Journal of Affective Disorders 344 (2024) 495–502

Contents lists available at ScienceDirect

Journal of Affective Disorders

journal homepage: www.elsevier.com/locate/jad

Research paper

Association between hearing loss and suicidal ideation: Discrepancy between pure tone audiometry and subjective hearing level

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ARTICLE INFO

Keywords:
Suicidal ideation
Hearing loss
Pure tone audiometry
Subjective hearing level

ABSTRACT

Background: This study aimed to evaluate hearing loss by combining pure tone audiometry (PTA) with subjective hearing level concerning suicidal ideation.
Methods: A total of 23,215 individuals from the Korea National Health and Nutrition Examination Survey (KNHANES) between 2009 and 2013 were included. PTA was categorized according to average audiometric threshold levels: normal (≤25 dB), mild (26–40 dB), and moderate-severe (>40 dB). The subjective hearing level was categorized as "no discomfort," "mild discomfort," and "considerable discomfort" for hearing without a hearing aid. Next, we classified hearing loss into nine groups by combining PTA and subjective hearing levels. Suicidal ideation was defined as answering yes to the following question: "Have you ever seriously thought about killing yourself in the past 1 year?" We conducted chi-square tests and multiple logistic regression analyses.
Results: Among the 23,215 participants aged ≥19 years (mean age 46.52 years), 3,214 (13%) reported having suicidal ideation. According to PTA, moderate to severe hearing loss was related to suicidal ideation (OR = 1.19, 95 % CI = 1.01–1.41). Subjective hearing loss was associated with suicidal ideation (mild: OR = 1.41, 95 % CI = 1.21–1.65; considerable: OR = 1.57, 95 % CI = 1.20–2.05). Moreover, as the subjective hearing level increased, the ORs of suicidal ideation increased in individuals with moderate to severe hearing loss (mild: OR = 1.52, 95 % CI = 1.24–1.88; considerable: OR = 1.81, 95 % CI = 1.39–2.36).
Limitations: The cross-sectional study limits the interpretation of causal relationships.
Conclusions: Subjective hearing loss was more strongly associated with suicidal ideation than hearing loss as measured by PTA.

1. Introduction

Hearing loss (HL) is a common chronic disease globally and is predicted to pose a disease burden ranking among the top ten by 2030 (Mathers and Loncar, 2006; Mathers et al., 2006). The total prevalence of HL in Korea is reportedly 22.73 %, with 9.31 % for unilateral HL and 13.42 % for bilateral HL (Jun et al., 2015). The prevalence of HL is high among older adults (Jun et al., 2015). As life expectancy and the older adult population increase worldwide, the percentage of HL may also increase among older adults (Christensen et al., 2009; Desai et al., 2001).

The measurement of HL includes pure tone audiometry (PTA) and subjective assessment of hearing. According to the results of PTA, HL is more prevalent in advanced age and individuals with diabetes, cardiovascular disease, and dementia (Abrams, 2017; Kim et al., 2020). When assessed by a self-reported questionnaire among 2438 participants, those with little trouble with hearing were classified as having mild HL (Dillard et al., 2022). Furthermore, those with moderate or high levels of trouble and deafness were categorized as having moderate or worse HL (Dillard et al., 2022). This cross-sectional study confirmed that mild, moderate, or worse HL is related to poor healthcare (i.e., access, quality, and satisfaction; (Dillard et al., 2022). Moreover, combining PTA and

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https://doi.org/10.1016/j.jad.2023.10.063
Received 16 March 2023; Received in revised form 29 September 2023; Accepted 9 October 2023
Available online 13 October 2023

subjective hearing level, previous studies classified participants as consistent, overestimating, and underestimating HL (Kim et al., 2017). Individuals with past medical records of hypertension and depression were associated with overestimated HL (Choi et al., 2019). Those who overestimated their HL were younger than those who underestimated their HL (Kamil et al., 2015; Kiely et al., 2012) and tended to be women more often (Kim et al., 2017).

HL can cause loneliness, social isolation, and poor health-related quality of life, which are related to physical functioning and mental health (Chia et al., 2007; Maharani et al., 2019; Weinstein and Ventry, 1982). According to previous systematic reviews, HL is associated with aspects of mental health, such as stress, anxiety, and depression (Jiang et al., 2020; Lawrence et al., 2020). In a study involving 84,850 adults, poor mental health was linked to suicidal risk factors for suicidal behaviors (i.e., suicidal ideation, plans, and attempts) (Nock et al., 2008). Previous studies have suggested that HL is also associated with suicidal behaviors, including suicidal ideation or suicidal attempts (Cosh et al., 2019a; Khurana et al., 2021; Parker et al., 2021).

