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ORIGINAL ARTICLE

Effects of self-reported hearing or vision impairment on depressive symptoms: a population-based longitudinal study

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Aims. The aims of this study were to investigate the effects of either hearing, vision or dual sensory impairment on depressive symptoms and to identify subgroups that are vulnerable and significantly affected.

Methods. Data from the 2006–2014 Korean Longitudinal Study of Aging (KLoSA) were used and a total of 5832 individuals were included in this study. Depressive symptoms were assessed using the Center for Epidemiologic Studies Depression (CES-D10) scale. Sensory impairment was assessed according to the levels of self-reported hearing or vision, which were categorised as either good (excellent, very good or good) or poor (fair or poor). The changes in hearing or vision from records of previous survey were investigated. Changes from good to poor, which indicates new onset, were defined as hearing impairment or vision impairment. Interactions of changes in hearing and vision were considered in the analysis. Dual sensory impairment was indicated when hearing impairment and vision impairment both developed at the same time. Demographic, socioeconomic and health-related factors were considered as potential confounders and were adjusted for in the generalised estimating equation model.

Results. Individuals with hearing impairment demonstrated significantly more severe depressive symptoms [$\beta = 0.434$, standard errors (S.E.) = 0.097, $p < 0.001$] than those who had good hearing. Those with vision impairment also showed significantly elevated depressive symptoms ($\beta = 0.253$, S.E. = 0.058, $p < 0.001$) than those with good vision. When the interactions between hearing and vision were considered, participants with dual sensory impairment showed significantly more severe depressive symptoms ($\beta = 0.768$, S.E. = 0.197, $p < 0.001$) than those with good hearing and vision. The effect of a single and dual sensory impairment on depressive symptoms was significant in both sexes and across age groups, except for vision impairment in male participants.

Conclusions. Hearing, vision and dual sensory impairment are significantly associated with depressive symptoms. Our results suggest that treatment or rehabilitation of either hearing or vision impairment would help prevent depression.

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Key words: Depression, dual sensory impairment, hearing loss, vision loss.

Introduction

Impaired hearing and vision are the most common conditions affecting older adults (Gopinath *et al.* 2009, Schneider *et al.* 2011; Rim *et al.* 2014; Jun *et al.* 2015). These sensory impairments have been found to be associated with physical function (Wallhagen *et al.* 2001; Crews & Campbell, 2004; Chia *et al.* 2006), daily living (Brennan *et al.* 2005; Mikkola *et al.* 2015), mental health (Lin *et al.* 2004; Chia *et al.* 2006; Lin *et al.* 2011; Lin *et al.* 2013; Contrera *et al.* 2016) and even mortality (Lee *et al.* 2007). In addition, most studies that have investigated the effects of sensory impairment have reported an association between hearing impairment and depression (Abrams *et al.* 2006; Hallam *et al.* 2006; Evans *et al.* 2007; Ishine *et al.* 2007; Gopinath *et al.* 2009; Lee *et al.* 2010; Carlsson *et al.* 2015; Tseng *et al.* 2016), as well as between vision impairment and depression (Rovner & Ganguli, 1998; Nyman *et al.* 2010; Garin *et al.* 2014; Giloyan *et al.* 2015). However, other studies have yielded contrasting results (Pronk *et al.* 2011; Mener *et al.* 2013; Loprinzi &

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Codey, 2014; Rim *et al.* 2014). The burden of a single sensory impairment has not been well established even in studies reporting significant associations between dual sensory impairment and depression (Lupsakko *et al.* 2002; Crews & Campbell, 2004; Harada *et al.* 2008; McDonnall, 2009; Bernabei *et al.* 2011; Kiely *et al.* 2013; Yamada *et al.* 2014). Moreover, subgroup analyses of individuals vulnerable to sensory impairment have also yielded controversial results (Ives *et al.* 1995; Tambs, 2004; Harada *et al.* 2008; Gopinath *et al.* 2009; Nachtegaal *et al.* 2009; Li *et al.* 2014). Therefore, we conducted this study to investigate the association between depressive symptoms and hearing or vision impairment in a population-based longitudinal setting. Subgroups were analysed to see whose depressive symptoms were significantly affected by sensory impairment. The effect of additional sensory impairment to pre-existing sensory impairment was also investigated.

Methods

Participants

The Korean Longitudinal Study of Aging (KLoSA) is a nationally representative longitudinal survey that was initiated in 2006 and has been conducted every other year since. Households are selected using a multistage stratified probability sampling method based on geographical areas. Respondents aged ⩾45 years were interviewed using computer-assisted personal interviewing methods. The questionnaires include items on demographics, family and social networks, physical and mental health, employment and retirement, income, and wealth. A total of 10 254 respondents were enrolled in 2006, and 8688, 7920, 7486 and 7029 participants were followed in the second to fifth waves of the KLoSA, respectively. We selected individuals with eligible data for hearing and vision who were not diagnosed with depression in 2006. Finally, 5832 individuals were included in this study.

Self-reported hearing and vision

Study participants were asked to report their perception of hearing and vision in all waves of the KLoSA. The level of self-reported hearing and vision were evaluated with a five-point scale (excellent, very good, good, fair or poor) and categorised as good (excellent, very good or good) or poor (fair or poor). This type of self-reported assessment and categorisation is also used in the analysis of English Longitudinal Study of Ageing (Chou, 2008). Based on the assessments, either hearing or vision changes from that recorded in the previous survey were investigated to record the onset of sensory impairment. Changes from good to poor, which indicates new onset, were defined as hearing impairment or vision impairment. No change in poor sensory function was regarded as a pre-existing sensory impairment. When the hearing and vision impairment were found to develop at the same time, it was defined as dual sensory impairment. All the study participants were asked to report their use of hearing aid or spectacles.

