

Original Investigation

Hearing Impairment Associated With Depression in US Adults, National Health and Nutrition Examination Survey 2005-2010

Chuan-Ming Li, MD, PhD; Xinzhi Zhang, MD, PhD; Howard J. Hoffman, MA; Mary Frances Cotch, PhD; Christa L. Themann, MA, CCC-A; M. Roy Wilson, MD

IMPORTANCE Depression among hearing impaired US adults has not been studied previously.

OBJECTIVE To estimate the prevalence of and risk factors for depression among adults with hearing loss.

DESIGN, SETTING, AND PARTICIPANTS Adults aged 18 years or older (N = 18 318) who participated in the National Health and Nutrition Examination Survey (NHANES), 2005-2010, a nationally representative sample.

INTERVENTIONS Multistage probability sampling of US population.

MAIN OUTCOMES AND MEASURES Depression, assessed by the 9-item Patient Health Questionnaire (PHQ-9) scale, and hearing impairment (HI), assessed by self-report and audiometric examination for adults aged 70 years or older.

RESULTS The prevalence of moderate to severe depression (PHQ-9 score, ≥ 10) was 4.9% for individuals reporting excellent hearing, 7.1% for those with good hearing, and 11.4% for participants who reported a little trouble or greater HI. Using excellent hearing as the reference, after adjusting for all covariates, multivariate odds ratios (ORs) for depression were 1.4 (95% CI, 1.1-1.8) for good hearing, 1.7 (1.3-2.2) for a little trouble, 2.4 (1.7-3.2) for moderate trouble, 1.5 (0.9-2.6) for a lot of trouble, and 0.6 (0.1-2.6) for deaf. Moderate HI (defined by better ear pure-tone average of hearing thresholds at 0.5, 1, 2, and 4 kHz within the range 35- to 49-dB hearing level) was significantly associated with depression among older women (OR, 3.9; 95% CI, 1.3-11.3), after adjusting for age, sex, race/ethnicity, lifestyle characteristics, and selected health conditions.

CONCLUSIONS AND RELEVANCE After accounting for health conditions and other factors, including trouble seeing, self-reported HI and audiometrically determined HI were significantly associated with depression, particularly in women. Health care professionals should be aware of an increased risk for depression among adults with hearing loss.

JAMA Otolaryngol Head Neck Surg. 2014;140(4):293-302. doi:10.1001/jamaoto.2014.42
Published online March 6, 2014.

Author Affiliations: Epidemiology and Statistics Program, National Institute on Deafness and Other Communication Disorders, National Institutes of Health, Bethesda, Maryland (Li, Hoffman); National Institute on Minority Health and Health Disparities, National Institutes of Health, Bethesda, Maryland (Zhang, Wilson); Division of Epidemiology and Clinical Applications, National Eye Institute, National Institutes of Health, Bethesda, Maryland (Cotch); Hearing Loss Prevention Team, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Cincinnati, Ohio (Themann); Office of the President, Wayne State University, Detroit, Michigan (Wilson).

Corresponding Author: Chuan-Ming Li, MD, PhD, Epidemiology and Statistics Program, National Institute on Deafness and Other Communication Disorders, National Institutes of Health, 6001 Executive Blvd, Ste 8300, Bethesda, MD 20892 (chuan-ming.li@nih.gov).

Unipolar depressive disorders have been reported¹ as the leading cause and adult-onset hearing impairment (HI) as the second leading cause of years of life lived with disability among adults in high-income countries. Furthermore, depression and HI have been associated^{2,3} with personal, societal, and economic burden. However, the relationship between depression and HI has not been reported in a nationally representative sample of US adults. Previous studies⁴⁻⁸ have been limited primarily to older adults or specific geographically or ethnically distinct populations, and these have shown conflicting results.

Using data from the 2005-2010 National Health and Nutrition Examination Survey (NHANES),⁹ we examined the re-

lationship between depression and self-reported HI for US adults aged 18 years or older. Because audiometric examination data were collected for adults aged 70 years or older, we also examined the association between depression and HI defined by hearing thresholds in this age range.

Methods

Participants

The NHANES, a nationally representative survey conducted by the National Center for Health Statistics, Centers for Disease Control and Prevention, uses a complex, multistage, prob-

ability sampling design to select participants representative of the civilian, noninstitutionalized US population.⁹ In NHANES 2005-2010, a total of 18 318 persons aged 18 years or older were interviewed at home and invited to a mobile examination center. Audiometric examinations, funded by the National Institute on Deafness and Other Communication Disorders, National Institutes of Health, were conducted on adolescents aged 12 to 19 years and adults aged 70 years or older.

The NHANES protocol was approved by the National Center for Health Statistics human subjects review board. Informed consent was obtained from all participants, who were financially compensated and received a report of the medical findings. In addition, transportation was provided to and from the mobile NHANES center, if necessary.

Outcome Measures

Self-reported Hearing Status

In a home interview before the mobile examination center examination, participants were asked the following question to rate their hearing (without a hearing aid): "Would you say your hearing is excellent, good, that you have a little trouble, moderate trouble, a lot of trouble, or are you deaf?" In this study, self-reported hearing difficulty was defined by responses of a little trouble or greater.