In Korea, 14,636 suicide deaths were reported in 2009 (WHO, 2021), and the age-standardized suicide rate was 21.2 per 100,000 population (WHO, 2021). The World Health Organization (WHO) announced that suicide is a public health problem worldwide and is one of the leading causes of death (WHO, 2021). Among 547 new mothers with HL measured by PTA, 49.7 % of those with HL were related to suicidal ideation. In 2014, according to a cross-sectional study of 7546 individuals with HL assessed by self-reporting, adjusted odds ratios for suicidal thoughts and suicide attempts were 1.90 and 3.58 in those with HL, respectively (Khurana et al., 2021). In the Cosh study, mild and severe HL, measured by a self-reported questionnaire, were associated with suicidal ideation from 2006 to 2008 (Cosh et al., 2019a). According to follow-up data from 2008 to 2012, the odds ratios of suicidal ideation in individuals with mild and severe HL increased from 1.29 to 1.47 and 1.78 to 1.97, respectively (Cosh et al., 2019a). Altogether, previous studies support a relationship between HL and suicidal ideation measured HL using PTA or subjective hearing level.

However, there is scarce evidence on the relationship between HL (PTA and subjective hearing level) and suicidal ideation using nationally representative data. Moreover, few studies have examined the association between PTA in combination with subjective hearing level and suicidal ideation. According to a previous study that combined PTA with subjective hearing level, the results exhibited an accuracy of 81.0 % and a sensitivity of 72.4 % and reflected HL effectively (Louw et al., 2018). This study hypothesized, first, that HL would be associated with suicidal ideation. Second, we assumed that the ORs of suicidal ideation would show differences according to combinations of PTA and subjective hearing level. After combining PTA with subjective hearing level, this study aimed to evaluate whether PTA or subjective hearing level is associated with suicidal ideation. Furthermore, we sought to confirm this association by stratifying gender and age.

2. Methods

2.1. Data and study population

The Korea Health and Nutritional Examination Survey (KNHANES) is a nationally representative survey conducted by the Korea Centers for Disease Control and Prevention since 1998 (Kweon et al., 2014). In 1998, 2001, and 2005, the KNHANES investigated >30,000 participants aged ≥1 year (Kweon et al., 2014). Since 2007, the KNHANES has annually investigated approximately 10,000 participants aged >1 year (Kweon et al., 2014). In 2007, a survey was conducted from July to December, and 4594 individuals participated (Kweon et al., 2014). The KNHANES consists of health interviews, health examinations, and nutrition surveys conducted by professional investigators (Kweon et al., 2014). In the KNHANES we used, mental health questionnaires evaluated stress, experienced depression for more than two consecutive weeks, suicidal ideation, and suicidal attempts (Supplementary Table 1). In total, 44,085 participants were included in the KNHANES 2009–2013. In this study, we excluded individuals under the age of 19 years (n = 10,480); 33,605 participants were included. Next, we excluded individuals with missing information on HL (n = 9842) and individuals with missing values for subjective hearing (n = 75). Finally, after excluding individuals with missing data on suicidal ideation (n = 473), 23,215 participants were included for analysis in this study (Supplementary Fig. 1).

2.2. Exposure variables: hearing loss measured by pure-tone audiometry and subjective hearing level

2.2.1. Hearing loss measured by pure tone audiometry

PTA was measured by a professional examiner or a trained otolaryngologist in a soundproof booth using an automatic audiometer (GSI SA-203; Entomed Diagnostics AB, Lena Nodin, Sweden;(Kim et al., 2019). Pure tone threshold values were evaluated at six frequencies of 0.5, 1, 2, 4, and 6 kHz in the right and left ears, respectively. To ensure the Korean Society of Otorhinolaryngology-Head and Neck Surgery trained validity, professional examiners or trained otolaryngologists. HL was defined as the average audiometric threshold level for frequencies of 500, 1000, 2000, and 4000 Hz. We divided HL into three groups: "normal hearing (≤25 dB)," "mild HL (26–40 dB)," and "moderate-to-severe HL (>40 dB)" (Deal et al., 2017).

2.2.2. Subjective hearing level

Subjective hearing was defined using the following: "Choose responses that best describe your hearing without hearing aids (Kamil et al., 2015), with possible responses "no discomfort," "mild discomfort," "considerable discomfort," and "cannot hear at all." Subjective hearing levels were categorized into three groups: "no discomfort," "mild discomfort," and "considerable discomfort" when hearing without a hearing aid. The response "cannot hear at all" was included in "considerable discomfort."

2.2.3. Combination of pure-tone audiometry and subjective hearing level

We combined HL measured with PTA and subjective hearing level to construct nine groups (Fig. 1). Additionally, we classified the individuals into three groups according to discrepancies between PTA and subjective hearing levels as consistent, underestimated, and overestimated HL (Kim et al., 2017). The consistent group consisted of participants whose PTA results coincided with their subjective hearing level. For underestimated HL, PTA results were mild (26–40 dB) or moderate-to-severe (>40 dB), while subjective hearing was reported as no discomfort. Furthermore, the PTA result was moderate to severe (>40 dB), but subjective hearing was reported as mild discomfort. For overestimated HL, PTA results indicated normal hearing (≤25 dB), while subjective hearing was reported as mild or considerable discomfort. Additionally, the PTA result was mild (26–40 dB), but subjective hearing was reported as considerable discomfort.

