

## Original Article

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# Age and sex differences in hearing loss association with depressive symptoms: analyses of NHANES 2011–2012

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## Abstract

**Background.** Depression is a common and significant health problem. Hearing loss is the third most common chronic physical condition in the USA and might be a factor in depression. To determine whether hearing loss is associated with depressive symptoms in US adults ages 20–69 years.

**Methods.** National Health and Nutrition Examination Survey (NHANES) data (2011–2012) were used to assess the potential relationship between hearing loss and depression, in adults (20–69 years) who answered the Patient Health Questionnaire (PHQ-9) depression screening module, with pure tone audiometry measurements, and complete information on the co-variables data ( $n = 3316$ ). The degree of speech-frequency hearing loss (SFHL) and high-frequency hearing loss (HFHL) were defined as slight/mild hearing loss  $\geq 26$ –40 dB; moderate/worse hearing loss  $\geq 41$  dB by pure tone audiometry examination.

**Results.** Moderate/worse HFHL was statistically significantly associated with depressive symptoms (OR 1.54, 95% CL 1.04–2.27) when the analyses were conducted among all participants. Further stratification by gender and age groups found that moderate/worse HFHL (OR 3.85, 95% CL 1.39–10.65) and moderate/worse SFHL (OR 5.75, 95% CL 1.46–22.71) were associated with depressive symptoms in women ages 52–69 years.

**Conclusions.** Moderate/worse speech frequency and HFHL are associated with depression in women ages 52–69 years, independent of other risk factors. Hearing screenings are likely to reduce delays in diagnosis and provide early opportunities for noise prevention counseling and access to hearing aids. Health professionals should be aware of depressive signs and symptoms in patients with hearing loss.

## Introduction

Depression is a common and significant health problem that negatively affects the quality of life of patients and their family members (Kessler and Bromet, 2013). A 2009–2012 report from the National Health and Nutrition Examination Survey (NHANES) found that 7.6% of Americans aged  $\geq 12$  years had moderate or severe depression (Pratt and Brody, 2014). Depression is among the leading causes of decreased work productivity (Stewart *et al.*, 2003). In fact, a Gallup survey conducted during 2011–2012 estimated an annual loss of \$23 billion in lost productivity as a result of workers suffering from depression (Witters *et al.*, 2013).

Hearing loss is the third most common self-reported chronic physical condition in the USA (Blackwell *et al.*, 2014). The estimated prevalence of hearing loss in US adults ages 20–69 years in 2012 was 31.1% for high-frequency hearing loss (HFHL) and 14.1% for speech-frequency hearing loss (SFHL) (Hoffman *et al.*, 2017). The diagnosis of hearing loss often is associated with poor quality of life, depression, and social isolation and its management starts after the occurrence of these negative consequences.

A recent study reported that among the risk factors for dementia, 35% of them were potentially modifiable: hearing loss was the main potentially modifiable factor (9.1%) with depression accounting for an additional 4% (Livingston *et al.*, 2017).

Several studies reported a significant positive association between hearing impairment measured by self-reported hearing impairment or pure tone audiometry and depression among older persons (Blay *et al.*, 2007; Huang *et al.*, 2010; Morikawa *et al.*, 2013), although this is not a universal finding (Chou and Chi 2004; Bergdahl *et al.*, 2005). NHANES cycle 2005–2010 measured pure tone audiometry only in a subset of the population: adolescents (12–19 years old) and in adults 70 years and older, whereas self-reported hearing problem was assessed in all age group. Using data from NHANES 2005–2010, Li *et al.* (2014) reported

a significant positive association between moderate hearing loss, defined by pure tone average, and depression in females aged  $\geq 70$  years. The researchers found no significant association between self-reported hearing impairment and depression in participants of both sexes aged  $\geq 70$  years.

NHANES wave 2011–2012 measured pure tone audiometry only in a subpopulation of adults aged 20–69 years. This cycle allowed us to evaluate the potential association between hearing loss (defined by pure tone audiometry) and depression among adults aged 20–69 years. This is the first study reporting the association of hearing loss based on thresholds of pure tone audiometry with depression in US adult (ages 20–69 years) from the most recently available NHANES data set.

