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Publication Date

2002

Peer reviewed

Vision Impairment and Combined Vision and Hearing Impairment Predict Cognitive and Functional Decline in Older Women

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OBJECTIVES: To determine the association between vision and hearing impairment and subsequent cognitive and functional decline in community-residing older women.

DESIGN: Prospective cohort study.

SETTING: Four metropolitan areas of the United States.

PARTICIPANTS: A total of 6,112 women aged 69 and older participating in the Study of Osteoporotic Fractures (SOF) between 1992 and 1994.

MEASUREMENTS: Five thousand three hundred forty-five participants had hearing measured, 1,668 had visual acuity measured, and 1,636 had both measured. Visual impairment was defined as corrected vision worse than 20/40. Hearing impairment was defined as the inability to hear a tone of 40 dB or greater at 2,000 hertz. Participants completed the modified Mini-Mental State Examination and/or a functional status assessment at baseline and follow-up. Cognitive and functional decline were defined as the amount of decline from baseline to follow-up that exceeded the observed average change in scores by at least 1 standard deviation.

RESULTS: About one-sixth (15.7%) of the sample had cognitive decline; 10.1% had functional decline. In multivariate models adjusted for sociodemographic characteristics and chronic conditions, vision impairment at baseline was associated with cognitive (odds ratio (OR) = 1.78,

95% confidence interval (CI) = 1.21–2.61) and functional (OR = 1.79, 95% CI = 1.15–2.79) decline. Hearing impairment was not associated with cognitive or functional decline. Combined impairment was associated with the greatest odds for cognitive (OR = 2.19, 95% CI = 1.26–3.81) and functional (OR = 1.87, 95% CI = 1.01–3.47) decline.

CONCLUSION: Sensory impairment is associated with cognitive and functional decline in older women. Studies are needed to determine whether treatment of vision and hearing impairment can decrease the risk for cognitive and functional decline. *J Am Geriatr Soc* 52:1996–2002, 2004.

Key words: vision impairment; hearing impairment; cognitive status; functional status; aged

Visual impairment and hearing loss are chronic and potentially treatable conditions that disproportionately affect the elderly. Difficulty seeing, even in those with glasses, increases steadily with age, and is estimated at 4% of older persons aged 65 to 74 to 16% of those aged 80 to 84 in the United States.¹ Similarly, it has been estimated that more than half of those aged 60 and older experience hearing impairment.² Undertreatment of sensory impairment in the elderly is common; uncorrected refractive error and unoperated age-related cataract together account for more than half of all visual impairment in older persons,¹ and up to 70% of hearing impairment in the elderly is not treated with hearing aids.³ Undoubtedly, these correctable deficits affect daily activities, such as reading or communicating with others, and global quality of life.⁴

There is growing evidence that sensory deficits in the elderly may have a profound effect on multiple health outcomes. Vision^{5–9} and hearing^{7,8} impairment have been associated with functional disability. Vision impairment has also been shown to increase risk of hip fracture,^{10,11} depression,¹² and mortality.¹³ Hearing impairment has been associated with increased balance problems,¹⁴ cognitive impairment,¹⁵ depression,¹² and mortality in men.¹⁶

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Supported by Grants AG05407, AR35582, AG05394, AR35584, and AR35583 from the Public Health Service, National Institutes of Health, Bethesda, Maryland. Support for Dr. Mangione was provided by the UCLA Center for Health Improvement in Minority Elders/Resource Centers for Minority Aging Research, National Institutes of Health, National Institute of Aging (AG-02-004).

This paper was presented at the 2002 Society of General Internal Medicine National Meeting, Atlanta, Georgia.

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Furthermore, there appears to be a synergistic relationship between vision and hearing loss with respect to functional dependence.⁷

Although prior studies of the effects of sensory impairment have focused on the outcome of functional status, few have examined the outcome of cognitive impairment, particularly in community-residing elderly persons. Some studies have used cross-sectional data and thus are unable to demonstrate the relationships between sensory impairment and future health outcomes. Furthermore, few studies have had an adequate number of subjects to examine the combined effect of vision and hearing impairment in the elderly.

Longitudinal data from the Study of Osteoporotic Fractures (SOF) provides an opportunity to examine the relationship between sensory impairment and subsequent functional and cognitive decline in community-residing older women. To this end, the current study has two goals: to examine the independent effects of vision and hearing impairment on subsequent cognitive and functional decline in elderly women and to examine the combined effect of vision and hearing impairment on the same outcomes.