2.3. Outcome variable: suicidal ideation

Suicidal ideation is indicated by the following question: "Within a recent 1 year, have you ever seriously thought about killing yourself?" We defined participants who answered yes to the suicidal ideation questionnaire as those with suicidal ideation.

2.4. Covariates

Covariates included gender, age (19–39, 40–59, ≥60 years), and sociodemographic variables (Conejero et al., 2016; Cosh et al., 2019a). These include household income, educational attainment, marital status (never married, married-living together, married-separate, divorced or widowed), comorbidity (Besser et al., 2018; Huh et al., 2021), and

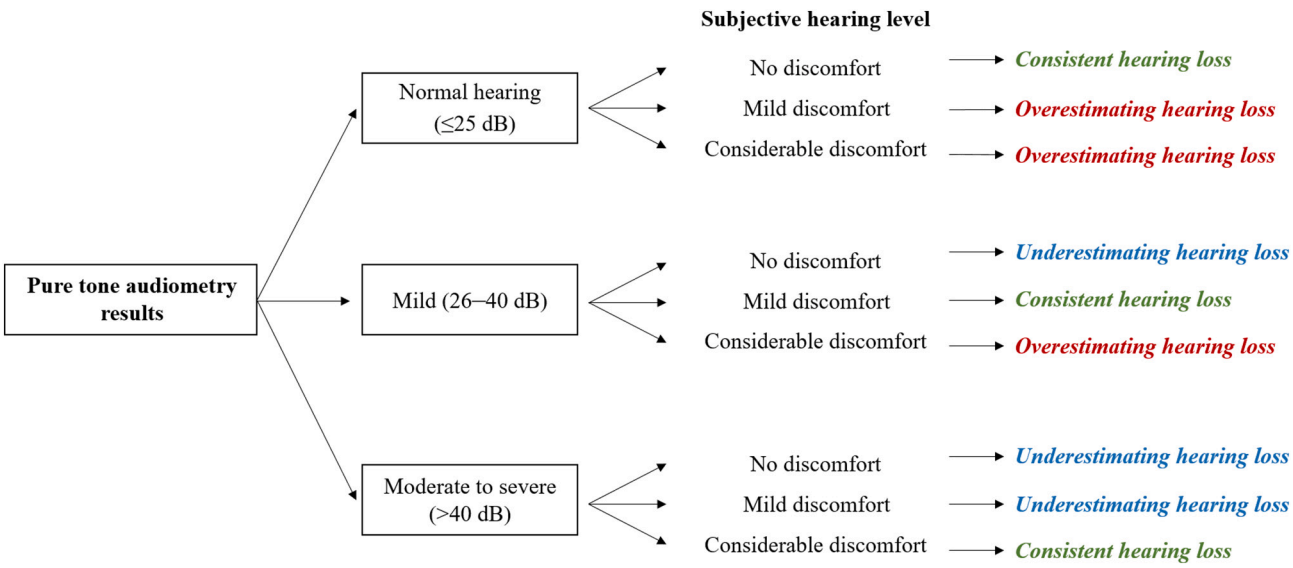

Fig. 1. Schematic diagram of combining pure tone audiometry with subjective hearing level: consistent, underestimating, overestimating hearing loss.

diagnosed depression (Arafat et al., 2022; Cosh et al., 2019b). Household income was defined as the monthly household income divided by the square root of the number of household members. Household income was grouped into the following quartiles: Q1 (lowest), Q2, Q3, and Q4 (highest). Based on the Korean education system, educational attainment (years) was divided into four groups: ≤6, 7–9, 10–12, and >12 years. Comorbidity was defined using the following question: "Have you ever been diagnosed with a chronic condition by a physician?" Comorbidity was defined as the number of chronic conditions (diabetes mellitus, stroke, myocardial infarction, hepatitis B, hypertension, angina arthritis, rheumatoid arthritis, asthma, and atopic dermatitis) divided into 0, 1, and 2 or more. Diagnosed depression was defined as individuals who answered "yes" to the following question: "Have you been diagnosed with depression by a physician?"