## Methods

### Study population

NHANES is a cross-sectional, nationally representative survey of the non-institutionalized civilian population in the USA conducted annually by the National Center for Health Statistics (NCHS) (Johnson *et al.*, 2013). The survey uses a multistage stratified probability sample based on selected counties, blocks, households, and persons within households. NCHS-trained professionals conducted interviews in participants' homes; extensive physical examinations, including blood and urine collection, were conducted at mobile exam centers. For our analyses, we included adult participants (ages  $\geq 20$  years) of NHANES 2011–2012 who answered the 9-question Patient Health Questionnaire (PHQ-9) depression screening module and had complete audiometric results. Participants with missing co-variables included in the multivariable-adjusted models were excluded, for a final sample size of 3316 participants.

### Outcome measure

The outcome was the presence or absence of depressive symptoms as determined by a participant's score on the PHQ-9, a depression screening module of the Primary Care Evaluation of Mental Disorders Questionnaire (PRIME-MD). The Depression Screener questions were asked by trained interviewers using the Computer-Assisted Personal Interviewing (CAPI) system as part of the Mobile Examination Center (MEC) private interview in Spanish or English. No proxies or interpreters were permitted for these questions. PHQ-9 contains nine questions that are used as a depression screener in NHANES 2011–2012. The questions are based on the 9 signs and symptoms for depression listed in the *Diagnostic and Statistical Manual of Mental Disorders, 4th edition* (DSM-IV) (APA, 1994). Responses to these nine questions were scored on a four-point Likert scale of 0–3, indicating that the participant experienced the symptom 'not at all,' 'on several days,' 'on more than half the days,' or 'nearly every day' during the past 2 weeks, for a total score ranging from 0 to 27. A prior validation study found that a score  $\geq 10$  achieved 88% sensitivity and 88% specificity for major depression (Kroenke *et al.*, 2001). Therefore, participants who scored  $\geq 10$  were defined as having current depressive symptoms.

### Audiometric measurements and definition of hearing loss

National Institute for Occupational Safety and Health trained examiners followed a standardized NCHS protocol to obtain audiometric measurements in specially designed and equipped mobile

examination center sound-treated rooms. Audiometers were calibrated according to NCHS specifications. Air conduction thresholds were measured for each ear at 0.5, 1, 2, 3, 4, 6, and 8 kHz across an intensity range of  $-10$  to 120 dB hearing level. Participant's test-retest response reliability was measured at 1 kHz frequency in each ear and the average was used in the analyses. Results were rejected if the test-retest thresholds differed by  $\geq 10$  dB. Further details of the measurement techniques are available on the NCHS website ([https://www.ncdc.gov/nchs/data/nhanes/2011-2012/manuals/audiometry\\_procedures\\_manual.pdf](https://www.ncdc.gov/nchs/data/nhanes/2011-2012/manuals/audiometry_procedures_manual.pdf)). Four audiometric frequencies (0.5, 1, 2, and 4 kHz) were averaged to define a SFHL and three audiometric frequencies (3, 4, and 6 kHz) were averaged to define a HFHL. Degrees of hearing impairment for SFHL and HFHL were categorized according to the following World Health Organization classifications: normal  $\leq 25$  dB, slight/mild = 26–40 dB, and moderate/worse  $\geq 41$  dB (see [http://www.who.int/pbd/deafness/hearing\\_impairment\\_grades/en/](http://www.who.int/pbd/deafness/hearing_impairment_grades/en/)).

### Covariates

The *a priori* covariates selected for inclusion in the models are associated with hearing impairment or depressive symptoms. These covariates include age (categorized in weighted tertiles), sex, race/ethnicity, education, poverty income ratio, marital status, obesity, alcohol consumption, cigarette smoking, diabetes, vision impairment, and chronic disease (cardiovascular disease or cancer).

