American Journal of Alzheimer's Disease & Other Dementias®
Volume 35: 1-8

DOI: 10.1177/1533317519871167
journals.sagepub.com/home/aja
SAGE

Gender Differences in the Association Between Hearing Loss and Cognitive Function

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Abstract

Objective: This study aimed to determine the association between hearing loss and cognitive function by gender in a nationally representative sample of older adults. **Methods:** We used data from the National Health and Nutrition Examination Survey (2010-2011) for 655 participants aged 60 to 69 years. The cognitive functioning component consisted of the Consortium to Establish a Registry for Alzheimer's disease, the Animal Fluency Test, and the Digit Symbol Substitution Test. We created a composite z score to represent global cognitive function. Regression models were used to examine the association between hearing loss and cognitive function. **Results:** Moderate/severe hearing loss was significantly associated with lower composite z score in males ($\beta = -28.67$, 95% confidence interval [95% CI] = −57.13 to −0.20) but not in females ($\beta = -8.82$, 95% CI = −36.61 to 18.96). **Conclusion:** There were gender differences in the association between hearing loss and cognitive function. Future studies need to investigate these gender-specific associations.

Keywords

dementia, cognition impairment, hearing loss, gender-specific association, aging

Introduction

The population of people aged 60 years or older was 962 million globally in 2017, and it will grow to 2.1 million in 2050; this population is growing faster than all younger age-groups.[1] At the same time, the World Alzheimer Report estimates that there are 50 million people in the world with dementia, and this community is likely to rise to approximately 152 million people by 2050. The current cost of the disease is approximately 1 trillion US dollars per year.[2] In fact, as cognitive dysfunction is one of the main symptoms of dementia, age-related cognitive decline has attracted great attention from academia and has also become an increasing public health challenge for governments.

Hearing impairment is another important public health problem in both developed and developing countries, with numerous negative effects on individuals, including difficulty with communication, depression, poor quality of life, and even increased mortality risk.[3-5] According to the World Health Organization, 466 million people in the world have hearing loss (6.1% of the global population), and approximately one third of persons older than 65 years are affected by disabling hearing loss.[6]

A growing body of literature has concluded that hearing loss might be a risk factor for dementia.[7-10] Furthermore, the Lancet Commission suggested that approximately 35% of dementia is attributable to a combination of 9 health and lifestyle factors, of which hearing loss is the highest, accounting for 9%.[11]

However, gender differences were not observed in their analyses, and related research is scarce. Two papers found that a statistically significant association between hearing impairment, measured by participant self-reporting, and cognitive impairment only existed in women aged 65 years and older.[12,13] This discrepancy indicates that gender-based health policies are necessary to maintain quality of life for older adults. Therefore, the purpose of this study was to assess the

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association between hearing loss measured by pure tone audiometry and cognitive function and to reveal whether any association differed by gender using the nationally representative data set of the National Health and Nutritional Examination Survey (NHANES 2011-2012).

Materials and Methods

Study Population

National Health and Nutritional Examination Survey is a cross-sectional survey using a complex, multistage design with a noninstitutionalized civilian population in the United States, conducted annually by the National Center for Health Statistics (NCHS). The survey combines interviews and physical examinations. Interviews include demographic, socioeconomic, dietary, and health-related questions. The examination section consists of medical, dental, and physiological measurements, as well as laboratory tests. Data set is publicly available at https://wwwn.cdc.gov/nchs/nhanes/Default.aspx. Sampling weights are considered in the analyses so that results can be generalizable to the US population. For our analyses, we included participants (aged 60-69 years) from the 2011-2012 cycle of NHANES who completed both cognitive tests and audiometric tests.