Audiometric Measure

In the NHANES 2005-2006 and 2009-2010 studies, the audiometric examination was administered to the full sample of older adults, aged 70 years or older ($n = 1535$). Air-conduction pure-tone thresholds were obtained in a sound-treated booth (Delta 143; Acoustic Systems) in the mobile examination center by trained examiners at 7 frequencies (0.5, 1, 2, 3, 4, 6, and 8 kHz, each ear) using an audiometer (AD226; Interacoustics) with supra-aural headphones (TDH-39; Telephonics) (replaced by insert earphones [E•A•Rtone 3A; Etymotic Research] for individuals with asymmetric hearing loss or collapsing ear canals). Ambient noise was monitored with a bioacoustic simulator (BA-201-25; Quest) and octave band monitor. Some participants with hearing aids ($n = 30$) were unable to remove them for the examination and were excluded. Additional people ($n = 18$) were excluded because of ear pain at the time of the examination. In this study, analysis of the hearing thresholds was based on a new HI classification recommended by the 2010 Global Burden of Disease Hearing Loss Expert Group.¹⁰ The recommendation uses better ear (BE) pure-tone averages (PTAs) of thresholds at 0.5, 1, 2, and 4 kHz. An earlier World Health Organization classification¹¹ used separate categories for children and adults; the new proposal is a unified classification based on uniform 15-dB hearing level (HL) increments in BE PTA. Six bilateral HI categories are recommended: mild (20- to 34-dB HL), moderate (35- to 49-dB HL), moderately severe (50- to 64-dB HL), severe (65- to 79-dB HL), profound (80- to 94-dB HL), and deaf (≥ 95 -dB HL).

Depression Measure

The 9-item Patient Health Questionnaire (PHQ-9)¹² depression scale was used to assess the frequency of symptoms experienced and reported by participants during the past 2 weeks.

The PHQ-9 scores, ranging from 0 to 27, indicate the presence and severity of depression, with scores of 5, 10, 15, and 20 being the cut-points for mild, moderate, moderately severe, and severe depression, respectively. The validity and reliability of the PHQ and its 9-item depression module to establish depressive diagnosis and grade severity have been documented.^{12,13} Scores of 10 or higher on the PHQ-9 have a sensitivity of 88% and specificity of 88% for major depression.¹² In the present study, the severity of depressive symptoms was evaluated using 2 categories: mild (PHQ-9 score, 5-9) and moderate to severe (PHQ-9 score, 10-27).

Covariates

Several potential confounding variables were taken into account, including sociodemographic and lifestyle characteristics, medical history, and health status, including trouble seeing. Variables included in the analyses were categorized as follows: age (18-44, 45-69, and ≥ 70 years), race/ethnicity (Hispanic, non-Hispanic black, non-Hispanic white, and other), educational level (<high school, high school graduate, and >high school), married or living with a partner (yes/no), living alone (yes/no), health insurance coverage (yes/no), body mass index (<25, 25 to <30, and ≥ 30 [calculated as weight in kilograms divided by height in meters squared]), smoking status (current, former, and never), binge drinking (ie, ever consumed ≥ 5 drinks of any alcoholic beverage almost every day [yes/no]), self-reported general health status (excellent, very good, or good; fair; and poor), trouble seeing even with glasses or contact lenses (yes/no), sleep disorder if diagnosed by a physician or other health professional (yes/no), self-reported history of cancer (yes/no), and ever worn a hearing aid (yes/no). Tinnitus was defined as experiencing ringing, roaring, or buzzing in the ears or head lasting 5 minutes or longer during the past year (yes/no). Poverty income ratio (PIR) is the ratio of annual income to the poverty threshold based on family size. If a family's total income is less than the official poverty threshold, then PIR is less than 1.00, whereas PIR values of 1.00 or greater indicate income above the poverty level. This variable was categorized as PIR less than 1, $1 \leq \text{PIR} < 3$, and PIR of 3 or more. Hypertension was defined by antihypertensive medication use or blood pressure of 140/90 mm Hg or higher. History of cardiovascular diseases (yes/no) was ascertained by self-report of coronary heart disease, angina, myocardial infarction, stroke, or congestive heart failure. Diabetes mellitus was defined as self-report of a diagnosis of the disease by a health care professional (excluding gestational diabetes mellitus) or hemoglobin A_{1c} level of 6.5% or more (to convert to a percentage of total hemoglobin, multiply by 0.01).

Statistical Analysis

Statistical analyses were performed using SAS, version 9.3 (SAS Institute, Inc), and SUDAAN, version 11.0 (Research Triangle Institute), to calculate national estimates and SEs while taking into account the survey's complex sampling design. Two-sided tests and a 5% significance level were used in the analysis. Participant characteristics are described using means for continuous variables and percentages for categorical variables. Multivariable logistic regression analysis with the cal-

ulation of odds ratios (ORs) and 95% CIs was used to assess associations between HI and depression after adjusting for selected covariates. Some analyses were stratified by sex and age groups. In all, 13.4% of participants (n = 2462) who did not have depression scores were excluded from subsequent analysis, leaving a sample of 15 856. Missing values were imputed for 0.6% of the participants who were missing some items in the depression score (n = 96) (75% were missing only 1 item). The multiple imputation procedure and the fully conditional specification method were used to impute missing data to minimize the bias associated with listwise deletion of participants with missing values. Five imputations per missing observation were performed, and the average measure was calculated using the SUDAAN software.

Results

The sample number and nationally weighted percentages with levels of significance for differences within variable categories are reported in **Table 1** for various sociodemographic, lifestyle, and medical history characteristics. In this NHANES 2005-2010 sample of 18 318 adults, the mean age was 49.6 years (range, 18 to ≥ 85 years), and 51.7% were women. The race/ethnicity distribution was 12.9% Hispanic, 11.5% non-Hispanic black, 69.4% non-Hispanic white, and 6.2% other. This table also provides results separately by hearing status and depression status. For example, it is evident that older adults (≥ 70 years) are much more likely to report HI, but this is not true for either mild or moderate to severe depression. In addition, women were much more likely to report depression symptoms than were men, but they were less likely to report HI. Non-Hispanic whites were more likely to report HI but less likely to report depression. Lower educational level was strongly associated with depression but also significantly associated with HI. Several lifestyle factors, such as living alone, higher body mass index, current/former smoker, binge drinking, and poorer self-rated health status were associated with HI and depression. Also, most of the specific health conditions (eg, hypertension, diabetes mellitus, cardiovascular disease, cancer, trouble seeing, and sleep disorders) were strongly associated with HI and depression.