We obtained information about age (years), sex, race/ethnicity, and education from the household interview. Race/ethnicity was categorized as non-Hispanic white, non-Hispanic black, Hispanic, and other. Poverty income ratio is a measure of socioeconomic status and represents the calculated ratio of household income to the poverty threshold after accounting for inflation and family size. Marital status was categorized as 'married or living with a partner' and 'single, or divorced, widowed.'

Body mass index (BMI) was calculated as weight divided by height squared ( $\text{kg}/\text{m}^2$ ). The adult population was categorized as either normal/underweight ( $\text{BMI} < 25 \text{ kg}/\text{m}^2$ ) or overweight/obese ( $\text{BMI} \geq 25 \text{ kg}/\text{m}^2$ ).

Alcohol consumption (amount consumed per week) and smoking information were obtained from the associated questionnaire. Smoking status was defined as never smoker (smoked  $< 100$  cigarettes ever), former smoker (not currently smoking, but has smoked  $\geq 100$  cigarettes ever), and current smoker ( $\geq 100$  cigarettes in lifetime and currently smoking every day or some days).

Diabetes was defined as glycated hemoglobin (A1C)  $\geq 6.5\%$ , or self-reported current use of insulin or diabetes medication. Cardiovascular disease was defined as having a positive response to any of the following statements: 'ever told you had congestive heart failure,' 'ever told you had coronary heart disease,' 'ever told you had angina/angina pectoris,' 'ever told you had a heart attack,' or 'ever told you had a stroke.' Cancer was defined as having a positive response to 'ever told you had cancer or malignancy.' Vision impairment was defined as self-reported 'trouble seeing even with glass/contacts.'

### Statistical methods

We used mobile examination center sample weights for analyses to account for the complex sampling design and non-response in NHANES. We used logistic regression to calculate adjusted odds ratios for having depressive symptoms. Sex and age group analyses

were stratified (ages 20–35, 36–51, and 52–69 years); age group stratification was based on the weighted tertiles of the study population. SAS 9.3 software (SAS Institute, Cary, NC) was used for all statistical analyses and SAS-Callable SUDAAN 10 (Research Triangle Institute, Research Triangle Park, NC) was used to account for the NHANES complex sample design. *p* values from Satterthwaite statistics for regression analyses were presented at the significance level <0.05.

## Results

Both audiometric and depression data were available for 3316 of the NHANES 2011–2012 adult participants ages 20–69 years. **Table 1** presents the weighted characteristics of the study population. The geometric mean age of all participants was approximately 41 years. Among the participants, 68.2% were non-Hispanic whites, 49.4% were females, and 16.8% were living in a family with income at or below poverty. The weighted prevalence of slight/mild and moderate/worse SFHL grades were 10.4% and 3.9%, respectively. Men had a statistically significant higher prevalence of SFHL than did women for slight/mild (14.3% *v.* 6.3%,  $\chi^2$  *p* = 0.001) and moderate/worse (5.1% *v.* 2.7%,  $\chi^2$  *p* = 0.001). The weighted prevalence of slight/mild and moderate/worse HFHL was 14.7% and 16.1%, respectively. Men had a statistically significant higher prevalence of HFHL than did women for slight/mild (16.7% *v.* 12.6%,  $\chi^2$  *p* < 0.001) and moderate/worse (25.5% *v.* 6.6%,  $\chi^2$  *p* < 0.001). Among the adults in this subpopulation, 8% were categorized as having depressive symptoms (PHQ-9  $\geq$  10), with a statistically significant higher prevalence in women (10.2%) than in men (5.8%) (**Table 1**).

Multivariate logistic regression analyses found that among all adults, moderate/worse HFHL ( $\geq$ 41 dB) was statistically significantly associated with depressive symptoms (OR 1.54, 95% CL 1.04–2.27) (**Table 2**). After stratification by sex, this statistically significant association was found in adult females (OR 2.39, 95% CL 1.06–5.39), but not in males (OR 1.23, 95% CL 0.63–2.42) (**Table 2**). Slight/mild HFHL was not associated with depression. Among all adults, SFHL was not associated with depressive symptoms (slight/mild OR 1.08, 95% CL 0.59–2.00; moderate/worse OR 1.88, 95% CL 0.92–3.86) (**Table 2**). After stratification by sex, a statistically significant association was found in adult female participants between moderate/worse SFHL ( $\geq$ 41 dB) and depression (OR 3.00, 95% CL 1.20–9.31) (**Table 2**).