2.5. Statistical analyses

As KNHANES data were extracted using multistage stratified cluster sampling rather than simple random sampling, this study was analyzed by reflecting complex sampling. Weights were used to consider complex sampling elements in the analysis. As this study used data from 2009 to 2013, the integrated ratio for each year was calculated as a fifth in proportion to the survey period. The weight was calculated as each year's weight multiplied by the integrated ratio, as follows: $W_{09–13} = W_{09} \times (1/5)$, $W_{09–13} = W_{10} \times (1/5)$, $W_{09–13} = W_{11} \times (1/5)$, $W_{09–13} = W_{12} \times (1/5)$, and $W_{09–13} = W_{13} \times (1/5)$, according to KNHANES recommendation (Kim, 2014). The PROC SURVEYFREQ procedure and chi-square test were conducted to describe the baseline characteristics in this study. The PROC SURVEYLOGISTIC procedure was used to assess the association between HL and suicidal ideation. PTA and subjective hearing level, as measurements of HL, were analyzed. Next, this procedure was repeated to examine the relationship between combinations of PTA and subjective hearing levels and suicidal ideation. For all logistic models, odds ratio (OR) and 95 % confidence intervals (CI) were calculated. Model 1 was adjusted for gender and age. Model 2 additionally adjusted for sociodemographic variables (e.g., household income, educational attainment, and marital status). Model 3 additionally adjusted for comorbidity. Model 4 adjusted for the diagnosis of depression. We also conducted stratified analyses for gender (men and women) and age (19–39 years, 40–59 years, and ≥ 60 years). After conducting stratified analyses, we performed a sensitivity analysis per the tinnitus status. Previous studies have demonstrated an association between tinnitus and both HL and suicidal ideation (Han et al., 2018; Hannula et al., 2011; Spankovich et al., 2018). Therefore, we conducted a sensitivity analysis to investigate the association between HL (combination of PTA and subjective hearing level) and suicidal ideation according to tinnitus status. Statistical significance was set at $P < 0.05$. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Inc., Cary, NC, USA).

2.6. Ethical approval

This study was approved by the institutional review board of the KCDC (2009–01CON–03–2C, 2010–02CON–21–C, 2011–02CON–06–C, 2012–01EXP–01–2C, and 2013–07CON–03–4C).

3. Results

Table 1 shows the general characteristics of the study population according to suicidal ideation. Of the 23,215 participants, 3214 individuals showed suicidal ideation, and women had a higher percentage of suicidal ideation than men. Several participants with suicidal ideation were more likely to occur in the older age group (≥60 years), in the group with the lowest household income, and in the group with the lowest educational attainment (<6 years).

Table 2 shows the association between HL measured using PTA, subjective hearing level, and suicidal ideation. According to the PTA results, moderate to severe HL was associated with suicidal ideation, compared with normal hearing (OR = 1.19, 95 % CI = 1.01–1.41). As the level of subjective hearing elevated, the OR of suicidal ideation increased from 1.41 (mild trouble: 95 % CI = 1.21–1.65) to 1.57 (considerable trouble: 95 % CI = 1.20–2.05).

Table 3 presents the association between the combinations of PTA and subjective hearing levels and suicidal ideation. Regardless of the PTA results, we confirmed that elevated levels of subjective hearing were related to suicidal ideation. When PTA results were normal, the ORs for suicidal ideation increased as the level of subjective hearing increased in the fully adjusted model (normal hearing and mild discomfort: OR = 1.60, 95 % CI = 1.25–2.06; normal hearing and considerable discomfort: OR = 1.87, 95 % CI = 0.63–5.59). However, when PTA results were normal, participants with considerable discomfort were not significantly associated with suicidal ideation. Among participants with mild HL, as subjective hearing level elevated, the ORs for suicidal ideation increased from 1.45 (mild HL and mild discomfort: 95 % CI = 1.12–1.88) to 2.14 (mild HL and considerable discomfort: 95 % CI = 0.87–5.24). In this case, participants with mild HL and

Table 1
General characteristics of the study population in KNHANES 2009–2013 (weighted).

Variables	Suicidal ideation				P-value
	No (n = 20,001) (weighted *N* = 24,499,579, 87.0 %)		Yes (n = 3214) (weighted *N* = 3,671,997, 13.0 %)		
Gender					<0.0001
Men	8966	51.6	959	34.6	
Women	11,035	48.4	2255	65.4	
Age(years)					<0.0001
19–39	5361	35.0	777	33.2	
40–59	8208	44.6	1074	38.7	
≥60	6432	20.4	1363	28.1	
Household income					<0.0001
Q1(lowest)	3538	14.7	1033	27.2	
Q2	4998	26.2	839	27.4	
Q3	5487	29.4	730	25.4	
Q4(highest)	5791	29.7	578	20.0	
Educational attainment(years)					<0.0001
≤6	4776	17.8	1340	32.0	
7–9	2306	10.7	351	10.9	
10–12	6925	39.4	905	35.2	
>12	5965	32.0	611	21.9	
Marital status					<0.0001
Never married	15,217	71.5	2078	60.9	
Married-living together	124	0.6	35	1.1	
Married-separate	2203	8.8	679	17.5	
Divorced, widowed	2437	19.1	418	20.5	
Comorbidity					<0.0001
0	12,480	69.8	1647	60.5	
1	4640	21.2	778	22.6	
2+	2500	9.0	688	16.8	
Diagnosed depression					<0.0001
No	19,394	97.5	2822	87.8	
Yes	585	2.5	391	12.2	
Hearing loss by pure tone audiometry					<0.0001
Normal (≤25 dB)	13,997	76.2	1943	68.7	
Mild (26–40 dB)	3396	14.0	588	15.1	
Moderate to severe (>40 dB)	2608	9.8	683	16.1	
Subjective hearing level					<0.0001
No discomfort	17,174	88.5	2478	80.3	
Mild discomfort	2342	9.7	558	15.9	
Considerable discomfort	485	1.8	178	3.8	