Prevalence of Self-reported HI

Among all participants, the prevalence of self-reported hearing status was 41.4% with excellent hearing; 36.9% with good hearing; 13.9%, a little trouble; 5.2%, moderate trouble; 2.3%, a lot of trouble; and 0.2%, deaf. The estimated prevalence of self-reported HI, defined as *a little trouble hearing or greater difficulty*, was 21.7% (95% CI, 20.6%-22.9%) for all participants, 25.0% (23.3%-26.8%) for men, and 18.7% (17.8%-19.6%) for women; hence, the estimated prevalence of any self-reported HI was higher in men than in women.

Prevalence of Depression

The estimated prevalence of moderate to severe depression (PHQ-9 score, ≥ 10) was 11.4% (95% CI, 10.1%-13.0%) for adults with any self-reported HI and 5.9% (5.3%-6.6%) for those with-

out HI. Among those with HI, the prevalence of depression was 9.0% (95% CI, 7.5%-10.8%) for men and 14.7% (12.7%-16.9%) for women. The estimated prevalence of depression was higher among adults with HI than in those without HI and higher among women than among men. The estimated prevalence of mild and moderate to severe depression, with and without HI, is presented in **Figure 1**. The prevalence of both levels of depression was significantly higher among men and women with HI.

Association Between Self-reported HI and Depression

Multivariate ORs (95% CI) for moderate to severe depression (PHQ-9 score, ≥ 10) are presented in **Table 2** by each reported level of hearing. In model 1, after controlling for age, sex, and race/ethnicity, significantly higher odds of depression were associated with any HI (except being deaf) compared with excellent hearing. In model 2, after controlling for socioeconomic characteristics and marital status in addition to age, sex, and race/ethnicity, the significant associations with HI category were slightly reduced in magnitude but remained highly significant. In model 3, self-reported HI remained significantly associated with depression in men and women, even after controlling for factors in model 2 as well as body mass index, smoking, binge drinking, general health status, hypertension, history of cardiovascular disease, cancer, diabetes, sleep disorder, and trouble seeing. Self-reported HI was significantly associated with depression in US adults after taking into account numerous other covariates.

Risk Factors for Depression With Self-reported HI

Among adults with any reported HI, the results listed in **Table 3** from multivariate logistic regression models (reported overall and separately by sex) indicate that being female, having a PIR less than 1, being a current smoker, binge drinking, fair or poor health status, trouble seeing, and sleep disorder were significantly associated with increased higher odds of depression. In participants aged 70 years or older, HI was significantly associated with decreased odds of depression. The strongest associations were with the self-rated health status categories fair and, especially, poor. Race/ethnicity, educational level, living alone, uninsured status, body mass index, and hypertension were not significant in any of the multivariate models in which all factors were adjusted for simultaneously.

The sex-specific models revealed that men and women share many of the same risk factors associated with depression, such as lower household income, binge drinking, general health status, trouble seeing, and sleep disorders. However, men have some specific risk factors; for example, the risk if married/living with partner was significantly reduced and if a current smoker was significantly increased only for men.

Global Burden of Disease Hearing Classification and Depression

Hearing loss based on air-conduction PTAs of thresholds at 0.5, 1, 2, and 4 kHz (PTA₅₁₂₄) were calculated for participants aged 70 years or older. The mean BE PTA₅₁₂₄ is displayed by self-reported hearing categories for that population in **Figure 2**. The PTA₅₁₂₄ increased as self-reported hearing category

Table 1. Selected Characteristics of US Adults Aged 18 Years or Older by Reported Hearing and Depression Status, NHANES 2005-2010^a

Characteristic	Sample Size, No. (N = 18 318)	All	Excellent or Good Hearing (n = 14 152)	HI (n = 4162)	P Value for χ^2	No Depression (n = 12 013)	Mild Depression (n = 2480)	Moderate to Severe Depression (n = 1363)	P Value for χ^2
Age, y									
18 to 44	8569	49.4	56.0	25.4		48.0	53.5	47.3	
45 to 69	6600	39.1	36.5	48.7	<.001	40.5	36.2	45.7	<.001
≥70	3149	11.5	7.5	25.9		11.5	10.3	7.0	
Sex									
Male	8918	48.3	46.3	55.6	<.001	51.4	41.6	35.8	<.001
Female	9400	51.7	53.7	44.4		48.4	58.4	64.2	
Race/ethnicity									
Non-Hispanic white	8569	69.4	66.4	79.9		71.5	69.1	63.3	
Non-Hispanic black	3836	11.5	12.9	6.8	<.001	10.8	10.7	15.9	<.001
Hispanic	5052	12.9	14.1	8.5		12.2	13.9	16.0	
Other	861	6.2	6.6	4.8		5.5	6.3	4.8	
Educational level									
<High school	5382	19.3	18.4	22.9		16.6	23.3	30.2	
High school graduate	4561	25.1	24.3	27.8	<.001	24.4	26.4	28.6	<.001
>High school	8310	55.6	57.3	49.3		59.0	50.3	41.2	
Poverty income ratio									
<1	3598	18.6	19.0	17.3		15.2	22.7	35.0	
1 to <3	7089	48.3	47.2	52.2	<.005	47.7	48.4	47.8	<.001
≥3	3234	33.1	33.8	30.5		37.1	28.8	17.2	
Married/living with partner	10 345	63.4	63.1	64.3	.32	66.8	58.4	50.9	<.001
Living alone	2544	13.3	12.0	17.7	<.001	12.3	14.5	16.8	<.001
Uninsured	4394	19.6	20.9	14.7	<.001	17.7	23.9	29.2	<.001
BMI									
<25 (Normal/underweight)	6139	36.4	38.1	30.4		36.3	33.8	31.3	
25 to <30 (Overweight)	6025	34.0	33.3	36.5	<.001	35.1	31.2	29.7	<.001
≥30 (Obese)	5437	29.5	28.6	33.1		28.5	35.0	39.0	
Smoking									
Current	3754	22.4	22.4	22.3		19.4	28.2	41.9	
Former	4261	24.4	21.7	33.7	<.001	25.5	24.3	19.6	<.001
Never	9104	53.2	55.9	44.0		55.1	47.5	38.5	
Binge drinker	2261	12.1	10.4	18.2	<.001	11.8	17.7	26.6	<.001
Self-rated health status									
Excellent, very good, or good	13 928	82.7	85.7	71.7		88.3	73.3	49.2	
Fair	3529	14.0	11.9	21.7	<.001	10.4	21.2	33.5	<.001
Poor	851	3.3	2.4	6.6		1.3	5.5	17.3	
Hypertension	5549	26.9	23.0	40.7	<.001	26.3	28.4	36.4	<.001
Diabetes mellitus	2012	8.0	6.8	12.6	<.001	7.2	9.7	13.3	<.001
Cardiovascular disease history	1946	8.2	5.8	16.5	<.001	7.0	9.3	14.8	<.001
Cancer history	1610	8.7	6.8	15.6	<.001	7.9	8.4	12.0	.04
Trouble seeing, even with glasses/contact lenses	3574	17.1	13.9	28.5	<.001	13.7	23.4	39.4	<.001
Sleep disorder	1304	7.3	6.3	10.9	<.001	5.6	9.8	22.1	<.001
Ever worn a hearing aid, age, y ^b									
18 to 19	7.0	0.8	0.1	10.3	<.05	0.3	0.8	0	.13
≥70	578	18.6	1.4	36.5	<.001	18.3	16.6	19.5	.68
Tinnitus, age, y ^b									
18 to 19	111	10.3	8.3	37.9	<.005	7.4	15.2	27.6	.01
≥70	452	15.5	11.3	19.8	<.001	16.2	16.2	19.8	.66