Depressive symptoms

Depressive symptoms were assessed using the shortened Center for Epidemiologic Studies Depression (CES-D10) scale (Radloff, 1977). The shortened CES-D10 scale consists of ten items listed in the 20-item original version by establishing item-total correlations and eliminating redundant items (Andresen *et al.* 1994). The CES-D10 scale has shown good predictive accuracy when compared with its full-length 20-item version. The time frame for assessing depressive symptoms was 7 days prior to the interview. Scores for depressive symptoms were treated as a continuous measure ranging from 0 to 10, while scores higher than three points indicated depressive disorder at baseline (Irwin *et al.* 1999).

Other covariates

We included the following potential confounding factors in the analysis: sex, age (45–64, ⩾65 years), education (⩽6, 6–12, >12 years), marital status (married, divorced or bereaved, unmarried), economic activity (employed, unemployed), household income (in quartiles) and social isolation (not isolated, isolated). Participants who maintained contact with friends or family members less frequently than once a month were regarded as isolated (Steptoe *et al.* 2013). Health-related factors such as regular exercise (0 times/week, 1–3 times/week, 4–7 times/week), body mass index (⩽18.5, 18.5–23, ⩾23 kg/m^2), smoking status (never, former, current), alcohol consumption (never, former, current), hypertension, diabetes mellitus, cerebrovascular disease, cancer, chronic lung disease, arthritis and self-rated health (good, poor) were also included. Cognitive function was assessed with the Mini-Mental State Examination (MMSE). Based on the MMSE scores, study participants' cognition statuses were categorised as normal (24–30 points), mild cognitive impairment (19–23 points) or moderate-to-severe cognitive impairment (⩽18 points).

Statistical analysis

A descriptive analysis of the study population was conducted at baseline. Participant characteristics

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according to change in hearing or vision were analysed with the χ^2 test and Fisher's exact test. To evaluate the association between hearing or vision change and CES-D10 scores, a generalised estimating equation (GEE) model was used. The GEE model can be used to analyse longitudinal correlated data, and accounts for time variations and correlations among repeated measurements in a longitudinal study design. Since dependent variable was normally distributed, identity link function was used in the GEE model. We adjusted for all covariates including demographic, socio-economic and health-related factors when performing the analyses. The interactions of hearing or vision changes were also analysed after adjustment for potential confounders. Subgroup analysis was performed based on sex and age; the reference groups in all subgroup analyses were individuals who still had good hearing and vision. A p-value <0.05 was considered statistically significant. The SAS software 9.4 (SAS Institute, Cary, NC, USA) was used for the data analysis.

Results

A total of 5832 individuals were included in this study and the data of the participants were analysed. The general characteristics of the study population at baseline are shown in Table 1. The mean ± standard deviation (S.D.) age of all participants was 59.9 ± 10.4 years, and there were 2786 male and 3046 female participants. The mean CES-D10 scores of all participants at baseline was 1.4 (±1.0).

The participant characteristics were analysed according to changes in the self-reported hearing and vision from the previous survey (Table 2). There were 5298 participants who reported no change from good hearing, 224 reported a change from good to poor (hearing impairment), 200 reported a change from poor to good and 110 reported no change in poor hearing. In terms of self-reported vision, 3926 reported no change in good vision, 791 reported a change from good to poor (vision impairment), 662 reported a change from poor to good and 453 reported no change in poor vision.

After adjustment for time and covariates in the GEE model, the CES-D10 scores of individuals with hearing impairment were significantly higher [$\beta = 0.434$, standard error (S.E.) = 0.097, $p < 0.001$] than those of individuals reporting no change in good hearing (Table 3). However, association between hearing aid use and CES-D10 scores was not significant ($\beta = 0.109$, S.E. = 0.146, $p = 0.453$). Vision impairment also resulted in significantly increased CES-D10 scores ($\beta = 0.253$, S.E. = 0.058, $p < 0.001$) when compared with no change in good vision. Although participants reporting no change in poor hearing did not show a significant increase in CES-D10 scores ($\beta = 0.132$, S.E. = 0.169, $p = 0.435$), those who reported no change in poor vision demonstrated significantly increased CES-D10 scores ($\beta = 0.295$, S.E. = 0.082, $p < 0.001$). Association between spectacles use and CES-D10 scores was not significant ($\beta = -0.077$, S.E. = 0.049, $p = 0.114$).

When compared with no change in good hearing and good vision, single impairment resulted in significantly increased CES-D10 scores (hearing impairment, $\beta = 0.548$, S.E. = 0.134, $p < 0.001$; vision impairment, $\beta = 0.257$, S.E. = 0.061, $p < 0.001$). The CES-D10 scores of participants with dual sensory impairment were also significantly increased ($\beta = 0.768$, S.E. = 0.197, $p < 0.001$), and the estimated coefficient was higher than those for single sensory impairments (Table 4).

