these potential broader implications of HL on the health and functioning of older adults. Additional research is needed to investigate the basis of these observed associations and whether hearing rehabilitative therapies could help reduce hospitalizations and improve self-reported health in older adults with HL.

Dane J. Genther, MD  
Kevin D. Frick, PhD  
David Chen, BS  
Joshua Betz, MS  
Frank R. Lin, MD, PhD

**Author Affiliations:** Department of Otolaryngology-Head and Neck Surgery, Johns Hopkins University School of Medicine, Baltimore, Maryland (Drs Genther and Lin and Mr Chen) (flin1@jhmi.edu); and Departments of Health Policy and Management (Dr Frick) and Biostatistics (Mr Betz), Johns Hopkins University Bloomberg School of Public Health, Baltimore, Maryland.

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**Study concept and design:** Genter, Frick, Chen, Lin.

**Acquisition of data:** Genter, Chen.

**Analysis and interpretation of data:** Genter, Frick, Betz, Lin

**Drafting of the manuscript:** Genter, Lin.

**Critical revision of the manuscript for important intellectual content:** Genter, Frick, Chen, Betz, Lin.

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1. Lin FR, Thorpe R, Gordon-Salant S, Ferrucci L. Hearing loss prevalence and risk factors among older adults in the United States. *J Gerontol A Biol Sci Med Sci*. 2011;66(5):582-590.
2. Lin FR, Metter EJ, O'Brien RJ, Resnick SM, Zonderman AB, Ferrucci L. Hearing loss and incident dementia. *Arch Neurol*. 2011;68(2):214-220.
3. Viljanen A, Kaprio J, Pyykkö I, Sorri M, Koskenvuo M, Rantanen T. Hearing acuity as a predictor of walking difficulties in older women. *J Am Geriatr Soc*. 2009; 57(12):2282-2286.
4. Centers for Disease Control and Prevention and National Center for Health Statistics. National Health and Nutrition Examination Survey. <http://www.cdc.gov/nchs/nhanes.html>. Accessed October 1, 2012.
5. World Health Organization. Prevention of deafness and hearing impaired grades of hearing impairment. [http://www.who.int/pbd/deafness/hearing\\_impairment\\_grades/en/index.html](http://www.who.int/pbd/deafness/hearing_impairment_grades/en/index.html). Accessed November 18, 2012.
6. Berkman LF, Glass T, Brissette I, Seeman TE. From social integration to health: Durkheim in the new millennium. *Soc Sci Med*. 2000;51(6):843-857.