Cognitive Function Assessment

In 2011-2012, NHANES conducted a series of assessments of the cognitive function of participants aged 60 years and older in the mobile examination center (MEC). The cognitive functioning component consisted of 3 parts: (1) word learning and recall modules from the Consortium to Establish a Registry for Alzheimer's disease (CERAD), (2) the Animal Fluency Test, and (3) the Digit Symbol Substitution Test (DSST). The CERAD Word Learning subtest is designed to assess immediate and delayed learning ability for new verbal information (memory subdomain), including 3 consecutive learning trials and a delayed recall.[14] In terms of learning trials, participants were instructed to read aloud 10 unrelated words, one at a time, as they were presented. Immediately following the presentation of the words, participants recalled as many words as possible. The delayed word recall occurred approximately 8 to 10 minutes from the start of the word learning trials, after completing the other 2 cognitive exercises (Animal Fluency and DSST). The maximum possible score for each trial was 10. The Animal Fluency Test examined categorical verbal fluency, a component of executive function.[15] Participants were required to name as many animals as possible in a minute, with 1 point given for each animal named. The DSST, a performance module from the Wechsler Adult Intelligence Scale III, relied on processing speed, sustained attention, and working memory.[16] The exercise was conducted using a paper form that has a key at the top containing 9 numbers paired with symbols. Participants have 2 minutes to copy the corresponding symbols in the 133 boxes that adjoin the numbers. The score was the total number of correct matches. Higher scores represented better cognitive function in all tests.

Audiometric Assessment

All audiometry component sections were performed by trained examiners in a dedicated sound-isolated room in the MEC. The National Institute for Occupational Safety and Health is responsible for not only providing professional training for health technicians but also regularly monitoring the performance of each health technician on a regular basis. All adults aged 20 to 69 years were eligible except those who were unable to remove their hearing aids or who could not tolerate the testing headphones. Air conduction thresholds were measured for both ears at 7 frequencies (0.5, 1, 2, 3, 4, 6, and 8 kHz) across an intensity range of −10 dB to 120 dB. To measure the reliability of the participant's response, the 1-kHz frequency was tested twice in each ear and if the threshold difference was more than 10 dB, then the results were rejected. The first test values were used in the analyses. Further detailed information regarding these procedures is available on the NCHS website.[17] Hearing loss is defined as the pure tone average of thresholds at 0.5, 1, 2, and 4 kHz in the better hearing ear. According to the World Health Organization classifications, grades of hearing impairment are normal ≤25 dB, slight/mild = 26 to 40 dB, and moderate/severe ≥41 dB.[18]

Covariates

A systematic review reported that many studies controlled for potentially confounding variables such as diabetes, hypertension, smoking status, high cholesterol, and history of stroke.[10] Therefore, the various covariates selected for inclusion in the models were thought to be related to cognitive function and/or hearing loss, based on previous research.[10,19,20] Demographic variables included age (continuous variable), gender (male and female), race/ethnicity (Mexican American/other Hispanic, non-Hispanic white, non-Hispanic black, and other race), education (≤high school and >high school), marital status (married/living with partner, widowed/divorced/separated, and never married), and poverty–income ratio (ratio of family income to poverty <1.00 and ≥1.00). A low level of high-density lipoprotein cholesterol was defined as <40 mg/dL in males and <50 mg/dL in females. Total cholesterol was divided into <200 and ≥200 mg/dL. Lifestyle habit variables included smoking status and alcohol consumption (<3 drinks/week and ≥3 drinks/year). Smoking status was collapsed into 3 levels: current smoker (smoked at least 100 cigarettes in life and smokes now), former smoker (smoked at least 100 cigarettes in life but does not smoke now), and never smoked (smoked less than 100 cigarettes in life). Hearing aid use was determined by participant self-reporting whether they used a hearing aid at least once a day in the past year. Medical history including diabetes (yes or no), hypertension (yes or no), and stroke (yes or no) was also self-reported by individuals.