The effects of hearing impairment on CES-D10 scores were significant in both male ($\beta = 0.422$, S.E. = 0.171, $p = 0.014$) and female participants ($\beta = 0.718$, S.E. = 0.212, $p < 0.001$). However, the effects of vision impairment were not significant in male participants ($\beta = 0.061$, S.E. = 0.088, $p = 0.493$) but were significant in female participants ($\beta = 0.402$, S.E. = 0.085, $p < 0.001$). The effects of dual sensory impairment were significant in both sexes (male participants, $\beta = 0.720$, S.E. = 0.267, $p = 0.007$; female participants, $\beta = 0.801$, S.E. = 0.290, $p = 0.006$). The effect of single sensory impairment on CES-D10 scores was significant in middle-aged adults (hearing impairment, $\beta = 0.826$, S.E. = 0.236, $p < 0.001$; vision impairment, $\beta = 0.212$, S.E. = 0.086, $p = 0.014$). In older adults, single sensory impairment was also significantly associated with CES-D10 scores (hearing impairment, $\beta = 0.476$, S.E. = 0.164, $p = 0.004$; vision impairment, $\beta = 0.339$, S.E. = 0.090, $p < 0.001$). The effects of dual sensory impairment were also significant in both age groups (middle age, $\beta = 0.952$, S.E. = 0.412, $p = 0.021$; old age, $\beta = 0.692$, S.E. = 0.222, $p = 0.002$).

Discussion

In a previous cohort study, a moderate or more severe degree of hearing impairment was associated with elevated odds ratios for depression; similar results were observed for vision impairment as well (Wallhagen *et al.* 2001). Another population-based study also demonstrated higher odds ratios for depression in participants with hearing loss, vision loss or both (Capella-McDonnall, 2005). According to other studies, vision impairment is likely to have a more significant effect on depression than hearing impairment when the interactions are considered (Crews & Campbell, 2004; Chou, 2008; Bernabei *et al.* 2011). In contrast, in another longitudinal study, hearing loss was the

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Table 1. *General characteristics and CES-D10 scores of the study population at baseline (2006)*

Variables	*N* (%) (Total = 5832)	CES-D10 scores, mean (±S.D.)	*p*-value
Hearing			
Good	5522 (94.7)	1.4 (±1.0)	<0.001
Poor	310 (5.3)	1.6 (±1.0)	
Vision			
Good	4717 (80.9)	1.4 (±1.0)	<0.001
Poor	1115 (19.1)	1.5 (±1.0)	
Hearing aid use			
No	5639 (96.7)	1.4 (±1.0)	0.004
Yes	193 (3.3)	1.6 (±0.9)	
Spectacles use			
No	4393 (75.3)	1.4 (±1.0)	0.949
Yes	1439 (24.7)	1.4 (±1.0)	
Sex			
Male	2786 (47.8)	1.4 (±1.0)	0.001
Female	3046 (52.2)	1.4 (±1.0)	
Age (years)			
45–64	3897 (66.8)	1.3 (±1.0)	<0.001
⩾65	1935 (33.2)	1.5 (±1.0)	
Education (years)			
>12	2580 (44.2)	1.3 (±1.0)	<0.001
6–12	995 (17.1)	1.4 (±1.0)	
⩽6	2254 (38.6)	1.5 (±1.0)	
Marital status			
Married	4949 (84.9)	1.4 (±1.0)	<0.001
Divorced or widowed	854 (14.6)	1.6 (±1.0)	
Single	29 (0.5)	1.3 (±1.0)	
Economic activity			
Employed	2652 (45.5)	1.3 (±1.0)	<0.001
Unemployed	3180 (54.5)	1.5 (±1.0)	
Household income			
First quartile (high)	1208 (20.7)	1.3 (±1.0)	<0.001
Second quartile	1774 (30.4)	1.4 (±1.0)	
Third quartile	1330 (22.8)	1.4 (±1.0)	
Fourth quartile (low)	1147 (19.7)	1.6 (±0.9)	
Social isolation			
Not isolated	5025 (86.2)	1.4 (±1.0)	0.003
Isolated	807 (13.8)	1.3 (±1.1)	
Regular exercise			
0/week	3330 (57.1)	1.5 (±1.0)	<0.001
1–3/week	1016 (17.4)	1.3 (±1.0)	
4–7/week	1478 (25.3)	1.3 (±1.0)	
BMI (kg/m^2)			
18.5–23	2444 (41.9)	1.4 (±1.0)	0.007
⩾23	3107 (53.3)	1.4 (±1.0)	
⩽18.5	188 (3.2)	1.6 (±1.0)	
Smoking status			
Never	4085 (70.0)	1.4 (±1.0)	0.017
Former smoker	590 (10.1)	1.4 (±1.0)	
Current smoker	1156 (19.8)	1.3 (±1.0)	
Alcohol use			
Never	3080 (52.8)	1.4 (±1.0)	0.001
Former user	314 (5.4)	1.5 (±1.0)	
Current user	2438 (41.8)	1.4 (±1.0)	
Hypertension			
Yes	1410 (24.2)	1.5 (±1.0)	<0.001
No	4422 (75.8)	1.4 (±1.0)	
Diabetes			
Yes	578 (9.9)	1.5 (±1.0)	0.035
No	5254 (90.1)	1.4 (±1.0)	
Cerebrovascular disease			
Yes	95 (1.6)	1.6 (±1.0)	0.015
No	5724 (98.1)	1.4 (±1.0)	
Cancer			
Yes	100 (1.7)	1.5 (±1.0)	0.352
No	5732 (98.3)	1.4 (±1.0)	
Arthritis			
Yes	684 (11.7)	1.6 (±1.0)	<0.001
No	5148 (88.3)	1.4 (±1.0)	
Self-rated health			
Good	4758 (81.6)	1.3 (±1.0)	<0.001
Poor	1074 (18.4)	1.7 (±1.0)	
MMSE			
Normal	4778 (81.9)	1.3 (±1.0)	<0.001
Mild cognitive impairment	707 (12.1)	1.6 (±0.9)	
Moderate-to-severe cognitive impairment	268 (4.6)	1.8 (±1.0)	

BMI, body mass index; MMSE, Mini-Mental State Examination; CES-D10, Center for Epidemiologic Studies Depression scale – ten items; S.D., standard deviation.

main driver of the association between dual sensory impairment and increased depressive symptoms, whereas impaired visual function was not (Kiely *et al.* 2013). In our study, the results are consistent with those from the study performed by Capella-McDonnall (2005), which also used self-reported assessment for sensory impairment. In her study, Capella-McDonnall reported that participants with dual sensory loss, vision loss only or hearing loss only had higher odds of depressive symptoms compared with those with no sensory loss. Moreover, she demonstrated that dual sensory loss had more significant effect on depressive symptoms than hearing loss only.