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); HI, hearing impairment; NHANES, National Health and Nutrition Examination Survey; PIR, poverty income ratio.

^a Hearing impairment was defined as any difficulty hearing. Depression categories were defined as follows: none, 9-item Patient Health Questionnaire (PHQ-9) score less than 5; mild, PHQ-9 score of 5 to 9; and moderate to

severe, PHQ-9 score of 10 or higher. Data are given as population-weighted percentages unless otherwise indicated. Denominators vary because of missing data.

^b Data were available only among those aged 18 to 19 years (n = 1186) and 70 years or older (n = 3149).

progressed from excellent to deaf for both men and women. Compared with men, women had lower PTA₅₁₂₄ values but higher PHQ-9 scores in the categories of hearing from excellent to a lot of trouble.

The prevalence of depression among persons with HI based on hearing thresholds using the Global Burden of Disease classification is presented in Table 4. Results from multivariable logistic regression with adjustment for different sets of covariates described in models 1, 2, and 3 indicate that moderate HI (35 dB HL ≤ BE PTA < 50 dB HL) in women aged 70 years or older was associated with increased odds of depression after

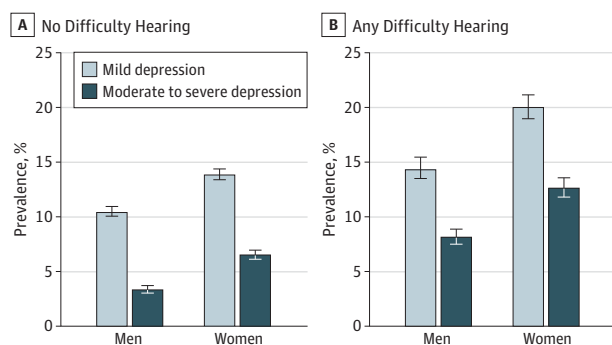
adjusting for covariates, but this was not true in men. Hearing loss in the BE of this degree of severity, PTA₅₁₂₄ of 35 dB HL or higher, is considered disabling hearing loss in the Global Burden of Disease classification.¹⁰

Discussion

In this recent nationally representative survey, 11.4% of US adults with self-reported HI had moderate to severe depression (PHQ-9 score, ≥10) and an additional 19.1% had mild depressive symptoms (PHQ-9 score, 5-9); depression rates were higher in women than in men. The prevalence of depression increased as HI became worse, except among participants who, by self-report, were deaf and least likely to report depression. Among people aged 70 years or older, no significant association between self-reported HI and depression was found; however, a significant association between a hearing threshold-based measure of moderate HI and depression was found in women, but not in men. To our knowledge, this is the first report using the PHQ-9 instrument to assess depressive symptoms in conjunction with questions on self-reported HI and hearing threshold-based measures of HI in a racially diverse, multiethnic national sample.

Hearing impairment, an invisible handicap and one of the most common chronic conditions of later life,¹⁴ can impose a heavy social and economic burden on individuals, families, communities, and countries. Hearing impairment tends to isolate people from friends and family because of a decreased ability to communicate; as such, untreated HI may have consid-

Figure 1. Prevalence of Depression Among US Adults by Sex and Reported Hearing Status, National Health and Nutrition Examination Survey 2005-2010



Limit lines indicate 95% CI.

Table 2. Prevalence and Multivariate ORs (95% CI) for Moderate to Severe Depression by Reported Hearing Status, US Adults, NHANES 2005-2010^a