METHODS

Subjects

The SOF is a multicenter study of elderly women recruited to identify risk factors for osteoporotic fractures and other health outcomes. The original sample consisted of 9,704 white women aged 65 and older, recruited from 1986 to 1988 in four metropolitan areas of the United States: Portland, Oregon; Minneapolis, Minnesota; Baltimore, Maryland; and the Monongahela Valley, Pennsylvania. Women were recruited from sources such as voter registration lists, jury selection rosters, and membership directories of health maintenance organizations. In an effort to increase the study incidence of new-onset hip fracture, African-American women were excluded because of their low incidence of

hip fractures.¹⁷ Also excluded were women who had prior history of bilateral hip replacement or prior hip fracture. All original participants underwent a standardized interview and clinical examination approximately every 2 years, covering multiple domains of health, potential lifestyle and dietary risk factors for falls and fractures, and sociodemographic characteristics. Details of the study design have been reported elsewhere.¹⁸

This report relies on data from a cohort of 6,112 subjects interviewed and examined at SOF Visit 4 from 1992 to 1994 (hereafter referred to as this report's baseline) with functional activity scores ($n = 6,094$) or cognitive function scores ($n = 4,850$) at follow-up. The sample of 6,112 with functional or cognitive status scores represents 87% of the entire 7,004 SOF cohort seen at baseline. The follow-up data described in this analysis were obtained at the SOF Visit 6 examination and interview conducted between 1997 and 1999 (hereafter referred to in this report as follow-up). Average follow-up time from Visit 4 to Visit 6 was 4.4 years. Because of resource constraints, not all subjects received measurements of visual acuity or audiometry testing. Figure 1 lists the distribution of participants in the vision and hearing testing cohorts and the sample sizes for the cognition and functional activity analyses within each cohort. Audiometry data were collected at baseline (SOF Visit 4) in a convenience sample of 5,345 subjects. Vision data were collected at baseline in a convenience sample of 1,668 subjects. The associations between declines in function and cognition were tested in the vision and hearing cohorts separately. A resulting total of 1,636 subjects had measurement of both visual and audiometry testing, and the models that examined the combined influence of vision and hearing impairment were tested using this sample. Sociodemographic and medical comorbidities were elicited from all subjects at baseline. All participants provided written informed consent, and all of the appropriate institutional review boards approved the protocol.

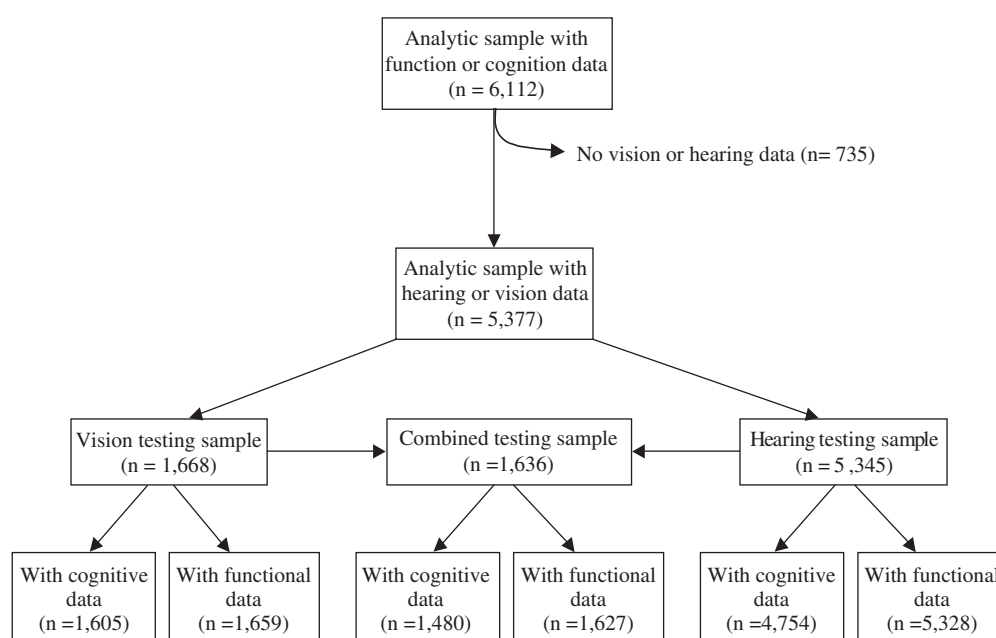


Figure 1. Study sample distribution by measurement cohort.