Values are presented as number (weighted percentage).
The sum of numbers may not apply to the total number in group due to missing values.

considerable discomfort were not significantly related to suicidal ideation. Among individuals who did not report discomfort in subjective hearing, moderate to severe HL was related to suicidal ideation (OR = 1.37, 95 % CI = 1.14–1.66). Participants who had moderate to severe HL were associated with suicidal ideation as the subjective hearing level increased (moderate to severe HL and mild discomfort: OR = 1.52, 95 % CI = 1.24–1.88; moderate to severe HL and considerable discomfort: OR = 1.81, 95 % CI = 1.39–2.36).

The gender-stratified associations of PTA with subjective hearing level and suicidal ideation are presented in Supplementary Fig. 2. Among men and women who did not report discomfort in subjective hearing, men and women with moderate to severe HL were related to suicidal ideation. The ORs were significant at 1.40 (95 % CI = 1.02–1.93) and 1.31 (95 % CI = 1.03–1.66), respectively—among

Table 2
Association between hearing loss measured by pure tone audiometry, subjective hearing level, and suicidal ideation.

	N	Case	OR (95 % CI) for suicidal ideation				*p* for interaction
			Model 1	Model 2	Model 3	Model 4	
Measured HL by PTA							0.0530
Normal (≤25 dB)	15,940	1943	1.00	1.00	1.00	1.00	
Mild (26–40 dB)	3984	588	1.13 (0.98–1.30)	1.01 (0.87–1.18)	1.00 (0.86–1.16)	0.99 (0.85–1.16)	
Moderate to severe (>40 dB)	3291	683	1.38 (1.18–1.61)	1.16 (0.99–1.37)	1.19 (1.00–1.40)	1.19 (1.01–1.41)	
Subjective hearing level							
No discomfort	19,652	2478	1.00	1.00	1.00	1.00	
Mild discomfort	2900	558	1.55 (1.35–1.79)	1.50 (1.30–1.74)	1.46 (1.26–1.70)	1.41 (1.21–1.65)	
Considerable discomfort	663	178	1.73 (1.35–2.21)	1.64 (1.27–2.12)	1.58 (1.22–2.05)	1.57 (1.20–2.05)	

Hearing loss measured by pure-tone audiometry and subjective hearing level were included in one model.
Model 1: Adjusted for gender and age.
Model 2: Model 1 + Adjusted for household income, educational attainment, and marital status.
Model 3: Model 2 + Adjusted for comorbidity.
Model 4: Model 3 + Adjusted for diagnosed depression.
Abbreviations: HL = Hearing Loss; PTA = PureTone Audiometry.
P for interaction (PTA*subjective hearing level) = 0.0530.

Table 3
OR and 95 % CIs for the association between the combination of measured hearing loss by pure tone audiometry and subjective hearing level and suicidal ideation in KNHANES 2009–2013 (weighted).

	Subjective hearing level						
	No discomfort		Mild discomfort		Considerable discomfort		p-trend
	OR (95 % CI)	P-value	OR (95 % CI)	P-value	OR (95 % CI)	P-value	
Measured HL by PTA							<0.0001
Normal (≤25 dB)	1.00 (reference)		1.60 (1.25–2.06)	0.0003	1.87 (0.63–5.59)	0.2602	
Mild (26–40 dB)	0.98 (0.83–1.17)	0.8590	1.45 (1.12–1.88)	0.0049	2.14 (0.87–5.24)	0.0976	
Moderate to severe (>40 dB)	1.37 (1.14–1.66)	0.0011	1.52 (1.24–1.88)	<0.0001	1.81 (1.39–2.36)	<0.0001	

Adjusted for gender, age, household income, educational attainment, marital status, comorbidity, and diagnosed depression.
Abbreviations: HL = Hearing Loss; PTA = PureTone Audiometry.

women with moderate to severe HL, the ORs for suicidal ideation increased as subjective hearing levels increased (moderate to severe HL and mild discomfort: OR = 1.33, 95 % CI = 1.02–1.74; moderate to severe HL and considerable discomfort: OR = 1.98, 95 % CI = 1.39–2.82).

The age-specific associations of PTA with subjective hearing level and suicidal ideation are shown in Fig. 2. Among individuals aged 19–39 years and 40–59 years with normal PTA results, those who reported mild discomfort in subjective hearing were associated with suicidal ideation (19–39 years: OR = 2.21, 1.38–3.52; 40–59 years: OR = 1.55, 95 % CI = 1.09–2.19). Moreover, individuals aged 40–59 years with mild discomfort in subjective hearing and moderate to severe HL had the largest OR for suicidal ideation at 1.69 (95 % CI = 1.07–2.67). Among individuals older than 60 years, those with moderate to severe HL but no discomfort in subjective hearing were associated with suicidal ideation (OR = 1.52, 95 % CI = 1.20–1.92). Furthermore, as the subjective hearing level increased, the ORs for suicidal ideation increased from 1.50 (95 % CI = 1.18–1.90) to 2.16 (95 % CI = 1.59–2.94) among individuals with moderate to severe HL.