Further stratification by age group showed that moderate/worse HFHL and moderate/worse SFHL were associated with depression in women  $\geq$ 52 years (**Table 3**). Moreover, in men, we found no associations between hearing loss and depression in the age groups 36–51 and 52–69 years (**Table 3**).

## Discussion

Our study of a US national population-based sample of adults aged  $\geq$ 20 years found that moderate/worse SFHL and HFHL ( $\geq$ 41 dB) are a significant predictor of depressive symptoms and that the person's sex is a potential moderator for these associations. When further stratified by age group, hearing loss was positively associated with depression only in female aged 52–69 years. Similarly, Li *et al.* (2014) analyzed NHANES 2005–2010 data and found a positive association between moderate SFHL (range 35–49 dB) and depression (PHQ-9  $\geq$ 10) in females, but not in males aged  $\geq$ 70 years. Data from the Blue Mountains Eye Study, also showed sex differences in the association between

hearing loss and depression, with mild SFHL (>25–40 dB hearing loss) positively associated with depressive symptoms in women (OR 1.95, 95% CI 1.15–3.31), but not in men (Gopinath *et al.*, 2009). In contrast, Shin and Hwang (2017), using data from the Korean National Health and Nutrition Examination Survey (KNANES) 2010–2013 on 18 563 participants aged  $\geq$ 20 years, reported a positive association between hearing loss (speech frequency pure tone average  $\geq$ 25 dB) and depression only in males aged  $\geq$ 60 years. Harada *et al.* (2008) also found that hearing loss (defined as failing to hear a 30 dB signal at 1 kHz bilaterally) was positively associated with depression in Japanese males aged  $\geq$ 65 years, but not in females.

Several studies address the relationship between hearing and depression based on perceived self-reported hearing impairment, rather than thresholds of pure tone audiometry, with inconsistent results. In a cross-sectional study of 3796 Japanese adults aged 65 and older, Morikawa *et al.* (2013) reported that self-reported hearing or visual impairment were independent risk factors for depressive symptoms. Blay *et al.* (2007) reported associations of hearing impairment (OR 1.26, 95% CI 1.12–1.42) and visual impairment (OR 1.32, 95% CI 1.16–1.50) with depression among Brazilian adults aged 60 years and older (*n* = 7040). Conversely, Lee *et al.* (2010) reported an association of hearing loss measured by audiometry, but not self-reported hearing impairment, with depressive symptoms in a Chinese population aged 60 years and older. Li *et al.* (2014) found that self-reported hearing impairment was significantly associated with an increased risk of depression in adults aged 18–69 years, but not in those 70 years and older, which audiometric hearing loss was associated with depression in older female.

Hearing impairment was also positively associated with depression in longitudinal studies. In the National Longitudinal Study on Hearing conducted in the Netherlands, reduced hearing ability was significantly associated with higher levels of depression in adults aged 40–49 years (Nachtegaal *et al.*, 2009). Saito *et al.* (2010) studied 580 adults aged  $\geq$ 65 years (261 men and 319 women) without depressive symptoms at the baseline. At the 3 years follow-up, they found that hearing impairment was associated with an elevated risk for depressive symptoms (OR 2.45, 95% CI 1.26–4.77).