MEASURES

Visual Impairment

Binocular visual acuity was tested using a standard protocol and Bailey Lovie Targets.¹⁹ Those who normally wore corrective lenses were asked to use them for the test. All tests were performed using standardized illumination of 50- to 70-foot Lamberts, and a "forced choice" method was employed, as is standard in most clinical studies. Visual impairment was defined as having corrected binocular vision worse than 20/40. This cutpoint was chosen because it has been used in other studies of visual impairment^{6,20} and is the visual acuity required in many states for an unrestricted driver's license.

Hearing Impairment

Hearing was tested following a standardized protocol with a hand-held audiometer (Welch-Allyn AudioScope3, Skaneateles Falls, NY) in a quiet room. The testing protocol did not allow for the use of hearing aids. Hearing impairment was defined as the inability to hear a tone of 40 dB or greater at 2,000 Hz frequency in the better ear. This conservative cutpoint was chosen because 2,000 Hz falls within the auditory frequency range most important for speech discrimination.² Information on the specific vision and hearing testing protocols is available from the corresponding author.

Combined Sensory Impairment

Subjects with vision and hearing impairment, as defined above, were classified as having combined sensory impairment.

Cognitive Decline

At baseline and follow-up visits, cognitive function was measured using a modified version of the Mini-Mental State Examination (3MS).^{21,22} The 3MS is a general test designed to screen for cognitive impairment, with components for concentration, language, and memory. The 3MS scores range from 0 to 26, with lower scores indicating poorer cognitive function. Cognitive decline was defined as the amount of change in 3MS scores from baseline to follow-up that exceeded the observed average change in scores by at least 1 standard deviation. This difference is equivalent to a loss of 3 or more points over time. The reference group consisted of subjects who declined less than 1 standard deviation, including those who stayed the same or improved.

Functional Decline

Based on questions from the 1984 National Health Interview Survey Supplement on Aging,²³ participants were asked at baseline and follow-up about their ability to perform five activities: walking, climbing stairs, preparing meals, shopping, and doing housework. Four levels of difficulty were reported: no difficulty, some difficulty, much difficulty, and unable to do the activity. Item scores ranged from 0 (unable) to 3 (no difficulty). The difference between item scores at baseline and follow-up was summed. Functional decline was defined as a decline in functional status exceeding the observed average change in scores by at least 1 standard deviation, equivalent to losing 5 or more points of functional ability over time. The reference group con-

sisted of subjects who declined less than 1 standard deviation, including those who stayed the same or improved.

Covariates

Those characteristics found in a related study to have been associated with sensory impairments and cognitive or functional decline were considered as candidate variables.²⁴ From these candidates, for the adjusted models, those that were significant at $P \leq .10$ in bivariate tests of association between the candidate covariate and each of the outcomes of interest were included. Continuous variables were used for age and body mass index (kg/m^2). Education level was categorized as less than 12 years, 12 years, and greater than 12 years. Current smoking status and benzodiazepine use were dichotomous variables. Three covariates—walking speed²⁵ (m/s), hand-grip strength²⁶ (kg), and Lubben social network^{27,28} (range 0–5, higher scores reflecting greater social interaction)—were dichotomized at the lowest quintile of the distribution observed in the cohort to reflect moderate impairment in each of these three unique domains. An unweighted sum of self-reported diabetes mellitus, arthritis, chronic obstructive pulmonary disease, congestive heart failure, angina pectoris, heart attack, and stroke was used to adjust for medical comorbidity.

Analyses

Comparison of Cohorts with Sensory Measures to the Overall Cohort

Because vision and hearing were measured in convenience samples from the overall SOF cohort, bivariate tests of association were performed to identify demographic and health variables that differed between participants who did and did not take these tests.

Unadjusted Tests of Association

Logistic regression models were calculated to test the association between visual, hearing, and combined impairment and declines in cognitive and functional status over time.

Adjusted Tests of Association

Two pairs of logistic regression models were constructed to test the statistical significance of the association between sensory impairment and cognitive and functional decline. The indicators for cognitive and functional decline are not mutually exclusive. These models were adjusted for the independent effects of the covariates described above. The first pair of models focused on vision and hearing impairment as independent predictors. The second pair of models focused on combined vision and hearing impairment as a predictor versus those without combined vision and hearing impairment. All statistical analyses were performed using SAS version 6.12 (SAS Institute, Inc., Cary, NC).