Characteristic	Sample Size, No.	Prevalence, % (95% CI) ^b	OR (95% CI) ^c		
			Model 1	Model 2	Model 3
All	15 854	7.1 (6.5-7.9)			
Excellent	6174	4.9 (4.2-5.6)	1 [Ref]	1 [Ref]	1 [Ref]
Good hearing	6031	7.1 (6.2-8.2)	1.6 (1.3-1.9) ^d	1.4 (1.1-1.8) ^d	1.4 (1.1-1.8) ^e
A little trouble hearing	2284	11.1 (9.4-13.1)	3.1 (2.5-3.9) ^d	2.6 (2.0-3.4) ^d	1.7 (1.3-2.2) ^d
Moderate trouble hearing	898	12.0 (9.5-15.0)	3.9 (2.9-5.3) ^d	3.7 (2.8-5.0) ^d	2.4 (1.7-3.2) ^d
A lot of trouble hearing	438	12.7 (9.4-17.0)	4.5 (2.9-6.8) ^d	3.2 (2.0-5.1) ^d	1.5 (0.9-2.6)
Deaf	29	5.2 (0.7-31.4)	1.5 (0.2-12.4)	1.5 (0.2-15.3)	0.6 (0.1-2.6)
Male sex	7808	5.2 (4.5-6.0)			
Excellent	2789	3.1 (2.4-3.9)	1 [Ref]	1 [Ref]	1 [Ref]
Good hearing	2928	4.8 (3.9-6.0)	1.7 (1.2-2.4) ^d	1.4 (0.9-2.0)	1.2 (0.8-1.8)
A little trouble hearing	1233	8.5 (6.6-10.8)	3.7 (2.4-5.6) ^d	2.9 (1.8-4.8) ^d	1.8 (1.0-3.1) ^e
Moderate trouble hearing	563	8.9 (5.9-13.2)	4.2 (2.6-6.9) ^d	3.7 (2.1-6.4) ^d	1.9 (1.1-3.2) ^e
A lot of trouble hearing	279	12.7 (8.6-18.5)	6.6 (3.9-11.2) ^d	3.9 (2.0-7.7) ^d	1.7 (0.9-3.2)
Deaf	16	0			
Female sex	8046	9.0 (8.1-9.9)			
Excellent	3385	6.3 (5.4-7.3)	1 [Ref]	1 [Ref]	1 [Ref]
Good hearing	3103	9.3 (8.1-10.7)	1.6 (1.3-1.9) ^d	1.5 (1.2-1.9) ^d	1.5 (1.1-1.9) ^d
A little trouble hearing	1051	14.2 (11.7-17.1)	2.9 (2.3-3.6) ^d	2.5 (1.9-3.2) ^d	1.6 (1.2-2.1) ^d
Moderate trouble hearing	335	17.1 (12.6-22.9)	3.8 (2.6-5.6) ^d	3.8 (2.5-5.6) ^d	2.8 (1.8-4.2) ^d
A lot of trouble hearing	159	12.7 (8.6-18.2)	2.9 (1.8-4.7) ^d	2.6 (1.6-4.2) ^d	1.4 (0.7-2.6)
Deaf	13	10.7 (1.4-50.5)	2.5 (0.3-20.3)	2.6 (0.3-26.0)	0.9 (0.2-4.0)

Abbreviations: NHANES, National Health and Nutrition Examination Survey; OR, odds ratio; Ref, reference.

^a Moderate to severe depression was categorized as a 9-item Patient Health Questionnaire score of 10 or higher. Data are presented for individuals who were not missing data about depression.

^b Population-weighted percentages.

^c Model 1 was controlled for age, sex, and race/ethnicity; model 2 was controlled for age, sex, race/ethnicity, marriage, living alone, educational level, income, and health insurance; and model 3 was controlled for age, sex, race/ethnicity, marriage, living alone, educational level, income, health insurance, body mass index, smoking, binge drinking, self-reported health status, cardiovascular disease, cancer, diabetes mellitus, hypertension, sleep disorder, and trouble seeing.

^d P < .01.

^e P < .05.

Table 3. Multivariate-Adjusted ORs (95% CI) for Moderate to Severe Depression in US Adults Who Reported HI, NHANES 2005-2010^a

Characteristic	Sample Size, No. (N = 3649) ^b	Multivariate-Adjusted OR (95% CI) ^c		
		All	Male	Female
Sex				
Male	2091	1 [Reference]		
Female	1558	2.0 (1.4-2.9) ^d		
Age, y				
18 to 44	782	1 [Reference]	1 [Reference]	1 [Reference]
45 to 69	1593	1.0 (0.7-1.4)	1.5 (0.8-3.0)	0.7 (0.4-1.3)
≥70	1274	0.4 (0.2-0.7) ^d	0.7 (0.3-1.7)	0.3 (0.1-0.6) ^d
Race/ethnicity				
Non-Hispanic white	2260	1 [Reference]	1 [Reference]	1 [Reference]
Non-Hispanic black	480	0.9 (0.6-1.5)	0.8 (0.4-1.6)	1.0 (0.5-1.9)
Hispanic	794	0.9 (0.6-1.2)	0.9 (0.6-1.5)	0.8 (0.5-1.2)
Other	115	0.7 (0.3-1.5)	1.1 (0.4-3.3)	0.4 (0.1-1.1)
Educational level				
<High school	1193	0.9 (0.6-1.3)	0.7 (0.4-1.3)	1.1 (0.7-1.8)
High school graduate	952	1.0 (0.6-1.5)	0.7 (0.4-1.2)	1.3 (0.8-2.3)
>High school	1497	1 [Reference]	1 [Reference]	1 [Reference]
Poverty income ratio				
<1	668	2.3 (1.4-3.8) ^d	2.7 (1.4-5.3) ^d	2.4 (1.2-4.8) ^e
1 to <3	1584	1.3 (0.8-2.2)	1.3 (0.7-2.6)	1.4 (0.7-2.9)
≥3	605	1 [Reference]	1 [Reference]	1 [Reference]
Married/living with partner	2189	0.8 (0.5-1.1)	0.5 (0.3-0.8) ^e	0.9 (0.5-1.7)
Living alone	678	1.3 (0.8-2.2)	1.0 (0.5-2.0)	1.5 (0.8-2.8)
Uninsured	644	1.3 (0.9-1.9)	1.6 (0.9-2.8)	1.1 (0.6-1.9)
BMI				
<25 (Normal/underweight)	1046	1 [Reference]	1 [Reference]	1 [Reference]
25 to <30 (Overweight)	1320	0.9 (0.6-1.4)	0.8 (0.5-1.4)	1.0 (0.6-1.9)
≥30 (Obese)	1173	1.0 (0.7-1.4)	1.1 (0.6-2.1)	1.1 (0.7-1.7)
Smoking				
Current	770	1.5 (1.1-2.2) ^e	1.8 (1.0-3.2) ^e	1.3 (0.8-2.2)
Former	1297	1.1 (0.7-1.6)	1.2 (0.6-2.5)	0.9 (0.5-1.6)
Never	1504	1 [Reference]	1 [Reference]	1 [Reference]
Binge drinker	742	1.5 (1.0-2.2) ^e	1.2 (0.7-1.9)	2.0 (1.1-3.7) ^e
Self-rated health status				
Excellent, very good, or good	2345	1 [Reference]	1 [Reference]	1 [Reference]
Fair	986	3.5 (2.3-5.2) ^d	3.6 (2.1-6.1) ^d	3.4 (2.1-5.7) ^d
Poor	315	11.5 (6.5-20.6) ^d	10.0 (4.9-20.6) ^d	14.0 (5.9-33.6) ^d
Hypertension	1678	0.9 (0.6-1.3)	1.0 (0.6-1.7)	0.7 (0.4-1.2)
Diabetes mellitus	596	0.9 (0.6-1.2)	0.6 (0.3-1.1)	1.2 (0.7-2.0)
Cardiovascular disease history	754	0.8 (0.6-1.3)	1.3 (0.7-2.2)	0.6 (0.3-1.0)
Cancer history	613	1.2 (0.8-1.9)	1.2 (0.5-2.7)	1.3 (0.8-2.1)
Trouble seeing, even with glasses or contact lenses	1122	2.1 (1.7-2.7) ^d	2.7 (1.8-4.3) ^d	1.7 (1.2-2.3) ^d
Sleep disorder	409	2.4 (1.7-3.4) ^d	2.1 (1.2-3.9) ^e	2.8 (1.6-4.9) ^d