Our results demonstrate that moderate/worse hearing loss is associated with depressive symptoms in women ages 52–69 years in the USA, independent of important covariates. Hearing loss has been shown to negatively affect the person's quality of life. For instance, hearing loss alters the ability of communicate with others, thereby affecting social relationships (Kamil and Lin, 2015), as well as employment opportunities (Hogan *et al.*, 2009). Our study found that women compared with men were more likely to experience depression related to hearing loss, one reason for this finding may be that women form deeper social relationships based on communicating feelings (Vigil, 2007), whereas men form social relationships based on shared activities (Spain, 1992) which may not be affected by hearing loss. Additionally, hearing loss has a profound effect on self-esteem and physical functioning, contributing to loss of independence and diminished quality of life (Strawbridge *et al.*, 2000; Dalton *et al.*, 2003; Chia *et al.*, 2007; Hawkins *et al.*, 2012; Chen *et al.*, 2014). Hearing impairment also negatively affects cognitive performance (Lin, 2011; Lin *et al.*, 2011, 2013), increases mortality risk (Yamada *et al.*, 2011) and has been associated with Alzheimer disease (Gates *et al.*, 2011) and particularly with dementia (Davies *et al.*, 2017; Golub *et al.*, 2017).

**Table 1.** Sample size and weighted characteristics of the National Health and Nutrition Examination Survey (NHANES) 2011–2012 adult participants

Characteristics	All	Male	Female
Participants	3316	1706 (50.6%; 0.94)	1610 (49.4%; 0.94)
Age (years), GM (SE)	41.10 (0.85)	40.87 (0.86)	41.34 (0.90)
BMI (kg/m <sup>2</sup> ), GM (SE)	28.23 (0.20)	28.07 (0.24)	28.39 (0.21)
Waist circumference (cm), GM (SE)	97.61 (0.60)	99.73 (0.75)	95.45 (0.59)
Ratio of family income-to-poverty	2.32 (0.13)	2.34 (0.14)	2.30 (0.12)
No depression, PHQ-9 ≤9	92.0 (0.88)	94.2 (0.92)	89.8 (1.19)
Depression, PHQ-9 ≥10% (SE)	8.0 (0.88)	5.8 (0.92)	10.2 (1.19)
Moderate and moderate severe depression, PHQ-9 = 10–19	7.1 (0.81)	4.9 (0.90)	9.3 (1.13)
Severe depression, PHQ-9 ≤20	0.9 (0.17)	0.9 (0.28)	0.9 (0.27)
HFHL ≤25 dB	69.2 (1.70)	57.8 (3.00)	80.8 (1.22)
HFHL ≥26–40 dB, % (SE)	14.7 (0.95)	16.7 (1.78)	12.6 (0.95)
HFHL ≥41 dB, % (SE)	16.1 (1.23)	25.5 (2.14)	6.6 (0.80)
SFHL ≤25 dB	85.7 (1.28)	80.6 (2.10)	90.9(1.14)
SFHL ≥26–40 dB, % (SE)	10.4 (0.99)	14.3 (1.87)	6.3 (0.84)
SFHL ≥41 dB, % (SE)	3.9 (0.55)	5.1 (0.79)	2.7 (0.54)
Poverty income ratio ≤1	16.8 (1.84)	16.4 (1.99)	17.2 (1.83)
Poverty income ratio >1	83.2 (1.84)	83.6 (1.99)	82.8 (1.83)
Diabetes, Yes, % (SE)	9.0 (0.78)	9.4 (1.23)	8.5 (0.81)
Cardio, Yes, % (SE)	5.1 (0.27)	5.6 (0.52)	4.5 (0.41)
Cardiovascular disease or cancer, Yes, % (SE)	11.4 (0.61)	10.7 (1.00)	12.0 (1.20)
<b>Marital status</b>			
Married or living with partner	61.1 (2.38)	62.0 (2.74)	60.2 (2.44)
Single, divorced, or widow	38.9 (2.38)	38.0 (2.74)	39.8 (2.44)
<b>Body weight status</b>			
BMI <25	30.2 (1.87)	28.5 (1.77)	31.9 (2.17)
BMI ≥25	69.8 (1.87)	71.5 (1.77)	68.1 (2.17)
<b>Smoking status</b>			
Current smoker, % (SE)	21.3 (1.30)	25.3 (2.07)	17.3 (1.40)
Former smoker, % (SE)	22.4 (1.54)	24.1 (1.64)	20.7 (2.36)
Never smoked, % (SE)	56.2 (1.46)	50.7 (1.90)	62.0 (2.08)
<b>Alcohol consumption</b>			
No alcohol, % (SE)	16.5 (1.01)	9.1 (0.83)	24.0 (1.72)
1–5 Drinks per week, % (SE)	74.0 (1.33)	75.6 (2.10)	72.4 (1.52)
>5 Drinks per week, % (SE)	9.5 (1.22)	15.3 (1.81)	3.5 (0.69)
<b>Education level</b>			
Less than high school, % (SE)	13.0 (1.78)	14.4 (1.87)	11.4 (1.78)
Completed high school, % (SE)	19.3 (1.61)	22.0 (2.26)	16.6 (1.56)
More than high school, % (SE)	67.7 (3.02)	63.5 (3.43)	72.0 (2.95)
<b>Race/ethnicity</b>			
Non-Hispanic white, % (SE)	68.2 (3.85)	68.4 (3.94)	68.0 (3.87)
Non-Hispanic black, % (SE)	11.0 (2.21)	9.7 (2.08)	12.4 (2.40)
Hispanic, % (SE)	13.5 (2.45)	14.3 (2.68)	12.6 (2.29)
Other, % (SE)	7.3 (1.11)	7.5 (1.14)	7.0 (1.20)
Vision impairment, No, % (SE)	86.2 (1.13)	87.3 (1.43)	85.0 (1.33)
Vision impairment, Yes, % (SE)	13.8 (1.13)	12.7 (1.43)	15.0 (1.33)