One reason for the varying results among previous studies might have been caused by the differing characteristics of study populations investigated. The

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Table 2. *CES-D10 scores of the study population according to self-reported hearing and vision changes (2006–2008)*

	Change of hearing					Change of vision				
Variables	Good → good (n = 5.298)	Good → poor (n = 224)	Poor → good (n = 200)	Poor → poor (n = 110)	p-value	Good → good (n = 3.926)	Good → poor (n = 791)	Poor → good (n = 662)	Poor → poor (n = 453)	p-value
Sex										
Male	2.5 (±2.5)	4.2 (±2.8)	2.9 (±3.0)	3.9 (±2.8)	<0.001	2.4 (±2.5)	3.4 (±2.9)	2.7 (±2.6)	3.3 (±3.0)	<0.001
Female	3.1 (±2.7)	4.9 (±2.9)	4.1 (±3.2)	4.8 (±2.8)	<0.001	2.9 (±2.6)	4.1 (±2.9)	3.0 (±2.8)	4.3 (±3.0)	<0.001
Age (years)										
45–64	2.6 (±2.5)	3.3 (±2.4)	2.2 (±2.5)	1.2 (±1.7)	0.016	2.5 (±2.4)	3.2 (±2.7)	2.5 (±2.5)	2.8 (±2.8)	<0.001
⩾65	3.4 (±2.8)	4.8 (±2.9)	4.0 (±3.2)	4.7 (±2.7)	<0.001	3.2 (±2.7)	4.3 (±3.0)	3.3 (±2.8)	4.4 (±3.0)	<0.001
Education (years)										
>12	2.4 (±2.4)	3.0 (±2.3)	2.6 (±2.9)	3.6 (±3.0)	0.050	2.3 (±2.3)	3.0 (±2.7)	2.4 (±2.3)	3.1 (±2.9)	<0.001
6–12	2.8 (±2.6)	4.0 (±3.2)	2.6 (±2.9)	3.8 (±3.0)	0.064	2.6 (±2.5)	3.8 (±2.9)	2.5 (±2.7)	3.9 (±3.2)	<0.001
⩽6	3.4 (±2.8)	5.2 (±2.8)	4.1 (±3.2)	4.4 (±2.8)	<0.001	3.3 (±2.8)	4.4 (±3.0)	3.3 (±2.8)	4.2 (±3.0)	<0.001
Marital status										
Married	2.7 (±2.6)	4.2 (±2.8)	2.9 (±3.0)	3.7 (±2.7)	<0.001	2.6 (±2.5)	3.5 (±2.8)	2.7 (±2.6)	3.6 (±3.0)	<0.001
Divorced or widowed	3.7 (±2.9)	5.3 (±2.8)	4.6 (±3.2)	5.6 (±2.8)	<0.001	3.4 (±2.8)	4.9 (±3.0)	3.5 (±3.0)	4.7 (±2.8)	<0.001
Single	2.8 (±2.8)	.	7.5 (±0.7)	.	0.026	2.9 (±2.9)	3.0 (±4.2)	5.7 (±3.2)	1.5 (±0.7)	0.419
Economic activity										
Employed	2.4 (±2.4)	4.1 (±2.5)	2.3 (±2.7)	3.1 (±2.8)	<0.001	2.3 (±2.3)	2.9 (±2.6)	2.4 (±2.3)	3.0 (±2.7)	<0.001
Unemployed	3.3 (±2.8)	4.7 (±3.0)	4.0 (±3.2)	4.6 (±2.8)	<0.001	3.1 (±2.7)	4.3 (±3.0)	3.2 (±2.9)	4.3 (±3.0)	<0.001
Household income										
First quartile (high)	2.4 (±2.4)	4.3 (±3.1)	3.1 (±2.8)	5.1 (±3.0)	<0.001	2.3 (±2.3)	3.6 (±2.9)	2.4 (±2.4)	2.9 (±2.8)	<0.001
Second quartile	2.8 (±2.6)	4.3 (±2.6)	2.9 (±3.0)	3.2 (±2.9)	<0.001	2.7 (±2.5)	3.4 (±2.8)	2.7 (±2.6)	3.8 (±2.9)	<0.001
Third quartile	3.4 (±2.8)	4.7 (±2.8)	4.2 (±3.4)	4.2 (±2.6)	<0.001	3.2 (±2.7)	4.3 (±3.0)	3.6 (±2.8)	4.1 (±3.0)	<0.001
Fourth quartile (low)	3.7 (±3.0)	4.8 (±3.1)	4.1 (±3.3)	5.0 (±2.7)	0.077	3.7 (±3.0)	4.2 (±3.0)	3.1 (±2.8)	4.6 (±3.1)	0.023
Social isolation										
Not isolated	2.7 (±2.6)	4.1 (±2.8)	3.1 (±3.1)	3.9 (±2.8)	<0.001	2.6 (±2.5)	3.5 (±2.9)	2.7 (±2.6)	3.6 (±3.0)	<0.001
Isolated	4.1 (±2.8)	6.4 (±2.3)	5.3 (±3.0)	5.2 (±2.7)	<0.001	3.8 (±2.6)	5.6 (±2.7)	4.2 (±2.8)	5.5 (±2.9)	<0.001
Regular exercise										
0/week	3.1 (±2.7)	5.1 (±2.8)	3.9 (±3.3)	4.5 (±2.9)	<0.001	2.9 (±2.7)	4.3 (±3.0)	3.1 (±2.8)	4.3 (±3.0)	<0.001
1–3/week	2.3 (±2.2)	3.5 (±2.8)	2.0 (±2.2)	3.5 (±2.5)	0.031	2.1 (±2.1)	2.8 (±2.6)	2.6 (±2.3)	3.0 (±2.9)	<0.001

