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# Hearing impairment and cognitive function among a community-dwelling population in Japan

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## Abstract

**Background:** Hearing impairment is a prevalent and chronic condition in older people. This study investigated the relationship between cognitive function and hearing impairment in a Japanese population.

**Methods:** A pure-tone average (0.5-2.0 kHz) was used to evaluate hearing impairment in 846 participants of the Iwaki Health Promotion Project who were aged at least 50 years old (310 men and 536 women). We also administered the Mini-Mental State Examination (MMSE), the Center for Epidemiologic Studies for Depression (CES-D) scale, Starkstein's apathy scale (AS) and the Short Form Health Survey Version 2 (SF-36v2). A multiple linear regression analysis assessed the association between hearing impairment and mental correlates.

**Results:** The overall prevalence of hearing impairment in this study population was 37.7%. The participants with hearing impairment were older and less educated compared to those with no hearing problems. We observed significant differences in the MMSE and AS scores between the mild/moderate to severe groups versus the non-impaired group. After adjusting for age, gender and amount of education, hearing impairment was significantly associated with MMSE and AS scores, but not with CES-D scores. Hearing impairment was significantly related to the social functioning (SF) and role emotional (RE) scores of the SF-36v2.

**Conclusions:** Hearing impairment is common among older people and is associated with cognitive impairment, apathy and a poor health-related quality of life. Screening for and correcting hearing impairments might improve the quality of life and functional status of older patients.

## Introduction

Age-related hearing impairment is a prevalent yet under-recognized health issue [1,2]. Previous studies [2-4] have reported a high prevalence of hearing impairment (between 35% and 45%) among older people. Hearing impairment is associated with decreased physical functioning, psychosocial impairments [5], increased social isolation [6], health condition [7] and health-related quality of life [8,9].

The association between hearing impairment and cognitive function has been recognized for many years [10]. In a case-control study, Uhlmann *et al.* [11] reported

that greater hearing impairment was associated with a higher probability of dementia. Furthermore, these authors stated that loss of sensory input due to hearing impairment might cause cognitive decline.

Some studies have also suggested that there is an association between hearing impairment and depression [1,12], whereas other studies have found no such association [13,14]. Differences in the samples and methods used as well as an inability to adjust for numerous potential confounders might explain these conflicting results. The coexistence of apathy, defined as reduced motivation or lack of initiative and motivation, among patients with late-onset depression, might also explain these differences [15,16]. Apathy may be confused with depression because both conditions feature loss of interest and initiative, fatigue and poor executive function in

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their symptomatologies [17]. Although several reports have mentioned that hearing impairment may increase the risk of depression, data are lacking regarding the relationship between hearing impairment and apathy.

The present study sought to clarify the relationship between hearing impairment and cognitive function in an older Japanese population. We also assessed the relationship between hearing impairment and apathy. To the best of our knowledge, this study is the largest to date to evaluate the association between hearing impairment and cognitive function in Japan.

## Methods

### Participants

The study was conducted between June 2008 and June 2009. We recruited 846 volunteers who were at least 50 years old (310 men and 536 women) and had participated in the Iwaki Health Promotion Project. The Ethics Committee of the Hirosaki University School of Medicine approved the data collection for this study. All participants provided written informed consent prior to the study. We obtained demographic data (age, gender, amount of education) using self-questionnaires and interviews.

### Hearing impairment assessment

A conventional audiometer (AA-73A, RION Co., Ltd. Tokyo, Japan) obtained air-conduction pure-tone thresholds in both ears at 500, 1,000 and 2,000 Hz. Using an average threshold over three frequencies for the better ear, we defined mild hearing impairment as participants who could not hear below 40 dB (to 25 dB) and moderate to severe hearing impairment as those who could not hear at higher thresholds than 40 dB.

### Assessment of mental correlates

The Mini-Mental State Examination (MMSE) was used to measure the participants' global cognitive status by assessing their orientation to place and time, short-term memory and episodic long-term memory, as well as their ability in subtraction, sentence construction and oral language ability. The maximum score on the MMSE is 30 [18].

To quantify apathy, we used the Japanese version of the Apathy Scale (AS) by Starkstein *et al.* [19-21]. The AS is a 14-item self-report scale that measures spontaneity, initiation, emotionality, activity level, and interest in hobbies. Answers were scored against four grades (0-3), and the total score was used for the analysis. The most reliable results were obtained at a cut-off score of 16 points.