4. Discussion

In this cross-sectional study, we examined the association between HL and suicidal ideation according to combinations of PTA and subjective hearing levels. Among participants with moderate-to-severe HL, we confirmed that the ORs for suicidal ideation were associated with an increasing level of discomfort in subjective hearing.

There has been a previous study on disparities between PTA and subjective hearing (Kim et al., 2017). PTA and subjective hearing were measured in the same way as in our study (Kim et al., 2017). This cross-sectional study using data from KNHANES reported that individuals with concordant, overestimated, and underestimated HL accounted for 80.1 %, 7.1 %, and 12.8 %, respectively (Kim et al., 2017). As the level of education increased, the OR of overestimating or underestimating HL decreased (Kim et al., 2017). The overestimation group is related to stress, anxiety, and depression (Kim et al., 2017). According to our study, the prevalence of suicidal ideation among individuals overestimating HL was higher than that among individuals underestimating HL from 2009 to 2013 in an age-adjusted model (Supplementary Fig. 3).

Our results showed that subjective HL is associated more with suicidal ideation than HL measured by PTA. Few studies have elucidated the kind of HL with which suicidal ideation is more associated. Some studies have confirmed the relationship between suicidal ideation and subjective HL, not HL measured by PTA. Previous studies have reported that HL measured using self-reported questionnaires is related to suicidal ideation or attempts (Cosh et al., 2019a; Khurana et al., 2021; Parker et al., 2021). A previous study involving 7546 participants reported that participants with HL had suicidal ideation or suicide attempt (Khurana et al., 2021).

Moreover, the OR of suicide attempts was 1.5 times higher than that for suicidal ideation (Khurana et al., 2021). This study, conducted with subjective HL, had the same structure as our study (Khurana et al., 2021). In the Cosh study, which included 5438 older individuals over 73 years of age, those who reported discomfort or inability to understand conversation were divided into mild and severe HL groups, respectively (Cosh et al., 2019a). Mild and severe HL were associated with suicidal ideation in both the fourth and follow-up data (Cosh et al., 2019a). In a previous study involving HL as a disability status, the OR for moderate to high levels of suicide risk was 2.85 among participants with HL (Parker et al., 2021).

Our findings showed that participants with moderate to severe HL measured by PTA had suicidal ideation according to their subjective hearing level. Previous studies that measured HL using PTA also confirmed a relationship with suicidal ideation (Kim et al., 2020). In an earlier study that included 16,799 individuals from 2009 to 2012, suicidal ideation was associated with HL (Kim et al., 2020). Furthermore, a previous study involving 49.7 % of participants with HL among 547 new mothers measured HL using audiograms (Akram et al., 2020). In this study, the risk of suicidal ideation was associated with new mothers who had HL (Akram et al., 2020). As seen in previous studies, HL resulting from PTA has been confirmed to be associated with suicidal ideation.

Additionally, another cross-sectional study reported this association according to gender- and age-stratified analysis (Shin and Hwang, 2017). In a previous cross-sectional study involving 18,563 participants, the OR for suicidal ideation with HL was 1.36 among women but was not significant among men (Shin and Hwang, 2017). Among men aged 60 years and older, suicidal ideation was related to HL in a model adjusted for age (Shin and Hwang, 2017). Among women with HL, the OR for suicidal ideation in the group aged over 60 years was 1.32 but was not significant for the other age groups (Shin and Hwang, 2017).

Based on the results from Table 3, as the discomfort in subjective hearing increased among those with moderate to severe HL, the ORs for suicidal ideation were statistically significant. This way, moderate to severe HL measured by PTA showed a significant association with suicidal ideation, regardless of their discomfort in subjective hearing level. However, although the PTA was within the normal range, mild subjective HL demonstrated a significant relationship with suicidal ideation. Interpretation of these findings and possible mechanisms for the association between subjective HL rather than PTA and suicidal ideation are as follows. Individuals with subjective HL experience negative social environments (Chen and Zhou, 2020; Heine and Browning, 2004). In previous studies, social isolation caused by communication difficulties or lack of social support was shown to be associated with self-reported hearing difficulties (Chen and Zhou, 2020; Heine and Browning, 2004). Negative social environments, such as social exclusion, critical appraisal, and social isolation, may lead to suicidal ideation or suicidal attempts (Akram et al., 2018; Parker et al., 2021). However, emotional social support and instrumental support are preventive factors for individuals with subjective HL (Parker et al., 2021). Among participants with subjective HL, perceived social support was negatively associated with suicidal ideation (Akram et al., 2020). In summary, individuals experiencing discomfort in subjective hearing may face negative environments and social isolation, which can lead to suicidal ideation if these conditions persist. Therefore, it is deemed that providing