Continued

Table 2. *Continued*

Variables	Change of hearing					Change of vision				
	Good → good (n = 5.298)	Good → poor (n = 224)	Poor → good (n = 200)	Poor → poor (n = 110)	p-value	Good → good (n = 3.926)	Good → poor (n = 791)	Poor → good (n = 662)	Poor → poor (n = 453)	p-value
4–7/week	2.7 (±2.5)	3.1 (±2.6)	2.6 (±2.8)	3.6 (±2.9)	0.373	2.6 (±2.5)	3.2 (±2.7)	2.5 (±2.5)	3.1 (±2.9)	0.005
BMI (kg/m^2)										
18.5–23	2.9 (±2.6)	4.7 (±3.0)	3.7 (±3.1)	4.5 (±2.6)	<0.001	2.7 (±2.5)	4.1 (±3.0)	2.9 (±2.7)	3.9 (±2.9)	<0.001
⩾23	2.8 (±2.6)	4.0 (±2.7)	3.1 (±3.1)	3.4 (±3.0)	<0.001	2.7 (±2.5)	3.5 (±2.9)	2.8 (±2.6)	3.7 (±3.0)	<0.001
⩽18.5	3.4 (±2.8)	5.9 (±2.3)	4.3 (±3.6)	5.1 (±3.2)	<0.001	3.3 (±2.8)	4.8 (±3.1)	3.1 (±2.6)	4.6 (±3.1)	0.013
Smoking status										
Never	2.9 (±2.7)	4.7 (±2.9)	3.7 (±3.2)	4.7 (±2.8)	<0.001	2.8 (±2.6)	4.0 (±2.9)	2.9 (±2.7)	3.9 (±3.0)	<0.001
Former smoker	2.7 (±2.6)	4.4 (±2.8)	2.8 (±2.9)	3.6 (±2.9)	0.001	2.5 (±2.4)	3.8 (±3.0)	2.8 (±2.6)	3.7 (±3.0)	<0.001
Current smoker	2.6 (±2.6)	4.1 (±2.7)	3.3 (±3.3)	3.4 (±2.7)	<0.001	2.5 (±2.5)	3.0 (±2.8)	2.8 (±2.6)	3.9 (±3.0)	<0.001
Alcohol use										
Never	3.1 (±2.7)	4.6 (±2.9)	4.0 (±3.2)	4.6 (±2.8)	<0.001	3.0 (±2.7)	4.2 (±3.0)	2.9 (±2.7)	4.1 (±3.0)	<0.001
Former user	3.1 (±2.8)	5.0 (±2.9)	4.5 (±3.3)	4.1 (±2.7)	<0.001	2.8 (±2.6)	4.5 (±2.8)	3.7 (±3.1)	4.8 (±2.9)	<0.001
Current user	2.4 (±2.4)	4.2 (±2.8)	2.3 (±2.7)	3.9 (±3.0)	<0.001	2.4 (±2.4)	3.0 (±2.6)	2.6 (±2.6)	3.0 (±2.8)	<0.001
Hypertension										
Yes	3.2 (±2.8)	4.8 (±2.9)	4.1 (±3.4)	4.4 (±2.9)	<0.001	3.0 (±2.7)	4.5 (±3.0)	3.0 (±2.8)	4.1 (±3.0)	<0.001
No	2.7 (±2.6)	4.4 (±2.8)	3.0 (±3.0)	4.2 (±2.8)	<0.001	2.6 (±2.5)	3.5 (±2.8)	2.8 (±2.6)	3.7 (±3.0)	<0.001
Diabetes										
Yes	3.5 (±2.8)	4.8 (±2.8)	4.2 (±3.1)	4.7 (±2.7)	0.007	3.2 (±2.7)	4.7 (±3.1)	3.1 (±2.8)	4.3 (±3.0)	<0.001
No	2.8 (±2.6)	4.5 (±2.9)	3.4 (±3.2)	4.2 (±2.9)	<0.001	2.6 (±2.5)	3.6 (±2.9)	2.8 (±2.7)	3.8 (±3.0)	<0.001
Cerebrovascular disease										
Yes	4.4 (±3.0)	5.4 (±2.9)	6.1 (±3.8)	5.8 (±3.3)	0.182	4.1 (±2.8)	5.7 (±3.1)	3.8 (±3.4)	6.0 (±3.3)	0.010
No	2.8 (±2.6)	4.5 (±2.9)	3.3 (±3.0)	4.2 (±2.8)	<0.001	2.7 (±2.5)	3.7 (±2.9)	2.9 (±2.7)	3.8 (±3.0)	<0.001
Cancer										
Yes	3.8 (±2.9)	7.0 (±2.2)	5.1 (±3.2)	5.3 (±2.7)	0.052	3.4 (±2.8)	5.5 (±2.7)	3.9 (±2.7)	5.5 (±3.1)	0.003
No	2.8 (±2.6)	4.5 (±2.9)	3.4 (±3.1)	4.2 (±2.8)	<0.001	2.7 (±2.5)	3.8 (±2.9)	2.8 (±2.7)	3.8 (±3.0)	<0.001
Arthritis										
Yes	3.8 (±2.8)	5.1 (±2.9)	4.3 (±3.4)	4.5 (±2.8)	0.003	3.4 (±2.8)	4.5 (±2.9)	3.8 (±2.9)	4.8 (±2.7)	<0.001
No	2.7 (±2.6)	4.3 (±2.8)	3.2 (±3.1)	4.2 (±2.9)	<0.001	2.6 (±2.5)	3.6 (±2.9)	2.7 (±2.6)	3.5 (±3.1)	<0.001
Hearing aid use										
Yes	2.5 (±2.4)	3.4 (±2.6)	2.5 (±2.7)	3.1 (±2.8)	0.001	2.5 (±2.4)	2.8 (±2.5)	2.4 (±2.4)	2.8 (±2.6)	0.016
No	4.4 (±2.9)	5.4 (±2.8)	5.2 (±3.1)	5.1 (±2.6)	<0.001	4.0 (±2.8)	5.4 (±2.9)	4.5 (±2.9)	5.0 (±3.0)	<0.001
Spectacles use										
Yes	3.2 (±3.0)	4.6 (±3.2)	3.8 (±2.8)	5.1 (±2.4)	0.088	3.4 (±2.8)	3.8 (±3.5)	3.4 (±2.8)	4.7 (±3.1)	0.422
No	2.8 (±2.6)	4.5 (±2.8)	3.4 (±3.2)	4.1 (±2.9)	<0.001	2.7 (±2.5)	3.8 (±2.9)	2.9 (±2.7)	3.8 (±3.0)	<0.001