GM, geometric mean; BMI, body mass index; SE, standard estimate; PHQ-9, Patient Health Questionnaire; HFHL, high-frequency hearing loss; SFHL, speech frequency hearing loss.

**Table 2.** Multivariate logistic regression<sup>a</sup> OR (95% CL) of having depression in the National Health and Nutrition Examination Survey (NHANES) 2011–2012 adult participants ages 20–69 years

	High frequency			Speech frequency		
	All	Male	Female	All	Male	Female
Sex						
Men	1.00			1.00		
Women	2.25 (1.45–3.48)			2.11 (1.33–3.34)		
Hearing loss ≤25 dB	1.00	1.00	1.00	1.00	1.00	1.00
Hearing loss ≥26–40 dB	1.47 (0.98–2.20)	1.83 (0.86–3.89)	1.32 (0.80–2.18)	1.08 (0.59–2.00)	0.69 (0.27–1.78)	1.66 (0.77–3.61)
Hearing loss ≥41 dB	1.54 (1.04–2.27)	1.23 (0.63–2.42)	2.39 (1.06–5.39)	1.88 (0.92–3.86)	1.05 (0.42–2.59)	3.34 (1.20–9.31)
<i>p</i> value trend	0.04	0.23	0.09	0.20	0.72	<0.05

<sup>a</sup>Adjusted for age, race/ethnicity, body weight status, smoking, education, alcohol consumption, poverty income ratio, diabetes, marital status, cardiovascular disease, cancer, vision impairment, and sex (except when stratified by sexes).

**Table 3.** Multivariate logistic regression<sup>a</sup> OR (95% CL) of having depression in the National Health and Nutrition Examination Survey (NHANES) 2011–2012 participants, by age group and sex