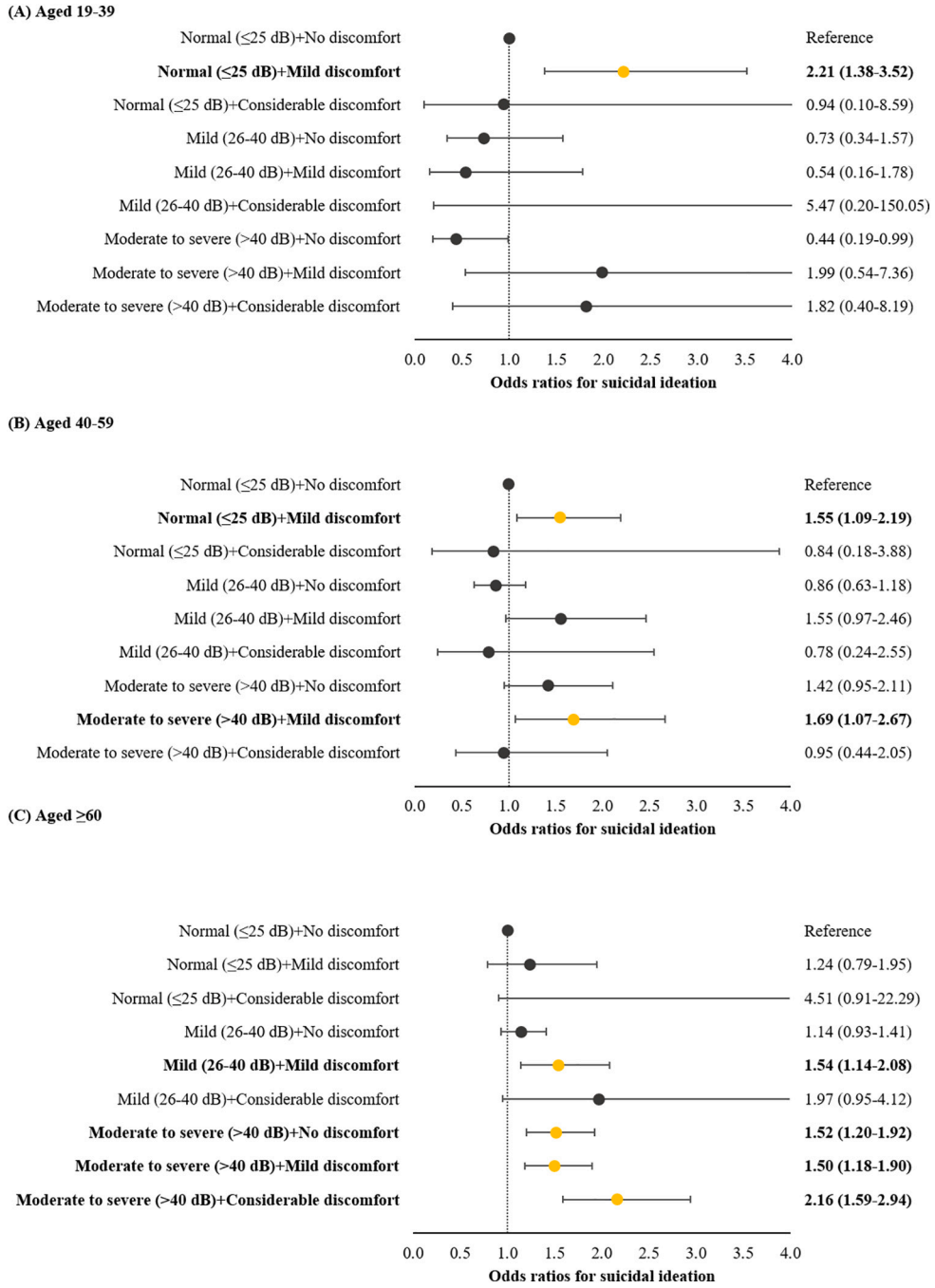

Fig. 2. Association between the combination of measured hearing loss by pure tone audiometry and subjective hearing level and suicidal ideation by age (KNHANES 2009–2013, weighted). ● indicates that it is statistically significant. Adjusted for gender, household income, educational attainment, marital status, comorbidity, and diagnosed depression.

emotional social support or instrumental support to people with subjective HL may prevent suicidal ideation. Our study also demonstrates a consistent message that an increase in discomfort in subjective hearing levels, regardless of PTA results, shows a linear trend with suicidal ideation (Table 3). Furthermore, a possible mechanism could be explained by the results of previous studies (Hannula et al., 2011; Spankovich et al., 2018). According to previous studies, discomfort in subjective hearing included tinnitus and was more frequently present than HL measured by PTA (Hannula et al., 2011; Spankovich et al., 2018). In a cross-sectional study involving 2176 population in the United States, participants with normal hearing by PTA but with past or persistent tinnitus were associated with subjective HL (Spankovich et al., 2018). A previous study including 28,930 individuals aged 19 years or older confirmed that tinnitus was related to suicidal ideation (Han et al., 2018). In our study, the OR for suicidal ideation showed a significant association in participants with normal hearing by PTA and mild discomfort in subjective hearing (Table 3). Our study's sensitivity analysis results showed that among individuals with tinnitus, those with normal hearing by PTA and mild discomfort in subjective hearing had a marginally significant association with suicidal ideation (Supplementary Table 3). Considering previous research and our results, one symptom that is more evident in the discomfort of subjective hearing than PTA is tinnitus. Therefore, individuals with normal hearing but mild subjective HL have significant implications for suicidal ideation.