Self-rated health										
Good	2.9 (±2.7)	4.5 (±3.1)	3.9 (±3.3)	4.6 (±3.0)	<0.001	2.7 (±2.5)	3.9 (±3.1)	2.7 (±2.6)	3.4 (±3.0)	<0.001
Poor	2.8 (±2.6)	4.5 (±2.8)	3.3 (±3.1)	4.1 (±2.8)	<0.001	2.7 (±2.6)	3.8 (±2.9)	2.9 (±2.7)	4.2 (±3.0)	<0.001
MMSE										
Normal	2.5 (±2.4)	3.7 (±2.6)	2.4 (±2.6)	3.1 (±2.8)	<0.001	2.4 (±2.4)	3.0 (±2.6)	2.6 (±2.5)	3.3 (±2.9)	<0.001
Mild cognitive impairment	3.9 (±2.9)	5.0 (±2.8)	4.9 (±3.2)	4.3 (±2.1)	0.016	3.9 (±2.9)	5.0 (±2.8)	3.1 (±2.9)	4.4 (±2.9)	<0.001
Moderate-to-severe cognitive impairment	5.2 (±3.1)	6.3 (±2.6)	5.6 (±3.1)	5.8 (±2.8)	0.089	5.4 (±3.0)	6.2 (±2.8)	5.0 (±3.2)	5.3 (±3.0)	0.015

BMI, body mass index; MMSE, Mini-Mental State Examination; S.D., standard deviation.

studies that reported no evident effect of hearing impairment on depression included relatively older adults in the analysis (⩾61 years, Bernabei *et al.*; ⩾65 years, Chou; ⩾70 years, Crews *et al.*) when compared with other studies (⩾50 years, Wallhagen *et al.*; ⩾55 years, Capella-McDonnall) (Wallhagen *et al.* 2001; Crews & Campbell, 2004; Capella-McDonnall, 2005; Chou, 2008; Bernabei *et al.* 2011). The effect of hearing impairment on depression was limited to middle-aged adults according to previous studies (Tambs, 2004; Nachtegaal *et al.* 2009). Therefore, the effect might have been attenuated by the inclusion of an older population. Moreover, the effect of vision impairment has shown to differ according to age (Evans *et al.* 2007; Nyman *et al.* 2010; Garin *et al.* 2014). Therefore, when analysing the effect of sensory impairment on depression, population's age and categorisation should be carefully considered.

The sex ratio of study participants included could be another reason for the results. Li *et al.* (2014) and Ives *et al.* (1995) reported a significant association between hearing impairment and depression in women (Ives *et al.* 1995; Li *et al.* 2014). Harada *et al.* (2008) found that hearing impairment was related to elevated odds of depression in men, but vision impairment was not (Harada *et al.* 2008). In contrast, in their study, hearing impairment did not show increased odds for depression in women, but vision impairment did. The different effects of sensory impairment in each sex should be considered when establishing intervention strategies or planning further research.

Because we investigated the change in sensory impairment, the effect of newly developed single sensory impairment on depressive symptoms in participants who already had a sensory impairment could be investigated. To our knowledge, the effect of pre-existing sensory impairment prior to dual sensory impairment has thus far been investigated only by McDonnall in 2009 (McDonnall, 2009). She showed that vision impairment prior to dual sensory impairment was associated with more severe depressive symptoms, whereas pre-existing hearing impairment was not, similar to that observed in our study (McDonnall, 2009). Although the additional impacts of single sensory impairment remains inconclusive in the literature review (Schneider *et al.* 2011), the results indicate that the addition of a newly developed hearing impairment to a pre-existing vision impairment may have a greater impact on depression.