Statistical Analyses

According to the NHANES Analytical Guidelines,[21] we used the MEC sample weights for analysis to account for the complex sampling design. Due to the wide range of cognitive functions in the elderly population and that cognitive tests can be influenced by floors and ceilings, we standardized the scores of 4 tests (CERAD Word List Learning Test, CERAD Word List Recall Test, Animal Fluency Test, and DSST) for analysis to minimize this effect. The CERAD total score was the sum of the scores of the CERAD Word List Learning Test and the CERAD Word List Recall Test. A composite *z* score was calculated as the sum of the 4 standardized scores from 4 cognitive tests, representing the global cognitive function. We used a multiple linear regression model to assess the association between hearing loss as a continuous variable and composite *z* scores among different genders. The β coefficients from regression indicated a change in composite *z* scores when hearing loss increased by 10 dB or with hearing aid use. In addition, we analyzed the correlation between hearing loss grades and composite *z* scores, as well as the correlation between hearing loss grades and each cognitive test score. Covariates adjusted in model 1 were hearing aid use and age. Then, the relevant demographic variables, cholesterol index, living habits, and medical history were incorporated into the regression model in turn. Participants who lacked data on covariates were excluded from the multiple linear regression models. All analyses were conducted using SAS version 9.4 (SAS Institute Inc, Cary, North Carolina), and 2sided *P* values <.05 were considered statistically significant.

Results

Table 1 displays descriptive statistics for the study population. Data from both cognitive tests and audiometric tests were available for 655 adult participants aged 60 to 69 years from NHANES 2011-2012. There were 337 (48.29%) males and 318 (51.71%) females. Hearing loss, on average, was 21.12 and 16.98 dB for males and females, respectively. Among males, 25.87% presented mild/slight hearing loss, and 7.09% presented moderate/severe hearing loss. Among females, the prevalence of mild/slight and moderate/severe hearing loss accounted for 11.68% and 6.29%, respectively. Hearing aids were used in 10.51% of males and 3.60% of females.

Table 2 displays relationship between hearing loss grades and cognitive function test scores, compared differences in cognitive function scores at different hearing loss grades. Among males, Animal Fluency Test score and DSST score differ in different hearing loss grades, with the lowest score for moderate/severe hearing loss. Among females, Animal Fluency Test score differs in different hearing loss grades, with the lowest score for moderate/severe hearing loss.

As given in Table 3, when hearing loss was a categorical variable, moderate/severe hearing loss (≥41 dB) was statistically associated with composite *z* scores only among males (β = −28.67, 95% confidence interval [95% CI] = −57.13 to −0.20), even after adjusting for all covariates. Hearing aid use was statistically associated with cognitive function in males (β = 37.76, 95% CI = 8.59-66.93) but not in females (β = −8.82, 95% CI = −36.61 to 18.96). The results of multiple linear regression models when hearing loss was expressed as a continuous variable were similar (the results were not shown).

The relationships between hearing loss grades and each cognitive function test in different genders were analyzed and presented in Table 4. For both gender groups, moderate/severe hearing loss (≥41 dB) was negatively associated with the Animal Fluency Test score, and this association did not change after controlling for potential confounding factors. In model 4, the β coefficients for males and females were −8.29 (95% CI = −15.87 to −0.72) and −7.95 (95% CI = −15.81 to −0.09), respectively.

Discussion

In this study of a US national population-based sample of adults aged 60 to 69 years, we found that hearing loss, especially moderate/severe hearing loss, was statistically associated with lower composite *z* score, and this association differed by gender, which only appeared in males but not in females. Furthermore, individuals who used hearing aids tended to have higher composite *z* scores only among males. In addition, moderate/severe hearing loss was associated with Animal Fluency Test score, which that represented executive function in both genders.

The association between hearing loss and dementia is widespread according to recent studies, despite being identified approximately 20 years ago.[22] Lin and colleagues found that hearing loss was independently associated with incident all-cause dementia.[23] Tay and colleagues found that persons with moderate to severe hearing loss had a lower mean Mini-Mental State Examination (MMSE) score than those without hearing loss.[24] Several prospective cohort studies yielded similar results. For instance, Deal and colleagues, using data from the Health, Aging and Body Composition study, reported that hearing loss was associated with an increased risk of developing dementia in older adults.[25] Amieva and colleagues, using data from the Personnes Agees QUID cohort, reported that self-reported hearing loss was associated with cognitive decline at the 25-year follow-up.[26] However, gender differences were not observed in their analyses.