RESULTS

Sociodemographic characteristics and medical comorbidities for the entire baseline cohort ($n = 6,112$) and the samples tested for vision impairment ($n = 1,668$) and hearing impairment ($n = 5,345$) are presented in Table 1. In the baseline study sample, 15.7% (762 of 4,850 with cognitive function scores) had cognitive decline, and 10.1% (616 of 6,094 with functional activity scores) had

Table 1. Baseline and Outcome Characteristics of the Overall Cohort and Those Undergoing Sensory Testing

Characteristic	Overall Cohort (n = 6,112)	Vision Testing Sample (n = 1,668)	Hearing Testing Sample (n = 5,345)
Sociodemographic characteristics			
Mean age	76.1	75.9	76.1
Education ≤ 12 years, %	59.8	58.7	59.4
Covariates			
Smoking, %	5.4	5.2	5.2
Coronary artery disease, %	14.7	13.2	14.7
Congestive heart failure, %	4.7	4.9	4.6
Diabetes mellitus, %	5.3	5.4	5.2
Chronic obstructive pulmonary disease, %	9.8	9.8	9.8
Stroke, %	4.2	3.9	4.4
Seizure, %	1.0	1.2	1.0
Parkinson's disease, %	0.5	0.2	0.5
Alzheimer's disease, %	0.2	0.1	0.2
Arthritis, %	20.3	18.5	20.6
Vertebral fracture, %	3.9	3.8	3.9
Benzodiazepine use, %	7.5	7.0	7.7
Body mass index, kg/m ²	26.6	26.6	26.5
Lubben social network (range 0–5)	3.2	3.2	3.2
Grip strength, kg	18.4	18.3	18.4
Walk speed, m/s	1.3	1.3	1.3
Baseline functional status (range 0–15)	13.6	13.9*	13.7
Baseline modified Mini-Mental State Examination (range 0–26)	24.6	24.5*	24.6
Outcome variables			
Functional decline over time, %	10.1	7.9*	9.6
Cognitive decline over time, %	15.7	14.8	15.6

* Differs significantly from overall cohort ($P \leq .01$).

functional decline. In the vision testing sample, 18.2% (303/1,668) of subjects had visual impairment. In the hearing test sample, 19.9% (1,065/5,345) of subjects had hearing impairment.

Compared with the SOF cohort overall, subjects in the hearing test cohort showed no significant differences on any of the covariates listed in Table 1. The smaller vision test cohort reported higher baseline functional activity scores and worse baseline cognitive 3MS scores but a lower percentage of functional decline at follow-up than the overall SOF cohort (Table 1). The differences in baseline functional status and cognitive status scores were quantitatively small and are accounted for in the analyses by the use of change scores.

In the bivariate analyses, covariates of age, education level, smoking status, medical conditions, body mass index, social network, hand-grip strength, walking speed, presence

of vertebral fracture, benzodiazepine use, baseline functional status, and baseline cognitive status were all associated with functional or cognitive decline at $P \leq .10$ and therefore were included in all multivariate models (data not shown).

In the unadjusted models (Table 2), both vision and hearing impairment were significantly associated with greater cognitive and functional decline over time. Vision impairment corresponded to an increased odds ratio (OR) of 2.21 (95% confidence interval (CI) = 1.59–3.08) for cognitive decline and 2.49 (95% CI = 1.71–3.62) for functional decline, whereas hearing impairment conferred an increased OR of 1.64 (95% CI = 1.37–1.97) for cognitive decline and 1.67 (95% CI = 1.37–2.04) for functional decline. Participants with combined vision and hearing impairment at baseline had an increased OR of 3.49 (95%

Table 2. Unadjusted Odds of Cognitive and Functional Decline Associated with Sensory Impairment

Predictor	Cognitive Decline	Functional Decline
	Odds Ratio (95% Confidence Interval)	
Vision impairment (best corrected vision worse than 20/40)	2.21 (1.59–3.08)*	2.49 (1.71–3.62) [†]
Hearing impairment (unable to hear 40 dB tone at 2 kHz in better ear)	1.64 (1.37–1.97) [‡]	1.67 (1.37–2.04) [§]
Combined impairment (vision and hearing impairment)	3.49 (2.15–5.65)	3.72 (2.20–6.27) [¶]

* n = 1,605; [†] n = 1,659; [‡] n = 4,754; [§] n = 5,328; ^{||} n = 1,480; [¶] n = 1,627.