	High frequency			Speech frequency		
	20–35 Years	36–51 Years	52–69 Years	20–35 Years	36–51 Years	52–69 Years
All participants						
Men	1.0	1.0	1.0	1.0	1.0	1.0
Women	1.57 (0.90–2.72)	1.99 (1.21–3.29)	3.97 (1.53–10.32)	1.57 (0.89–2.75)	1.92 (1.23–3.00)	3.01 (1.13–8.06)
Hearing loss ≤25 dB control	1.0	1.0	1.0	1.0	1.0	1.0
Hearing loss ≥26–40 dB cases	1.33 (0.54–3.25)	1.33 (0.73–2.45)	1.91 (0.99–3.70)	2.20 (0.47–10.26)	1.43 (0.55–3.70)	1.10 (0.37–3.27)
Hearing loss ≥41 dB cases	0.23 (0.02–2.33)	1.32 (0.43–4.00)	2.96 (1.31–6.69)	0.41 (0.03–5.28)	0.89 (0.18–4.35)	2.69 (0.81–8.94)
<i>P</i> trend	0.18	0.61	0.01	0.30	0.73	0.22
Male						
Hearing loss ≤25 dB	1.0	1.0	1.0	1.0	1.0	1.0
Hearing loss ≥26–40 dB	0.81 (0.19–3.40)	3.24 (0.73–14.42)	2.98 (0.46–19.21)	1.25 (0.11–13.66)	0.45 (0.08–2.64)	0.57 (0.22–1.43)
Hearing loss ≥41 dB	0.28 (0.03–2.74)	1.12 (0.29–4.34)	2.25 (0.56–9.06)	0.67 (0.04–11.02)	2.30 (0.81–6.54)	0.82 (0.15–4.40)
<i>P</i> trend	0.50	0.18	0.36	0.93	0.13	0.39
Female						
Hearing loss ≤25 dB	1.0	1.0	1.0	1.0	1.0	1.0
Hearing loss ≥26–40 dB	4.61 (0.63–33.60)	0.62 (0.24–1.62)	1.78 (0.92–3.42)	4.41 (0.78–24.90)	3.57 (0.68–18.84)	1.35 (0.34–5.38)
Hearing loss ≥41 dB	–	2.65 (0.26–26.27)	3.85 (1.39–10.65)	–	–	5.75 (1.46–22.71)
<i>P</i> trend	0.28	0.23	0.03	0.20	0.17	0.04

<sup>a</sup>Adjusted for age, race/ethnicity, body weight status, smoking, education, alcohol consumption, poverty income ratio, diabetes, marital status, cardiovascular disease, cancer, vision impairment, and sex (except when stratified by sexes).

A meta-analysis commissioned by *The Lancet* found that the relative risk for dementia in persons with hearing loss was almost twice the risk for dementia in those without hearing loss (pooled RR 1.94, 95% CI 1.38–2.73) (Livingston *et al.*, 2017). The authors reported that 35% of the risk factors for dementia were potentially modifiable, with hearing loss representing the highest percentage (9.1%) and depression an additional 4% (Livingston *et al.*, 2017). Management of hearing loss and

depression might contribute to the prevention or delay of dementia (Livingston *et al.*, 2017).

The use of the structured self-report assessment PHQ-9, although, *per se*, not a diagnostic instrument, is a strength of the present analysis. The PHQ-9 is widely used in psychiatric research and has a high degree of correlation with clinical interviews (Martin *et al.*, 2006). However, the present study also has several limitations, the most important being its cross-sectional design.

The depressive symptoms status in our study is limited to answers in the PHQ-9 about the experience of the participants during the past 2 weeks, so the depressive symptoms status might reflect a short-term health condition, and not necessarily a chronic condition. Another limitation to conclusive evidence is the single point in time measurement of audiometric thresholds. Several studies have raised concerns of potential false-positive rates of high frequency audiogram notches, such as 6 and 8 kHz, which might be the result of high subject variability and calibration error for TDH-type headphones (Schlauch and Carney, 2011).

Our analysis found that hearing loss is a risk factor for depression. Many studies have shown that hearing loss can affect the quality of life through diminished social interaction, increased loneliness, and cognitive performance. The National Academy of Sciences recommends using patient visits 'to assess and discuss potential hearing difficulties that could affect doctor-patient communication and overall patient well-being, to encourage individuals and their family members and caregivers to discuss hearing concerns, to raise awareness among older adults about age-related hearing loss, and to encourage referral when appropriate.' (NAS, 2016). Health professionals should be aware of signs and symptoms of depression among persons with hearing loss and refer patients for mental health services.

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**IRB approval.** CDC/ATSDR has determined that our study meets the criteria for research not involving identifiable human subjects per federal regulation 45 CFR 46; therefore, it does not require institutional review board (IRB) approval.

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