The Center for Epidemiologic Studies for Depression (CES-D) scale was used to measure participants' depressive status [22,23]. This questionnaire has been used widely to measure depressive symptoms and screen for

depression [24,25]. The CES-D is a 20-item self-report measure that focuses on depressive symptoms over the previous week. The maximum score is 60, and lower scores are associated with greater depression.

The Short Form Health Survey Version 2 (SF-36v2) was used to assess participants' health-related quality of life (HRQOL). The SF-36v2 is a standardized international 36-item self-administered questionnaire that was translated, adapted, and validated for use in Japan [26]. This measures eight QOL domains of health status: physical functioning (PF), role physical (RP), bodily pain (BP), general health perception (GH), vitality (VT), social functioning (SF), role emotional (RE), and mental health (MH). For each QOL domain, a score ranging from 0 to 100 is calculated; higher scores indicate the higher perceptions of HRQOL. In addition, scores in all eight domains are combined to calculate more comprehensive indicators of physical and mental health: the Physical Component Summary (PCS), and the Mental Component Summary (MCS). The PCS and MCS are standardized (Japanese average = 50, standard deviation = 10) to compare to the general population or to results of other studies.

### Statistical analysis

We computed descriptive statistics to describe the demographic and clinical variables. A one-way analysis of variance (ANOVA) was used to compare demographic and clinical characteristics between groups. The Dunnett test was used for post hoc comparisons. Pearson's correlation analysis was used to assess the relationship between SF-36v2 scores and hearing impairment. After adjusting for confounding demographic factors (age, gender and amount of education), a multiple linear regression analysis was used to examine the relationships between hearing loss and MMSE, CES-D, AS and SF-36v2 scores. We considered a value of  $P < 0.05$  to be significant. We analyzed the data using PASW Statistics (v. 18) for Windows (SPSS Inc., Chicago, IL, USA).

## Results

### Demographic characteristics

The average hearing thresholds for participants who were 50-59, 60-69 and  $\geq 70$  years old were  $19.9 \pm 7.0$  dB,  $23.5 \pm 8.0$  dB and  $29.4 \pm 11.6$  dB, respectively. We divided the participants into three groups according to their level of hearing impairment thresholds: none ( $< 25$  dB),  $n = 527$ ; mild (25-39 dB),  $n = 265$ ; and moderate to severe ( $> 39$  dB),  $n = 54$ . The prevalence of hearing impairment in our sample was 37.7%. Table 1 lists the participants' clinical characteristics. The participants with hearing impairment were older and less educated compared to those with no hearing problems. In addition, we observed significant differences in the MMSE score between the mild/moderate to severe groups

**Table 1 Demographic characteristics of the subjects**

	Total, n = 846	Hearing impairment			ANOVA P value
		None (-24 dB), n = 527	Mild (25-39 dB), n = 265	Moderate to severe (-40 dB), n = 54	
Age	63.9 ± 8.3	61.3 ± 7.4	67.3 ± 7.9 <sup>a</sup>	72.6 ± 6.7 <sup>a</sup>	< 0.001
Amount of education	10.8 ± 2.2	11.3 ± 2.0	10.1 ± 2.2 <sup>a</sup>	9.1 ± 2.2 <sup>a</sup>	< 0.001
MMSE score	27.8 ± 2.6	28.3 ± 2.1	27.1 ± 2.8 <sup>a</sup>	25.6 ± 3.5 <sup>a</sup>	< 0.001
CES-D score	9.7 ± 6.1	9.5 ± 6.1	10.0 ± 6.3	10.0 ± 5.3	0.536
Apathy scale score	13.9 ± 6.3	13.4 ± 6.2	14.6 ± 6.5 <sup>a</sup>	15.2 ± 6.4 <sup>b</sup>	< 0.05

Data are presented as mean ± SD.

<sup>a</sup>Indicates a significant difference ( $P < 0.05$ ) from no hearing impairment group.

<sup>b</sup>Indicates a statistical trend with no hearing impairment group ( $P < 0.10$ ).

ANOVA = analysis of variance; CES-D = Center for Epidemiologic Studies for Depression scale; MMSE = Mini-Mental State Examination.

versus the non-impaired group. The mild hearing impairment group had higher AS scores than the non-impaired group, whereas the moderate to severe hearing impairment group did not.

#### SF-36v2 scores by degree of hearing impairment

Table 2 shows the SF-36v2 scores by degree of hearing impairment. We observed significant differences in PF, RP and PCS scores when we compared the mild and moderate to severe groups to the each auditory status subgroup was compared to the non-impaired group. The mild hearing impairment group showed lower BP scores and higher MCS scores compared to the non-impaired group, whereas the moderate to severe hearing impairment group did not. SF and RE scores were lower for the non-impaired group compared to the moderate to severe hearing impairment group.