Table 3. Adjusted Odds of Cognitive and Functional Decline Associated with Sensory Impairment

Predictor	Cognitive Decline	Functional Decline
	Odds Ratio (95% Confidence Interval)	
Vision impairment (best corrected vision worse than 20/40)*	1.78 (1.21–2.61) [†]	1.79 (1.15–2.79) [‡]
Hearing impairment (unable to hear 40 dB tone at 2kHz in better ear)*	1.38 (0.95–2.00) [†]	1.10 (0.71–1.73) [‡]
Combined impairment (vision and hearing impairment)	2.19 (1.26–3.81) [†]	1.87 (1.01–3.47) [‡]

* Both independent hearing and vision impairment predictors were included in both models; n = 1,333 for cognition models, and n = 1,453 for function models.

[†] Covariates used in the multivariate model for cognitive decline were medical comorbidities, age, education, smoking, vertebral fracture, benzodiazepine use, body mass index, Lubben social network, grip strength, walking speed, and baseline cognitive status.

[‡] Covariates used in the multivariate models for functional decline were medical comorbidities, age, education, smoking, vertebral fracture, benzodiazepine use, body mass index, Lubben social network, grip strength, walking speed, and baseline functional status.

CI = 2.15–5.65) for cognitive decline and 3.72 (95% CI = 2.20–6.27) for functional decline during the 4-year follow-up period.

In the multivariate models (Table 3), vision impairment was significantly associated with increased odds of cognitive decline (OR = 1.78, 95% CI = 1.21–2.61) and functional decline (OR = 1.79, 95% CI = 1.15–2.79), but hearing impairment was no longer correlated with increased odds of functional decline (OR = 1.10, 95% CI = 0.71–1.73). In those with hearing impairment, there was a trend toward greater odds of cognitive decline over time (OR = 1.38, 95% CI = 0.95–2.00). Taking into account hearing aid use and the interaction between hearing aid use and hearing impairment did not alter these results (data not shown). Subjects who had combined hearing and vision impairment also had greater odds of experiencing cognitive decline (OR = 2.19, 95% CI = 1.26–3.81) and functional decline (OR = 1.87, 95% CI = 1.01–3.47). Although these ORs are larger than those for participants with vision impairment alone, the CIs overlap with those from the models with vision impairment alone.

DISCUSSION

In this report, a twofold increase in odds of cognitive and functional decline over time associated with vision impairment is described. Additionally, a trend toward increased odds of cognitive impairment for those with hearing loss at baseline has been identified. Although subjects with combined vision and hearing impairment appeared to be at greatest risk for cognitive and functional decline, the CIs for those ORs overlapped with those for visual impairment alone. Given this finding, it is not possible to determine whether combined sensory impairment truly confers a greater risk of cognitive or functional decline than visual impairment alone.

This longitudinal analysis contributes to a better understanding of the role of vision impairment in predicting subsequent cognitive decline in community-dwelling elderly women. Previous cross-sectional studies have been few and inconclusive regarding vision impairment and its relationship with cognitive decline.^{29,30} In a cross-sectional analysis, one study examined 156 elderly individuals from the Berlin Aging Study and found that measured visual acuity was associated with poorer performance in intelligence tests covering five cognitive domains.³¹ These results were extended in another study that found, in a 2-year prospective

study of subjects from the Australian Longitudinal Study of Aging, that visual impairment was associated with declines in memory in the elderly,³² but this study was limited in its ability to adjust for confounding variables, including medical comorbidities. The covariate-adjusted findings of the current study indicate that vision impairment in elderly women is an independent risk factor for subsequent cognitive decline when cognition is measured over multiple domains using a standard measure of cognitive function (3MS).

It was found that subjects with hearing impairment had a nonsignificant trend toward greater cognitive decline over time. Although prior cross-sectional and longitudinal studies have suggested an association between hearing impairment and cognitive decline in persons with dementia or in institutionalized elderly patients,^{15,33,34} this association has not been reported in older persons without dementia.^{35,36} Similar to the findings in this report, another study did not identify hearing impairment as a risk factor for cognitive decline (measured using the Wechsler Memory Scale and Jacobs Cognitive Screening Test) over 5 years for a cohort of healthy elderly men and women.³⁷ The exclusion of subjects with major medical illnesses or regular prescription medications limited the significance of this finding. The aforementioned study did not find an association between hearing and cognitive decline over the 2-year period of the Australian Longitudinal Study of Aging.³² Both of these prospective studies used smaller cohorts than the one employed in this study, and it may be possible that studies thus far have not had sufficient statistical power to elucidate the possible association between hearing loss and cognition decline in community-based older persons.