Our results indicated that moderate/severe hearing loss was associated with global cognitive function only in males aged 60 to 69 years in the United States, independent of important covariates. Our study has expanded the scarce literature about hearing loss and cognitive function and further demonstrated the existence of gender differences. However, 2 studies in Korea found that poor hearing was a significant predictor of cognitive impairment only among women aged 65 years and older.[12,13] The reasons for the different results of the above studies may be due to different biological samples in different countries and different assessment methods for cognitive function and hearing loss. Our study created a composite *z* score

Table 1. Weighted Characteristics of Participants Aged 60 to 69 Years With Both Cognitive and Audiometric Testing, NHANES 2011 to 2012.[a]

Characteristics	All	Male	Female
Participants, n (%)	655 (100)	337 (48.29)	318 (51.71)
Age, mean years (SD)	63.89 (0.19)	63.88 (0.27)	63.90 (0.23)
Hearing loss, mean dB (SD)	18.98 (0.93)	21.12 (1.25)	16.98 (1.52)
Hearing loss grades, n (%)			
Normal (≤25 dB)	511 (74.79)	238 (67.04)	273 (82.03)
Mild/slight (26-40 dB)	105 (18.53)	71 (25.87)	34 (11.68)
Moderate/worse (≥41 dB)	39 (6.68)	28 (7.09)	11 (6.29)
Hearing aid use, n (%)[b]	30 (6.93)	24 (10.51)	6 (3.60)
Race/ethnicity, n (%)			
White	208 (78.54)	107 (79.51)	101 (77.64)
Black	226 (8.79)	118 (8.02)	108 (9.51)
Hispanic	153 (6.77)	75 (6.45)	78 (7.06)
Other	68 (5.90)	37 (6.02)	31 (5.79)
Education, n (%)			
≤High school	304 (30.96)	163 (31.41)	141 (30.55)
>High school	351 (69.03)	174 (68.59)	177 (69.45)
Marital status[c]			
Married or living with partner	384 (69.34)	235 (79.40)	149 (59.96)
Widowed, divorced, or separated	216 (25.58)	75 (14.68)	141 (35.75)
Never married	53 (4.99)	26 (5.84)	27 (4.20)
Poverty–income ratio, n (%)[d]			
<1	115 (8.48)	50 (7.99)	65 (8.93)
≥1	487 (86.45)	255 (88.59)	232 (84.45)
Tobacco smoking, n (%)[e]			
Current	114 (16.06)	81 (22.47)	33 (10.08)
Former	211 (32.27)	141 (40.26)	70 (24.82)
Never	329 (51.61)	115 (37.27)	214 (64.99)
Total cholesterol			
<200 mg/dL	355 (53.36)	208 (63.75)	147 (43.66)
≥200 mg/dL	300 (46.64)	129 (36.25)	171 (56.34)
HDL-C			
<40 mg/dL in males and <50 mg/dL in females	209 (25.69)	96 (23.30)	113 (27.92)
≥40 mg/dL in males and ≥50 mg/dL in females	446 (74.31)	241 (76.70)	205 (72.08)
Hypertension, n (%)	375 (49.36)	190 (50.42)	185 (48.36)
Diabetes, n (%)[f]	153 (17.45)	81 (18.53)	72 (16.45)
Stroke, n (%)[g]	32 (4.25)	16 (4.97)	16 (3.58)

Abbreviations: HDL-C, high-density lipoprotein cholesterol; NHANES, National Health and Nutritional Examination Survey; SD, standard deviation.
[a]All percentages shown were of weighted sample.
[b]Missing response: 1 male.
[c]Missing responses: 1 male and 1 female.
[d]Missing responses: 32 males and 21 females.
[e]Missing response: 1 female.
[f]Missing responses: 10 males and 18 females.
[g]Missing response: 1 male.

that represented global cognitive function rather than relying on psychometric tests, particularly the MMSE. In addition, an inaccurate measurement of hearing thresholds may reduce the sensitivity of detecting associations. Pure tone audiometry instead of self-reporting from individuals was used to evaluate the hearing loss condition, which probably made our results more consistent and reliable.