#### Multiple regression analysis for mental correlates

Table 3 details the multiple regression analysis for the MMSE, CES-D and AS scores in association with age, gender and amount of education. MMSE and AS scores

were independently and significantly associated with hearing impairment.

#### The relationship between SF-36v2 scores and hearing impairment

Table 4 shows the single and multiple correlations between hearing impairment and SF-36v2 scores. We observed significant correlations between hearing level and the PF, RP, BP, SF, RE, PCS and MCS scores. After adjusting for age, gender and amount of education, the SF and RE scores were significantly related to hearing impairment.

#### Discussion

This study evaluated the association between hearing impairment and cognitive function among a community-dwelling population in Japan. The prevalence rate of hearing impairment in this sample was 37.7%; furthermore, we observed an age-related increase of hearing thresholds among participants. We found a significant association between hearing impairment and cognitive function using the MMSE. Hearing impairment was also

**Table 2 Short Form 36 (SF-36) scores by degree of hearing impairment**

	Total, n = 846	Hearing impairment			ANOVA P value
		None (-24 dB), n = 527	Mild (25-39 dB), n = 265	Moderate to severe (-40 dB), n = 54	
PF	80.7 ± 19.7	83.4 ± 18.7	76.6 ± 19.9 <sup>a</sup>	74.4 ± 23.2 <sup>a</sup>	< 0.001
RP	87.2 ± 20.5	89.1 ± 19.3	85.2 ± 21.1 <sup>a</sup>	78.7 ± 24.4 <sup>a</sup>	< 0.001
BP	71.3 ± 22.7	72.9 ± 22.4	68.7 ± 23.1 <sup>a</sup>	67.8 ± 21.8	< 0.05
GH	60.4 ± 17.6	60.5 ± 16.9	60.1 ± 19.1	61.2 ± 16.5	0.912
VT	65.8 ± 19.7	65.5 ± 19.4	67.1 ± 19.6	62.2 ± 22.0	0.210
SF	90.7 ± 17.2	91.2 ± 16.5	91.1 ± 16.9	83.3 ± 23.4 <sup>a</sup>	< 0.01
RE	89.7 ± 19.2	90.9 ± 18.0	89.4 ± 19.1	79.3 ± 26.7 <sup>a</sup>	< 0.001
MH	76.2 ± 17.7	75.8 ± 17.5	76.7 ± 18.2	76.9 ± 17.2	0.742
PCS	46.3 ± 12.4	48.0 ± 11.7	44.1 ± 12.3 <sup>a</sup>	40.2 ± 14.8 <sup>a</sup>	< 0.001
MCS	53.0 ± 9.0	52.4 ± 8.9	54.1 ± 9.2 <sup>a</sup>	53.8 ± 9.7	< 0.05

Data are presented as mean ± SD.

<sup>a</sup>Indicates a significant difference ( $P < 0.05$ ) from no hearing impairment group.

ANOVA = analysis of variance; BP = bodily pain; GH = general health perception; MCS = Mental Component Summary; MH = mental health; PCS = Physical Component Summary; PF = physical functioning; RE = role emotional; RP = role physical; SF = social functioning; VT = vitality.

**Table 3 Multiple regression analysis for mental correlates**

Independent variables		Beta coefficient	t Value	P value
MMSE	Age	-0.154	-4.220	< 0.001
	Gender	-0.170	-5.688	< 0.001
	Education	0.320	9.174	< 0.001
	Hearing level	-0.141	-4.177	< 0.001
CES-D score	Age	-0.058	-1.355	0.176
	Gender	-0.067	-1.915	0.056
	Education	-0.108	-2.652	< 0.01
	Hearing level	0.026	0.650	0.516
Apathy scale	Age	-0.087	-2.065	< 0.05
	Gender	-0.041	-1.183	0.237
	Education	-0.139	-3.476	< 0.01
	Hearing level	0.094	2.434	< 0.05

CES-D = Center for Epidemiologic Studies for Depression scale.

significantly related to AS scores, but not to CES-D scores.

Previous studies have shown that hearing ability predicts cognitive function. Multiple cross-sectional studies [12,27,28] have found a significant relationship between hearing impairment and cognitive function, even after adjusting for confounding factors. Furthermore, in longitudinal study on women who were at least 69 years old, Lin *et al.* [29] demonstrated that hearing impairment had tendency to associate with cognitive decline (OR 1.38, 95% CI 0.95 to 2.00).