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); HI, hearing impairment; NHANES, National Health and Nutrition Examination Survey; OR, odds ratio.

^a Hearing impairment was defined as any difficulty hearing, that is, a little trouble hearing or greater difficulty.

^b Denominators vary because of missing data.

^c The ORs were calculated after controlling for all other variables listed in the table.

^d P < .01.

^e P < .05.

erable negative social, psychological, cognitive, and health effects.³ The impact of HI may be profound, with consequences for social, functional, and psychological well-being as well as the overall health of the individual. A meta-analysis¹⁵ reported that HI is among the most common chronic conditions associated with depression in people aged 65 years or older.

In the present study based on a nationally representative sample, HI was significantly associated with an increased risk of depression in adults of all ages, but was most pronounced in those aged 18 to 69 years. The findings are consistent with the results from a Norwegian population-based study¹⁶ of 50 398 adults aged 20 to 101 years. In a subsequent Dutch study, Nachtegaal et al¹⁷ reported that poorer hearing is significantly asso-

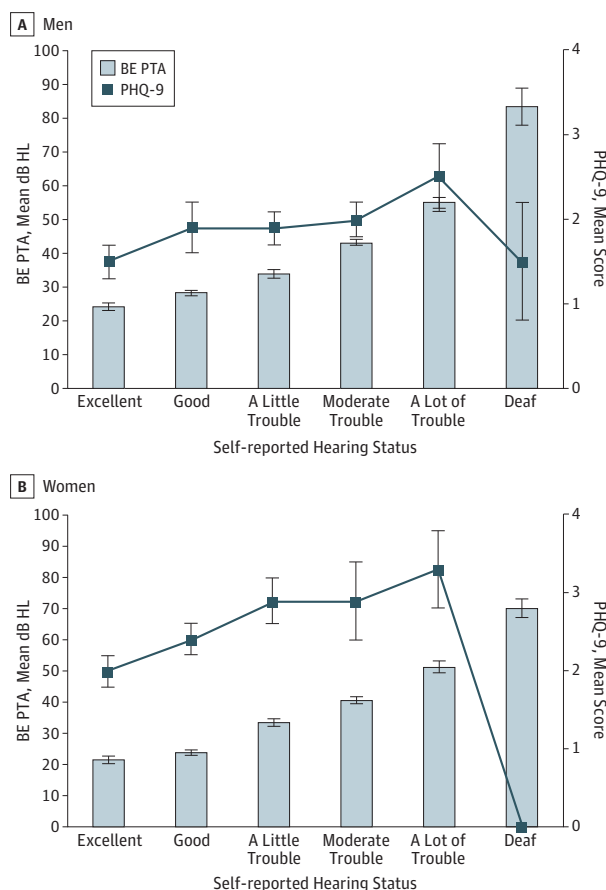
ciated with depression in middle-aged adults (aged 40-49 years). Consistent with previous studies,^{7,18} the Dutch study did not find a significant association among participants aged 50 to 70 years. For older adults (aged >85 years), HI appeared to be protective against depression.⁸ Persons in different age groups may need to cope with psychosocial issues differently because of differences in lifestyle, responsibility, and circumstances.

Our results differ from those of Harada et al,¹⁹ who reported that HI is associated with depression in males but not in females. We found HI to be associated with depression in both men and women, although the prevalence of depression among those with any HI was higher in women (14.7%) than in men (9.0%). In the Blue Mountains Study,²⁰ the investigators also found depressive symptoms to be more common in women than in men with HI. The present study shows that women had a higher prevalence of depression compared with men. On average, men begin to lose their hearing at high frequencies (3-6 k Hz) during middle age, probably resulting from a variety of factors but especially due to noise.²¹ Women, on average, have fairly well-preserved hearing at the higher frequencies, which are critical for understanding speech in noisy environments, until after reaching age 65 or 70 years, when they experience a steady decline.^{22,23}

Additionally, we found that self-reported HI was significantly associated with increased odds of depression in each of our 3 major racial/ethnic groups: Hispanics, non-Hispanic blacks, and non-Hispanic whites (Figure 3). After controlling for covariates, no significant differences were observed in terms of race/ethnicity (Table 3). Unlike the present study, the investigation of Lee and Gomez-Marín¹⁸ evaluated associations between depression and HI defined by an audiometric threshold measure in targeted samples of US Hispanics living in geographic clusters (ie, Cuban-American, Mexican-American, and Puerto Rican adults aged 20-74 years) based on the Hispanic Health and Nutrition Examination Survey, 1984-1986. They concluded that the HI sample of Hispanics overall was not at increased risk of major depressive disorder despite the finding that the odds of HI were significantly greater among Puerto Ricans reporting more depressive symptoms.