Regarding the outcome of functional decline, the current results are fairly consistent with previous studies that have investigated whether vision and hearing impairment confer increased risk of functional decline over time. In general, prior studies of varying research designs and methods of vision and hearing measurement have shown a fairly strong association between vision impairment and subsequent functional disability^{5,8,38} and a smaller and less consistent association between hearing impairment and subsequent functional disability.^{8,38} A study using data from the Longitudinal Study of Aging, showed that self-reported visual impairment but not hearing impairment was associated with greater activity of daily living (ADL)³⁹ disability after 4 years.⁴⁰ The current results, using measured rather than self-reports of sensory impairment, show similar results.

A report analyzing data from the first National Health and Nutrition Examination Survey (NHANES I)⁴¹ and its first Epidemiologic Follow-up Study⁴² demonstrated independent associations between vision and hearing impairment and functional outcomes in the elderly over 10 years.⁷ Self-reported and measured vision were associated with poorer 10-year ADL and instrumental activity of daily living (IADL)⁴³ outcomes, but hearing impairment was only associated with greater disability on the Rosow-Breslau scale,⁴⁴ which includes functional tasks that are more physically challenging than the ADL and IADL tasks. The relatively young age of the population (55–74 at baseline) and lack of baseline functional measures to observe a temporal change in functional ability over time limited these results. The current study, in an older female cohort with baseline and follow-up functional measures over a 4-year period of time, showed results for vision and hearing impairment that were consistent with the NHANES¹ analysis, but some of the more vigorous functional outcome measurements, such as the Rosow-Breslau scale, that may have been more sensitive to detecting earlier or smaller functional decrements over time were not included.

The high prevalence of vision and hearing impairment in the study cohort allowed for examination of subjects with combined impairments. Few prior studies have examined the effect of multiple sensory impairments. One study demonstrated a synergistic effect with hearing and vision impairment on functional outcome,⁷ but with respect to the outcome of cognitive decline, no studies have explicitly studied combined hearing and vision impairment predictors, to the authors' knowledge. These results suggest the need for future studies examining the role of multiple sensory impairments on health outcomes that have sufficient power to examine multiple domains of sensory impairment simultaneously.

There are several important limitations to the analyses. First, the study included only Caucasian women, thus the results are limited in their generalizability across sex and ethnic groups. Second, a cognitive screening instrument (3MS) that was primarily administered verbally, with one component that required vision (copying an overlapping pentagon figure) was employed, which possibly biased against those with severe hearing and vision impairment. However, the study employed experienced clinicians who were instructed to indicate on the response sheet if the subject had difficulty hearing the questions, which happened infrequently, and none of the subjects had corrected vision worse than 20/100. Third, the prevalence of measured visual impairment (18%) in this cohort of community-residing older women is higher than that previously reported in population-based studies, such as the Salisbury Eye Evaluation Study¹ (7%) and the Blue Mountains Eye Study⁴⁵ (10%), and may be due to the older age of the SOF cohort. The use of a rigorous protocol for vision testing reduced the likelihood of a systematic bias in the way vision was tested, accounting for the observed difference. Because hearing was tested using hand-held audiometry, participants who used hearing aids could not wear them during testing. Even though adjustment for hearing aid use did not affect the influence of hearing impairment on cognitive function, the inability to measure corrected hearing may have biased the association with cognitive function toward the null.

Finally, the use of a convenience sample for sensory testing and the exclusion of subjects who had missing data for the outcomes of interest raise the possibility of a selection bias toward healthier subjects with less sensory impairment and lower rates of functional and cognitive decline than the population at large. Because of this, it is not appropriate to extrapolate from these observed rates of impairment to population-based samples.

This study demonstrates that vision impairment is associated with greater odds of cognitive and functional decline over time in older women. The findings also suggest that hearing impairment may be associated with increased odds of cognitive impairment over time. From a clinical perspective, screening for vision and hearing impairment in the elderly may not only improve the patient's short-term quality of life, but may also identify those who are at increased risk for future cognitive and functional decline. From a preventive standpoint, there is growing evidence that correcting vision^{46–48} and hearing^{4,46} impairments can lead to improvement in quality of life and functional status in the elderly. Further well-designed studies are needed to determine whether treating vision impairment can attenuate or prevent subsequent cognitive decline.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Honghu Liu for assisting with the interpretation of the multivariate models.

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