In clinical aspect, the differences shown in results might seem small. However, considering that CES-D10 scores of more than three points were treated as clinically significant depressive symptoms in the KLoSA survey, the differences do not represent a small change. Moreover, it needs to be considered

Table 3. *Results of generalised estimating equation for changes of hearing, vision and other covariates*

Variables	CES-D10 scores		
	β	S.E.	p-value
Change of hearing			
Good → good	Ref.		
Good → poor	0.434	0.097	<0.001
Poor → good	0.069	0.106	0.513
Poor → poor	0.132	0.169	0.435
Hearing aid user	0.109	0.146	0.453
Change of vision			
Good → good	Ref.		
Good → poor	0.253	0.058	<0.001
Poor → good	−0.022	0.057	0.700
Poor → poor	0.295	0.082	<0.001
Spectacles user	−0.077	0.049	0.114
Time (every 2 years)	−0.145	0.015	<0.001
Sex			
Male	Ref.		
Female	0.005	0.077	0.950
Age (years)			
45–64	Ref.		
⩾65	−0.004	0.056	0.940
Education (years)			
>12	Ref.		
6–12	0.124	0.072	0.086
⩽6	0.138	0.067	0.039
Marital status			
Married	Ref.		
Divorced or widowed	0.416	0.077	<0.001
Single	0.336	0.489	0.492
Economic activity			
Employed	Ref.		
Unemployed	0.415	0.049	<0.001
Household income			
First quartile (high)	Ref.		
Second quartile	0.115	0.049	0.019
Third quartile	0.301	0.065	<0.001
Fourth quartile (low)	0.135	0.101	0.180
Social isolation			
Not isolated	Ref.		
Isolated	1.110	0.069	<0.001
Regular exercise			
0/week	Ref.		
1–3/week	−0.294	0.052	<0.001
4–7/week	−0.208	0.047	<0.001
BMI (kg/m^2)			
18.5–23	Ref.		
⩾23	−0.085	0.044	0.057
⩽18.5	0.111	0.114	0.330
Smoking status			
Never	Ref.		
Former smoker	0.075	0.082	0.360
Current smoker	0.032	0.081	0.697
Alcohol use			
Never	Ref.		
Former user	0.319	0.087	<0.001
Current user	−0.096	0.061	0.113
Hypertension	−0.013	0.054	0.808
Diabetes	0.081	0.071	0.258
Cerebrovascular disease	0.590	0.126	<0.001
Cancer	0.419	0.112	<0.001
Chronic lung disease	0.091	0.172	0.599
Arthritis	0.190	0.070	0.006
Self-rated health			
Good	Ref.		
Poor	0.487	0.043	<0.001
MMSE			
Normal	Ref.		
Mild cognitive impairment	0.642	0.061	<0.001
Moderate-to-severe cognitive impairment	1.080	0.100	<0.001

BMI, body mass index; MMSE, Mini-Mental State Examination; CES-D10, Center for Epidemiologic Studies Depression scale – ten items; β, estimated coefficient; S.E., standard error; Ref., reference.
The effects of change in hearing or vision on depressive symptoms were analysed after adjustment for demographic, socioeconomic and health-related factors as potential confounders.

that the change happened only in 2 years, which indicates that the differences only occurred in the previous survey. Being in a poor sensory impairment without intervention, especially in dual sensory impairment, would aggravate depressive symptoms over time and lead to the development of clinically significant depressive symptoms in several years.

The underlying mechanisms of the association between sensory impairment and depression are not well known. The most commonly adopted aetiologies of depression are loneliness and social isolation caused by sensory deprivation (Dalton *et al.* 2003; Pronk *et al.* 2011; Chen *et al.* 2013; Steptoe *et al.* 2013). In support of the hypothesis, our results also showed that social isolation was a significant factor related to depression. The results emphasise the importance of social contact among people with impaired sensory functions.

The limitation of this study is the self-reported measurement of sensory impairment; nevertheless, we tried to use the same method as that in the English Longitudinal Study of Ageing (Chou, 2008). Although self-reported assessments of hearing or vision have been widely used, controversies regarding

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Table 4. *Results of generalised estimating equation for interaction between hearing and vision change*