We did not find a significant relationship between depression and self-reported HI among men or women aged 70 years or older. Rather, we found a significant association between depression and a threshold-based measure of moderate HI, defined as BE PTA₅₁₂₄ between 35 and 50 dB HL, among women. These apparently inconsistent results may reflect the tendency of people in different age groups to assess their HI differently. For example, older people may be less likely to self-report HI activity limitations compared with younger people.²⁴ Lee et al²⁵ also found an independent association between depression and measured hearing loss in older people, but not between depression and self-reported hearing loss. Self-reported HI may not adequately substitute for threshold-based measures of HI among older people. Alternatively, Andersson and Green²⁶ reported that anxiety scores did not correlate with pure-tone thresholds for hearing; however, anxiety did correlate with self-reported hearing difficulty in elderly patients with HI. Anxiety is important, but it is possible that signs of depression are strongly related to self-perceived HI.

Figure 2. Better Ear Pure-Tone Average (BE PTA) and 9-Item Patient Health Questionnaire (PHQ-9) Mean Score by Reported Hearing Status, National Health and Nutrition Examination Survey 2005-2006 and 2009-2010



Air conduction, BE PTA of thresholds at 0.5, 1, 2, and 4 kHz, measured in decibels hearing level (HL) scale, for men (A) and women (B) for US adults aged 70 years or older. Limit lines indicate 95% CI.

In the present study, the prevalence of depression increased as HI became greater, ie, from excellent hearing to a lot of trouble, but decreased among those who self-reported as being deaf. Kvam et al²⁷ reported that people who are deaf have significantly more symptoms of mental health problems compared with those who are not deaf. Nevertheless, our findings are consistent with those of previous studies⁸ that did not find a significant association between depression and self-reported deafness or a threshold-based measure of deafness. In the Blue Mountains Study,²⁸ depression symptoms were significantly higher in participants aged 60 years or older with mild HI, but not in those with moderate to severe hearing loss.

The strongest association was for participants with moderate trouble hearing. Among respondents reporting at least some hearing loss, the categories with weakest association (ie, lowest ORs in model 3) (Table 2) with depression were the two with the most trouble hearing (ie, a lot of trouble or deaf). One reason for this result may be that people with severe to profound HI have had a different experience in their exposure and

Table 4. Multivariate ORs (95% CI) for Moderate to Severe Depression in US Adults Aged 70 Years or Older, NHANES 2005-2006 and 2009-2010

GBD Hearing Classification, dB HL	Sample No.	Depression, %	Mean PHQ-9 Score	OR (95% CI) ^a			
				Crude	Model 1	Model 2	Model 3
All							
BE PTA <20	299	4.7	2.2	1 [Ref]	1 [Ref]	1 [Ref]	1 [Ref]
20 ≤ BE PTA < 35	614	3.9	2.2	0.9 (0.6-1.4)	0.9 (0.6-1.5)	0.9 (0.6-1.5)	1.4 (0.6-2.9)
35 ≤ BE PTA < 50	412	5.8	2.6	1.3 (0.8-2.4)	1.5 (0.8-2.8)	1.5 (0.8-2.8)	2.1 (0.8-5.4)
BE PTA ≥50	210	2.8	1.9	0.6 (0.2-1.5)	0.8 (0.3-2.0)	0.7 (0.3-1.8)	1.1 (0.3-3.9)
Men							
BE PTA <20	109	5.5	1.7	1 [Ref]	1 [Ref]	1 [Ref]	1 [Ref]
20 ≤ BE PTA < 35	295	4.0	1.8	1.0 (0.5-1.9)	1.0 (0.5-2.0)	1.1 (0.5-2.4)	2.0 (0.5-8.1)
35 ≤ BE PTA < 50	236	2.2	2.3	0.5 (0.2-1.1)	0.5 (0.2-1.2)	0.5 (0.2-1.2)	0.5 (0.1-2.8)
BE PTA ≥50	149	2.8	1.7	0.6 (0.2-1.8)	0.7 (0.2-2.1)	0.6 (0.2-1.8)	1.0 (0.1-9.3)
Women							
BE PTA <20	190	4.4	2.4	1 [Ref]	1 [Ref]	1 [Ref]	1 [Ref]
20 ≤ BE PTA < 35	319	3.8	2.5	0.8 (0.4-1.7)	0.8 (0.4-1.7)	0.8 (0.4-1.6)	1.5 (0.6-3.5)
35 ≤ BE PTA < 50	176	9.3	3.0	2.2 (1.1-4.2) ^b	2.5 (1.2-5.1) ^b	2.6 (1.3-5.3) ^b	3.9 (1.3-11.3) ^b
BE PTA ≥50	61	2.9	2.4	0.5 (0.1-3.0)	0.8 (0.1-3.9)	0.7 (0.1-3.6)	0.9 (0.1-5.8)

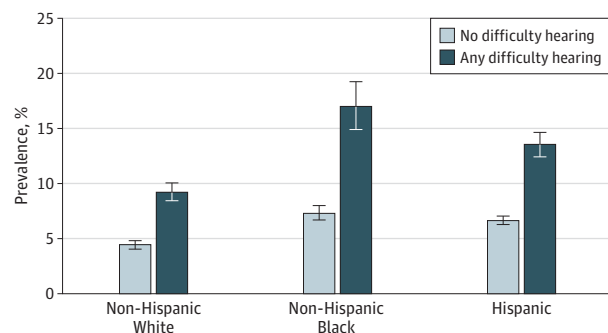
Abbreviations: BE, better ear; GBD, Global Burden of Disease; HL, hearing level; NHANES, National Health and Nutrition Examination Survey; OR, odds ratio; PHQ-9, 9-item Patient Health Questionnaire; PTA, pure-tone average of thresholds at frequency 0.5, 1, 2, and 4 KHz; Ref, reference.