The exact mechanism of hearing loss associated with cognition and dementia has not been elucidated. In an extensive review, Wayne and Johnsrude summarized multiple hypotheses about hearing loss related to dementia: the cognitive load on perception hypothesis, the sensory deprivation hypothesis, the information degradation hypothesis, and the common cause hypothesis.[27] The sensory deprivation hypothesis considers that the association between hearing loss and cognitive impairment involves various psychosocial factors.[28] Individuals with hearing loss struggle to communicate and maintain relationships, often leading to social isolation. In a community-based longitudinal study, Fratiglioni and colleagues reported that a poor or limited social network increased the risk of dementia by 60%.[29] Men were more sensitive to hearing loss because studies found that men have greater social networks than women, while people with more social activity tend to be more sensitive to hearing loss.[30,31] In addition, by dividing loneliness into 2

Table 2. Relationship Between Hearing Loss Grades and Cognitive Function Test Scores, NHANES 2011 to 2012.[a]

Variables	Hearing Loss Grades			*P* Value
	Normal (≤25 dB)	Mild/Slight (26-40 dB)	Moderate/Severe (≥41 dB)	
Male				
Composite z score	7.86 (4.28)	−6.86 (8.95)	−23.99 (12.42)	.0913
CERAD	10.98 (3.25)	2.85 (4.1)	0.36 (10.33)	.2878
Animal Fluency Test	−0.66 (1.98)	−3.00 (3.67)	−11.34 (3.31)	.0223[b]
DSST	−2.45 (1.44)	−6.70 (1.94)	−13.00 (3.64)	.0254[b]
Female				
Composite z score	29.16 (3.38)	16.21 (11.65)	16.72 (17.34)	.0704
CERAD	24.47 (2.18)	18.58 (5.82)	30.62 (6.35)	.4537
Animal Fluency Test	1.13 (1.35)	−5.12 (2.75)	−6.37 (3.84)	.0129[b]
DSST	3.56 (1.03)	2.75 (5.17)	−7.54 (7.44)	.0923

Abbreviations: CERAD, Consortium to Establish a Registry for Alzheimer's disease; DSST, Digit Symbol Substitution Test; NHANES, National Health and Nutritional Examination Survey; SD, standard deviation.
[a]In this table, the cognitive function test scores were presented in the form of mean (SD).
[b]$P < .05$.

Table 3. Regression Coefficients β (95% Confidence Intervals) of Hearing Loss Grades for Cognitive Function (Composite z Score), NHANES 2011 to 2012.[a]

Variables	Model 1	Model 2	Model 3	Model 4
Male				
Hearing loss grades				
Normal (≤25 dB)	Referent	Referent	Referent	Referent
Mild/slight (26-40 dB)	−13.37 (−33.26 to 6.52)	−4.30 (−18.31 to 9.71)	−2.61 (−17.13 to 11.91)	−1.29 (−15.8 to 13.22)
Moderate/severe (≥41 dB)	−45.32 (−71.11 to −19.53)[b]	−28.09 (−56.12 to −0.06)[c]	−28.17 (−55.78 to −0.55)[c]	−28.67 (−57.13 to −0.20)[c]
Hearing aid use	54.19 (26.20 to 82.18)[b]	35.89 (8.07 to 63.72)[c]	38.56 (10.59 to 66.52)[c]	37.76 (8.59 to 66.93)[c]
Female				
Hearing loss grades				
Normal (≤25 dB)	Referent	Referent	Referent	Referent
Mild/slight (26-40 dB)	−12.66 (−33.22 to 7.90)	−7.80 (−26.18 to 10.58)	−7.28 (−25.26 to 10.71)	−8.33 (−24.14 to 7.48)
Moderate/severe (≥41 dB)	−11.90 (−45.99 to 22.18)	−3.89 (−17.23 to 9.45)	−3.04 (−17.77 to 11.68)	−1.45 (−19.51 to 16.61)
Hearing aid use	17.81 (−21.06 to 56.68)	−1.97 (−25.93 to 22.00)	−1.89 (−25.42 to 21.64)	−8.82 (−36.61 to 18.96)

Abbreviation: NHANES, National Health and Nutritional Examination Survey.
[a]Adjusted covariates: Model 1 = hearing aid use, age. Model 2 = Model 1 + (race/ethnicity, education, marital status, poverty–income ratio, total cholesterol, and high-density lipoprotein cholesterol). Model 3 = Model 2 + (smoking status and alcohol consumption). Model 4 = Model 3 + (diabetes, hypertension and stroke).
[b]$P < .01$.
[c]$P < .05$.