Associations between hearing impairment and depression have also been reported. Some cross-sectional studies [1,12,30,31] have found a positive correlation between hearing impairment and depression. However, Gopinath *et al.* [14] did not find the association between hearing impairment and depression using the CES-D

**Table 4 Multiple correlation between Short Form 36 (SF-36) and hearing level**

	Single correlation		Multiple correlation				
	r	P value	B	SE	t Value	Beta	P value
PF	-0.173	< 0.001	-0.059	0.074	-0.790	-0.029	0.430
RP	-0.154	< 0.001	-0.082	0.079	-1.028	-0.038	0.304
BP	-0.091	< 0.01	-0.168	0.092	-1.828	-0.071	0.068
GH	-0.018	0.593	-0.042	0.071	-0.582	-0.023	0.561
VT	-0.006	0.852	-0.129	0.079	-1.628	-0.063	0.104
SF	-0.096	< 0.01	-0.151	0.070	-2.165	-0.084	< 0.05
RE	-0.154	< 0.001	-0.177	0.076	-2.332	-0.089	< 0.05
MH	0.011	0.751	-0.121	0.071	-1.698	-0.066	0.090
PCS	-0.208	< 0.001	-0.054	0.046	-1.186	-0.042	0.236
MCS	0.072	< 0.05	-0.061	0.035	-1.730	-0.065	0.084

Multiple model included age, gender and duration of education as confounders.

BP = bodily pain; GH = general health perception; MCS = Mental Component Summary; MH = mental health; PCS = Physical Component Summary; PF = physical functioning; RE = role emotional; RP = role physical; SF = social functioning; VT = vitality.

scale in participants who were at least 60 year old in the Blue Mountain study. In addition, Chou [13] did not find an association between hearing impairment and depression in the English Longitudinal Study of Aging in participants who were at least 50 year old. We found a relationship between hearing impairment related with apathy, but not with then CES-D scale. Previous studies [32,33] have suggested that apathy and depression have different etiologies in older people. Depression measurements often include items that evaluate apathy. Therefore, these depression measures might overestimate depression and underestimate of apathy [34-36].

In this study, hearing impairment was significantly associated with adjusted scores of SF-36v2 standardized scores in social functioning (SF) and role emotional (RE) domains. These results suggest that people with hearing impairment might experience more negative emotional reaction and social functioning limitations compared to participants without hearing problems. Conversely, previous studies [8,9] have noted that five or six domains of the SF-36 scores are related to hearing impairment after adjusting for confounders. The differences in these findings might be due to differences in sample size or ethnic group.

The mechanisms for the association between hearing impairment and cognitive function are not clear. One possible explanation for this relationship is that reductions in the quality or quantity of auditory input lead to structural or functional changes in the brain, which results in a decline of cognitive function. In this study, we found a relationship between hearing impairment and SF and RE scores on the SF-36v2. These aspects might cause cognitive decline or apathy. Another explanation might be that brain damage causes both hearing impairment and decline of mental function in older people. We did not image the brains of our participants, therefore we cannot evaluate this possibility.

The current study has several limitations. First, this study was cross-sectional study, so we cannot determine whether hearing impairment causes cognitive decline and apathy. To do so, a follow-up survey will be necessary. Second, the MMSE was primarily administered verbally; however, one component requires participants to copy an overlapping pentagon. This section might be biased against participants with severe hearing and vision impairments. Third, because all participants were volunteers with interests in their health, they may be healthier than the general population. Thus, those not in the study may have poorer cognitive outcomes [37]. This 'selective bias' must also be considered in studies of older populations. Although people with severe hearing impairments may not live to old age [38], our findings indicate that hearing impairment is an independent risk factor of cognitive decline.

## Conclusions

Hearing impairment is common among older people, and it is associated with cognitive impairment, apathy and poorer HRQOLs. Hearing impairment screening for older patients may not only improve patients' short-term QOL, but also identify those who are at increased risk for future cognitive decline and apathy. From a preventive standpoint, there is growing evidence that correcting hearing impairments can improve QOL and functional status in older people.

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## Authors' contributions

NS conceived the study, designed the study, conducted the statistical analysis, interpreted the data and wrote the initial draft of the manuscript. SK had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. AS, HS and NYF contributed to study design and assisted in drafting the manuscript. TU and SN completed initial survey construction, recruitment of participants. SK and AN participated in the data collection and the interpretation of the results. All authors have approved the manuscript.

## Competing interests

The authors declare that they have no competing interests.

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