^a Model 1 was controlled for age, sex, and race/ethnicity; model 2 was controlled for age, sex, race/ethnicity, marriage, living alone, educational level, income,

and health insurance; and model 3 was controlled for age, sex, race/ethnicity, marriage, living alone, educational level, income, health insurance, body mass index, smoking, binge drinking, self-reported health, cardiovascular disease, cancer, diabetes mellitus, hypertension, sleep disorder, hearing aids, tinnitus, and trouble seeing.

^b P < .05.

Figure 3. Prevalence of Moderate to Severe Depression Among US Adults by Race/Ethnicity and Reported Hearing Status Based on the National Health and Nutrition Examination Survey 2005-2006 and 2009-2010



Limit lines indicate 95% CI.

access to health care interventions for hearing. They are much more likely to have been identified and encouraged to try rehabilitation (eg, hearing aids, alternative listening devices, and cochlear implants). Thus, their lower prevalence of depression may be because more of them have had access to hearing health care services and thereby have obtained more help and earlier interventions compared with those with mild to moderate HI.²⁹

Reduction in depressive symptoms and an improved quality of life were reported in previous studies^{4,8,20} of older adults using hearing aids. No information was collected on the use of hearing aids among persons aged 20 to 69 years in the present study. Data were available on the use

of hearing aids among individuals aged 70 years or older, but we did not find a significant association between non-use of hearing aids and depression among the older adults. The National Council on the Aging³⁰ found that people with HI who did not use hearing aids more often stated that they had sadness, depression, worry, anxiety, paranoia, less social activity, emotional turmoil, and insecurity. In that study, both those with HI (56%) and their family members (66%) reported benefits from hearing aid use in terms of better relationships at home, more confidence, and better relationships with others. However, only 36% of people who had hearing aids and 39% of family members of hearing aid users stated there had been improvement of mental health.

Although data on the use of hearing aids were not available for all participants, as noted in Table 1, we attempted to investigate the effect of hearing aid use on depression. The prevalence of depression among participants who reported use of a hearing aid (9.1%) was lower than that among persons who did not report use of a hearing aid (11.7%). However, after controlling for potential confounders, no significant difference was found between the 2 groups (data not shown). Our result is consistent with the report by Nachtegaal et al.¹⁷ However, the NHANES question was phrased as, “Have you ever worn a hearing aid?” We do not know whether respondents answering in the affirmative used a hearing aid during the time interval for which they were asked about depressive symptoms. We concluded that it was not possible to assess whether hearing aid use affects depression based on our analysis of NHANES 2005-2010 data.

Although this study has several strengths, including a nationally representative adult sample and an effective detection of depressive symptoms using a short, easy-to-

administer, well-validated instrument, there are some limitations. Audiometric threshold measurements were available only for adults aged 70 years or older, thus precluding our assessment of the association between depression and hearing threshold-based measures of HI in young or middle-aged adults. In the audiometric sample of participants aged 70 years or older, 11% partially completed the examination and 8% did not have an audiometric examination. Among those who did not have or complete the audiometric examination, “time constraint” was listed most frequently as the reason because the mobile examination center evaluations in NHANES overall include many other tests, all of which need to be completed in a period of 2.5 to 3.0 hours. Also, because of the limited sample size of NHANES (approximately 3000 adults per year aged ≥18 years), detailed results are not available for many smaller racial/ethnic groups represented in the United States. Finally, be-

cause of the cross-sectional design of the survey, we cannot determine whether HI predates depression or to what extent self-reported depression may affect self-perceived HI.

Conclusions

We found a strong association between HI and depression among US adults of all ages, particularly women and those younger than 70 years. The prevalence of moderate to severe depression was higher among US adults aged 18 years or older with self-reported HI (11.4%) compared with those without HI (5.9%). Health professionals may be better able to improve the quality of life among people with HI by recognizing the signs and symptoms of depression and referring patients for mental health services.

ARTICLE INFORMATION

Submitted for Publication: July 8, 2013; final revision received January 3, 2014; accepted January 15, 2014.

Published Online: March 6, 2014.
doi:10.1001/jamaoto.2014.42.

Author Contributions: Dr Li had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Li, Zhang, Hoffman, Cotch.

Acquisition, analysis, or interpretation of data: Li, Hoffman, Themann.

Analysis and interpretation of data: All authors.

Drafting of the manuscript: Li, Hoffman, Themann.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Li, Zhang, Hoffman.

Obtained funding: Hoffman.

Administrative, technical, or material support: Zhang, Hoffman, Cotch, Themann, Wilson.

Study supervision: Hoffman.

Conflict of Interest Disclosures: None reported.

Funding/Support: The National Health and Nutrition Examination Survey (NHANES) hearing questionnaire and examination component was supported with research contract funds via Interagency Agreement between the National Institute on Deafness and Other Communication Disorders (NIDCD)/National Institutes of Health and the National Center for Health Statistics (NCHS)/Centers for Disease Control and Prevention (CDC). The NIDCD also provided funding via Interagency Agreement to the National Institute for Occupational Safety and Health/CDC for calibration and maintenance of the audiometric equipment, training and monitoring the performance of health technicians conducting the hearing examinations, and jointly editing the preliminary data files.

Role of the Sponsor: The NCHS staff contributed to the design and conduct of NHANES overall but were not involved in the analysis or interpretation of results in this manuscript; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Disclaimer: The findings and conclusions in this report are those of the authors and do not

necessarily represent the official position of their respective federal agencies.

Previous Presentation: Preliminary findings from this report were presented orally at the annual meeting of the American Auditory Society; March 9, 2013; Scottsdale, Arizona.

Additional Contributions: We thank the NHANES participants, without whom this study would not have been possible, and the professional staff of NHANES and Westat Inc who conducted the study. May Chiu, BS, and Katalin Losonczy, MA, members of the Epidemiology and Statistics Program at the NIDCD, provided technical support. No financial compensation was given for these services.

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