dimensions of social and emotional loneliness, a study found that men tended to be more socially lonely than women in a community sample of 1 255 adults aged 65 years and older.[32] Gender differences in social networks and social loneliness may be responsible for the gender differences in association between hearing loss and cognitive function. Our results suggested that males may be more susceptible to psychosocial factors, so hearing loss leads to a greater risk of cognitive impairment. Additionally, males with hearing loss undergoing active psychosocial intervention at an early stage may reduce the risk of cognitive impairment. However, these findings still need to be confirmed in large-scale and representative cohort studies.

Additionally, clinicopathologic differences in Alzheimer's disease may account for our results. Within the neuropathologically diagnosed Alzheimer's disease cohort, men were younger at onset of cognitive symptoms and had a shorter disease duration.[33] Before the ninth decade (ie, 80-89 years) of life, men with Alzheimer's disease were overrepresented, with a peak frequency in the seventh decade (ie, 60-69 years) of life. Similarly, an epidemiological study reported that mild cognitive impairment was more frequently diagnosed among

Table 4. Regression Coefficients β (95% Confidence Intervals) of Hearing Loss Grades for Cognitive Function Test Scores, NHANES 2011 to 2012.[a]

Variables	Model 1	Model 2	Model 3	Model 4
Male				
CERAD				
Normal (≤25 dB)	Referent	Referent	Referent	Referent
Mild/slight (26-40 dB)	−7.42 (−17.72 to 2.89)	−4.56 (−13.67 to 4.55)	−3.69 (−12.19 to 4.81)	−2.31 (−9.91 to 5.30)
Moderate/severe (≥41 dB)	−18.13 (−37.85 to 1.60)	−13.58 (−33.73 to 6.58)	−12.83 (−32.25 to 6.59)	−13.94 (−33.96 to 6.07)
Animal Fluency Test				
Normal (≤25 dB)	Referent	Referent	Referent	Referent
Mild/slight (26-40 dB)	−1.28 (−9.18 to 6.63)	2.03 (−4.44 to 8.50)	2.48 (−4.82 to 9.78)	2.34 (−5.14 to 9.81)
Moderate/severe (≥41 dB)	−15.15 (−23.36 to −6.94)[b]	−9.03 (−16.56 to −1.51)[c]	−9.35 (−17.54 to −1.17)[c]	−8.29 (−15.87 to −0.72)[c]
DSST				
Normal (≤25 dB)	Referent	Referent	Referent	Referent
Mild/slight (26-40 dB)	−4.67 (−9.59 to 0.25)	−1.78 (−5.50 to 1.95)	−1.4 (−5.54 to 2.75)	−1.32 (−5.26 to 2.62)
Moderate/severe (≥41 dB)	−12.04 (−21.09 to −2.99)[c]	−5.48 (−17.47 to 6.51)	−5.98 (−16.64 to 4.68)	−6.43 (−16.98 to 4.12)
Female				
CERAD				
Normal (≤25 dB)	Referent	Referent	Referent	Referent
Mild/slight (26-40 dB)	−5.58 (−15.43 to 4.28)	−4.11 (−14.40 to 6.19)	−3.31 (−13.33 to 6.71)	−3.97 (−14.55 to 6.60)
Moderate/severe (≥41 dB)	5.55 (−10.00 to 21.10)	9.54 (−0.78 to 19.87)	10.49 (0.00 to 20.98)	9.55 (−1.40 to 20.50)
Animal Fluency Test				
Normal (≤25 dB)	Referent	Referent	Referent	Referent
Mild/slight (26-40 dB)	−6.22 (−12.62 to 0.18)	−5.85 (−14.68 to 2.99)	−6.57 (−15.39 to 2.26)	−7.06 (−15.17 to 1.04)
Moderate/severe (≥41 dB)	−7.19 (−14.43 to 0.06)	−7.18 (−12.03 to −2.32)[b]	−7.37 (−13.2 to −1.55)[c]	−7.95 (−15.81 to −0.09)[c]
DSST				
Normal (≤25 dB)	Referent	Referent	Referent	Referent
Mild/slight (26-40 dB)	−0.87 (−10.51 to 8.78)	2.15 (−5.12 to 9.42)	2.60 (−4.94 to 10.14)	2.71 (−4.03 to 9.44)
Moderate/severe (≥41 dB)	−10.27 (−24.03 to 3.50)	−6.25 (−11.31 to −1.2)[c]	−6.16 (−11.61 to -0.71)[c]	−3.05 (−7.23 to 1.13)