This study has several limitations. First, we could not explain the causality of the associations because of the cross-sectional study design. This means that it is not possible to interpret whether suicidal ideation occurs at the same time as HL. Suicidal ideation usually occurs when an illness persists, or one is placed in a negative environment. Specifically, it is rare for people who think of suicide to have HL or to be diagnosed. Therefore, in this study, HL and suicidal ideation were used as the exposure and outcome variables, respectively. In future research, mental disorders, such as depression, suicidal ideation, and suicide attempts, should be designated in longitudinal studies among individuals with HL. Second, this study used KNHANES data from 2009 to 2013 rather than recent data. Due to changes in hearing equipment and measurement environment from 2009, we could not analyze data from 2009 to 2013 together with data from 2019 to 2020. Nevertheless, we used nationally representative data and targeted a larger population than previous studies. Third, suicidal ideation requires validation and reliability testing. However, suicidal ideation has been used as a term in other studies (Kye and Park, 2017; Song and Lee, 2016). A cross-sectional study that involved suicidal ideation (n = 5573) and suicidal attempts (n = 331) used the same questionnaire about suicidal ideation as our study (Song and Lee, 2016). In a previous study of 19,599 participants, researchers used an identical survey about suicidal ideation as that in our study (Kye and Park, 2017). Fourth, we did not measure other hearing-related factors due to data limitations. Previous studies have shown that factors such as noise exposure and tinnitus are associated with subjective HL (Spankovich et al., 2018). Additionally, tinnitus is related to suicidal ideation (Han et al., 2018). Therefore, we conducted a sensitivity analysis with the tinnitus variable (Supplementary Table 3). Further research should investigate the association between subjective hearing levels related to other otolaryngological factors and suicidal ideation. Lastly, there is no data on other mental disorders or a history of psychiatric disorders affecting suicidal ideation (Nock et al., 2008; Oquendo et al., 2005). However, since numerous studies have elaborated on the association between HL and depression, individuals diagnosed with depression by physicians were also used as a covariate variable in this study.

Despite these limitations, the results of our study have numerous strengths and significant implications for clinical trials. To the best of our knowledge, our findings provide robust evidence that subjective HL is more strongly associated with suicidal ideation than HL measured by PTA. Therefore, this study suggests that moderate to severe HL and more discomfort in subjective HL are more likely to be associated with suicidal ideation. Additionally, the present study used KNHANES, which presents nationally representative data for the general Korean population, conducted by clinical physicians, health interviewers, and professionally trained staff. Our findings were statistically significant in a larger population than reported in previous studies (Akram et al., 2018; Cosh et al., 2019a; Khurana et al., 2021; Kim et al., 2020; Parker et al., 2021; Shin and Hwang, 2017). Longitudinal research is needed to investigate the presence of suicidal ideation among individuals with HL. In future research, it is essential to conduct longitudinal observations to examine suicidal ideation among individuals with HL measured by PTA and those with discomfort in subjective hearing. As our research results indicate, more caution should be exercised regarding the suicidal ideation of people with subjective HL.

5. Conclusions

Our study combined PTA with subjective hearing to confirm whether PTA and subjective hearing have a higher association with suicidal ideation. We found that subjective HL was more strongly related to suicidal ideation than HL measured by PTA. Moreover, our results indicated that moderate to severe HL was associated with suicidal ideation according to the level of subjective HL. Our findings suggest essential considerations and evidence of suicidal ideation, which is a global public health problem that can lead to death. More attention to and timely interventions for suicidal ideation among individuals with subjective HL are warranted. Further studies should consider subjective HL to prevent poor mental health in primary care settings.

Funding/support

This research was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government (MSIT) (No. 2020R1C1C1003502).

Role of the funder/sponsor

The funding sources had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or the decision to submit the manuscript for publication.

CRediT authorship contribution statement

Jeong Hyun Ahn: Conceptualization, Methodology, Formal analysis, Data curation, Investigation, Project administration, Writing – original draft, Writing – review & editing. **Ji Su Yang:** Investigation, Writing – review & editing. **Jinsei Jung:** Conceptualization, Writing – review & editing. **Sunghyuk Kang:** Conceptualization, Writing – review & editing. **Sun Jae Jung:** Supervision, Conceptualization, Methodology, Data curation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We would like to thank Editage (www.editage.co.kr) for English language editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jad.2023.10.063.

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