	Change of vision											
	Good → good			Good → poor			Poor → good			Poor → poor		
Change of hearing	*β*	S.E.	*p*-value	*β*	S.E.	*p*-value	*β*	S.E.	*p*-value	*β*	S.E.	*p*-value
Total (*n* = 5832)												
Good → good	Ref.			0.257	0.061	<0.001	−0.041	0.059	0.491	0.261	0.089	0.003
Good → poor	0.548	0.134	<0.001	0.768	0.197	<0.001	0.259	0.269	0.336	0.440	0.208	0.034
Poor → good	−0.075	0.148	0.614	0.000	0.284	1.000	0.429	0.239	0.073	0.396	0.211	0.060
Poor → poor	−0.321	0.243	0.188	0.184	0.315	0.559	−0.165	0.347	0.634	1.038	0.277	<0.001
Males (*n* = 2786)												
Good → good	Ref.			0.061	0.088	0.493	0.038	0.088	0.662	0.129	0.144	0.372
Good → poor	0.422	0.171	0.014	0.720	0.267	0.007	0.268	0.351	0.446	0.526	0.306	0.086
Poor → good	−0.200	0.174	0.251	0.277	0.398	0.488	0.419	0.319	0.189	0.301	0.341	0.377
Poor → poor	−0.415	0.297	0.162	0.322	0.403	0.424	−0.412	0.435	0.345	0.713	0.334	0.033
Females (*n* = 3046)												
Good → good				0.402	0.085	<0.001	−0.090	0.080	0.263	0.341	0.112	0.002
Good → poor	0.718	0.212	<0.001	0.801	0.290	0.006	0.228	0.410	0.579	0.382	0.282	0.176
Poor → good	0.132	0.259	0.610	−0.298	0.392	0.447	0.446	0.355	0.209	0.505	0.265	0.056
Poor → poor	−0.047	0.430	0.913	−0.049	0.486	0.920	0.216	0.572	0.706	1.346	0.410	0.001
Middle age (45–64, *n* = 3897)												
Good → good	Ref.			0.212	0.086	0.014	−0.083	0.081	0.309	0.269	0.136	0.048
Good → poor	0.826	0.236	<0.001	0.952	0.412	0.021	2.097	0.670	0.002	0.527	0.404	0.191
Poor → good	0.016	0.247	0.949	−0.121	0.418	0.773	1.255	0.487	0.010	−0.372	0.547	0.497
Poor → poor	−0.392	0.465	0.399	−0.711	1.758	0.686	−0.467	1.206	0.699	−0.881	0.896	0.325
Old age (⩾65, *n* = 1935)												
Good → good	Ref.			0.339	0.090	<0.001	0.003	0.087	0.977	0.258	0.117	0.027
Good → poor	0.476	0.164	0.004	0.692	0.222	0.002	−0.036	0.286	0.899	0.460	0.227	0.043
Poor → good	−0.149	0.192	0.435	0.009	0.341	0.978	0.185	0.270	0.493	0.453	0.226	0.045
Poor → poor	−0.300	0.274	0.274	0.136	0.324	0.674	−0.204	0.362	0.574	1.176	0.286	<0.001

β, estimated coefficient; S.E., standard error; Ref., reference.

The effects of interactions between change in hearing and vision on depressive symptoms were analysed after adjustment for demographic, socioeconomic and health-related factors as potential confounders.

the effect of sensory impairment on depression identified via assessment methods exist (Rovner & Ganguli, 1998; Wallhagen *et al.* 2001; Tambs, 2004; Capella-McDonnall, 2005; Evans *et al.* 2007; Ishine *et al.* 2007; Chou, 2008; Lee *et al.* 2010; Bernabei *et al.* 2011; Pronk *et al.* 2011; Zhang *et al.* 2013; Garin *et al.* 2014; Li *et al.* 2014; Yamada *et al.* 2014; Giloyan *et al.* 2015). The study performed by Kiely *et al.* (2013) is noteworthy in that they used an objective measurement of hearing and vision in a large population (Kiely *et al.* 2013). According to their study, either hearing loss or dual sensory loss had significant effects on depressive symptoms, whereas vision loss did not. Interestingly, this result is contrary to previous studies that investigated the association between depression and hearing or vision impairments via self-reported measurements (Crews & Campbell, 2004; Chou, 2008; Bernabei *et al.* 2011). One study reported a significant effect of vision impairment or dual sensory impairment on depression, but not hearing impairment. These discrepancies could be attributable to the age effects of self-report measurement (Kiely *et al.* 2012). Therefore, careful consideration is required when interpreting results based on self-reported measurements.

Another limitation is the lack of data, which need to be considered for sensory impairment and depression. Data on nutrition or diet quality, which are known to be associated with not only depression but also sensory impairment, were not eligible to be obtained from the KLoSA (Jacka *et al.* 2010; Lin *et al.* 2010; Gopinath *et al.* 2014; Muurinen *et al.* 2014). In addition, CES-D10 scores of participants who did not have any depressive symptoms due to taking antidepressants were also not available. Although there were 126 participants who took antidepressants from second to fifth surveys, they had to be excluded from the analysis due to their lack of CES-D10 scores.

The strength of our study is the numerous covariates included in the analysis that might be potential confounders. We considered demographic, socioeconomic and health-related factors in the analyses, according to prior studies (Chou, 2008; Huang *et al.* 2010; Kiely *et al.* 2013). In terms of underlying medical condition, elevated depressive symptoms were associated with either arthritis, cerebrovascular disease or cancer, but not with hypertension or diabetes. Self-rated health was also significantly associated with depressive symptoms, as shown in the previous study (Ambresin *et al.* 2014). The associations, not only with medical conditions but also with education, marital status or cognitive impairment, were consistent with those reported by (Kiely *et al.* 2013).

Regarding correction of sensory impairment, several studies report that hearing aids or cochlear implants have a protective effect on depression (Gopinath *et al.* 2009; Boi *et al.* 2012; Mener *et al.* 2013; Castiglione *et al.* 2016; Choi *et al.* 2016). Interventions such as spectacles and cataract surgery also resulted in decreased symptoms of depression (Owsley *et al.* 2007; Meuleners *et al.* 2013). Although either the use of hearing aid or spectacles were not associated with decreased depressive symptoms in our study, newly developed sensory impairment warrants attention and interventions to improve mental health.

Conclusion

We demonstrated that depressive symptoms are significantly increased in individuals with newly developed hearing or vision impairment aged $\geqslant 45$ years when potential confounders are adjusted for. Significant effects of dual sensory impairment on depressive symptoms were also found when the interactions of hearing and vision were taken into consideration. The dual sensory impairment resulted in increased depressive symptoms across sexes and age groups. Our results suggest that more attention should be paid to people with newly developed sensory impairment to improve mental health.

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Conflicts of Interest

None.

Availability of Data and Materials

The raw data of Korean Longitudinal Study of Aging are available from the website of Korea Employment Information Service (http://survey.keis.or.kr/). Registration is required before to download the data.

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