Abbreviations: CERAD, Consortium to Establish a Registry for Alzheimer disease; DSST, Digit Symbol Substitution Test; NHANES, National Health and Nutritional Examination Survey.

[a] Adjusted covariates: Model 1 = hearing aid use, age. Model 2 = Model 1 + (race/ethnicity, education, marital status, poverty–income ratio, total cholesterol, and high-density lipoprotein cholesterol). Model 3 = Model 2 + (smoking status and alcohol consumption). Model 4 = Model 3 + (diabetes, hypertension and stroke).

[b] $P < .01$.

[c] $P < .05$.

men than in women in the elderly population aged 70 to 89 years.[34] For the elderly population aged 60 to 69 years in our study, males were more likely to develop cognitive impairment than females, contributing to gender differences in terms of the association between hearing loss and cognition.

In our study, self-reported hearing aid use was associated with a higher composite *z* score in males. However, the gender differences in hearing aids effects must be interpreted with caution because the number of participants using hearing aids was small (24 males and 6 females). Indeed, there are studies that confirm the gender differences in improvement in some of the specific domains of quality of life among people with age-related hearing loss after hearing aid use.[35] Many other studies found that treating hearing loss with hearing aids may ameliorate cognitive decline, and hearing aid use is effective at improving hearing-specific health-related quality of life in old adults.[26,36-38] According to Bisgaard and Ruf, hearing aid users were less exhausted at the end of the day compared with nonusers with similar hearing loss and exhibit less depressive and forgetfulness symptoms.[39] These results strongly support the advice to using hearing aids, regardless of gender, to counter hearing loss and the adverse effects of hearing loss.

Studies have suggested that reallocable processing resources are used to support auditory processing when listening becomes difficult. These reallocation resources are not available for more central cognitive processes, resulting in impaired other cognitive processes such as executive functions and working memory resources.[40,41] This could explain why, in this study, moderate/severe hearing loss was associated with a lower Animal Fluency Test score, which represented poor executive function. Executive function decline occurs early and is prevalent in Alzheimer's disease.[42] Furthermore, executive dysfunction leads to more other functional impairments in patients with Alzheimer's disease.[43] Given the association between hearing loss and executive function in males and females, there is an urgent need to develop interventions capable of maintaining or slowing the decline of executive function.

There are several limitations in our study. First, our result was based on cross-sectional data rather than a longitudinal cohort study. Thus, we can only identify the association but not the causality between hearing loss and cognitive function, making it difficult to observe the etiology behind the connection. Second, since NHANES no longer performed audiometry after the 2011 to 2012 cycle, we are unable to obtain the latest data and a larger sample size. Additionally, we cannot exclude the potential effect of recall bias on the medical history data.

Conclusion

Our data derived from a nationally representative survey of NHANES 2010 to 2011 revealed gender differences in the association between hearing loss and cognitive function in older adults aged 60 to 69 years in the United States. We found that the association between moderate/severe hearing loss and global cognitive function was only present in males. Our results may provide research directions for proper experimental research and optimize treatment policies with regard to gender differences. Future studies need to investigate this gender-specific association.

Authors' Contributions

Bowen Huang and Guilan Cao contributed equally to this work. Bowen Huang and Guilan Cao conceived and designed this study, analyzed and interpreted data, and wrote the manuscript. Yanran Duan, Siyu Yan, and Mingming Yan conducted data collection and statistical analyses. Hongwei Jiang and Ping Yin reviewed the manuscript. All authors read and approved the final manuscript.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The study was supported by the National Natural Science Foundation of China (No. 81573262).

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Supplemental Material

Supplemental material for this article is available online.

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