Association Between Hearing Loss and Postural Instability in Older Korean Adults

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IMPORTANCE Hearing loss is one of the most frequently occurring sensory disabilities worldwide. The association between hearing loss and postural instability in an older population remains to be studied.

OBJECTIVE To determine whether the odds of postural instability increase with the degree of hearing loss and to suggest criteria for hearing rehabilitation for postural instability.

DESIGN, SETTING, AND PARTICIPANTS This cross-sectional population-based study of 3864 participants 40 years and older with hearing loss used data from 2010 through 2012 in the fifth edition of the Korea National Health and Nutrition Examination Survey, a nationwide survey of South Korea. Pure tone audiometry was performed on both the left and right sides and each hearing grade of each side was classified into 1 of 3 subcategories: normal hearing, mild hearing loss, or moderate hearing loss (moderate hearing loss or worse). Postural instability was defined as the failure to remain standing on a foam pad surface with feet 10 cm apart with arms folded and hands cupping the elbows and eyes closed. A binomial logistic regression model was used to assess the association between hearing loss and postural instability. Data were analyzed from August 18, 2019, to September 2, 2019.

EXPOSURES Age-related hearing loss defined as a threshold of 26 dB or more.

MAIN OUTCOMES AND MEASURES The degree of hearing loss and postural instability.

RESULTS Of the 3864 participants included in the study, the mean (SD) age was 57.8 (11.3) years and 2135 (55.2%) were women. Female sex was associated with higher odds of postural instability compared with male sex (odds ratio [OR], 1.65; 95% CI, 1.12-2.42, adjusted for age and hearing status), and the odds of postural instability increased with every 1 year increase in age (OR, 1.13; 95% CI, 1.10-1.16, adjusted for sex and hearing status). Unilateral or bilateral mild hearing loss was not associated with an increase in the odds of postural instability, but moderate hearing loss present on at least 1 side was associated with an increase in the odds of postural instability: unilateral moderate hearing loss group (OR, 2.71; 95% CI, 1.12-6.10, adjusted for age and sex), one mild and the other moderate hearing loss group (OR, 2.18; 95% CI, 1.16-4.09, adjusted for age and sex), and bilateral moderate hearing loss group (OR, 2.34; 95% CI, 1.27-4.33, adjusted for age and sex).

CONCLUSIONS AND RELEVANCE Aging, female sex, and having hearing loss were associated with postural instability in this analysis. Moderate or worse hearing loss present on at least 1 side was associated with increased odds of postural instability. Future research in this area is warranted to identify more precise interrelationships and preventive measures.
Hearing loss affects 6.1% of the world’s population and is one of the most frequently occurring sensory disabilities. Hearing loss results from the accumulation of sensory cell damage in the inner ear and is the most common chronic disorder in the aging population. Sensory cells of the inner ear lack regenerative capacity making this damage hard to correct. This change also affects vestibular organs, and many patients with age-related hearing loss also experience dizziness.

Hearing loss and dizziness are associated with falls, one of the most common and serious health problems in older adults. Retaining balance function is a complex process involving various sensory inputs from vestibular and motor organs. As aging disrupts these processes, postural instability or falls occur. Hearing loss is also reported to be an independent risk factor of falls and is adversely affected by aging.

Auditory and vestibular systems function together although their exact mechanism of interaction is not clear. To date, there is a lack of studies analyzing the association between hearing loss and postural instability in the general population. A 2019 study of hearing loss and fall-related injury analyzed self-reported symptoms and history rather than objective measurements. There is also a lack of understanding of the degree or type of hearing loss that accompanies postural instability. In the present study, the association between hearing loss and postural instability in people 40 years and older was analyzed using the Korea National Health and Nutrition Examination Survey data from 2010 through 2012, and we present criteria for identifying the hearing loss group at risk for developing concurrent postural instability.

**Methods**

**Study Population**

This cross-sectional study includes data from 2010 through 2012 from the fifth Korea National Health and Nutrition Examination Survey, a survey of the South Korean population (51.6 million) performed by the Korean Ministry of Health and Welfare. This nationwide survey includes health and nutrition interviews and health examinations. A yearly recruitment of 10,000 to 12,000 individuals in approximately 4600 households is performed to represent the population using a multistage clustered and stratified random sampling method. Hearing tests were performed in participants 12 years and older and dizziness tests were conducted in participants 40 years and older. Therefore, all participants who underwent both tests were more than 40 years old. A total of 3864 participants were included in this study. Data were analyzed from August 18, 2019, to September 2, 2019. This study was approved by the institutional review board of the Korean Centers for Disease Control and Prevention, and all participants provided written informed consent.

**Assessment of Hearing Loss**

Hearing loss was determined using the mean values of the frequency thresholds of 0.5, 1, 2, and 3 kHz measured by pure tone audiometry. Hearing loss was defined as a mean threshold of 26 dB or more, with a threshold of 26 to 40 dB classified as mild hearing loss and a threshold of more than 40 dB classified as moderate hearing loss. Thus, hearing loss was classified into 3 categories: normal, mild hearing loss (threshold of 26-40 dB), and moderate hearing loss (threshold of more than 40 dB). Right and left hearing were independently evaluated. Based on these categories, we classified the study participants into 6 groups: bilateral normal, unilateral mild hearing loss, bilateral mild hearing loss, unilateral moderate hearing loss, bilateral moderate hearing loss, and unilateral mild hearing loss and contralateral moderate hearing loss.

**Assessment of Postural Instability**

Postural instability evaluation of participants in the Korea National Health and Nutrition Examination Survey was performed by the foam balance test using a 50 cm × 50 cm × 12 cm polyurethane foam pad. Participants were asked to stand with feet 10 cm apart with arms folded and hands cupping the elbows and to keep their body as stable as possible. The duration was measured in seconds until balance was lost (falling, side-stepping, hopping, or pivoting) under 4 different conditions. Condition 1 was on a firm surface (not on a polyurethane foam pad) with the eyes open. Condition 2 was the same as condition 1 except that participants were asked to close their eyes. Conditions 3 and 4 were the same as conditions 1 and 2, respectively, except that participants were on a foam pad surface. Participants who could maintain the stance for 15 seconds in conditions 1 and 2 were deemed to have passed the test. Conditions 3 and 4 were determined based on the same standard as conditions 1 and 2 except that the test time was 20 seconds.

Condition 1 allowed the participant to use all sensory inputs (vision, vestibular function, and proprioception) to maintain the stance. Condition 2 blocked the participant from receiving visual information. Condition 3 allowed the participant to receive reduced somatosensory input and proprioception. Condition 4 allowed the participant to rely only on vestibular function.

All participants were required to perform all 4 conditions, but only the results of condition 4 were used to assess the association between auditory and vestibular function. Postural instability was defined as a participant who failed under condition 4.
Statistical analyses were performed using Statistical Package for the Social Sciences, version 22.0 (IBM). Data were expressed using mean and SD for quantitative measures. Comparison between 2 selected groups of sex, age and hearing threshold was performed using t test and χ² test. A binomial logistic regression model was used to assess the association between hearing loss and postural instability. Odds ratios (ORs) and 95% CIs were calculated. Because postural instability was thought to be affected by sex or age, an adjusted OR was calculated for these 2 factors. Effect sizes were estimated through Cohen $d$.

**Results**

A total of 3864 participants 40 years and older were included in the study, with a mean (SD) age of 57.8 (11.3) years; 2135 (55.2%) were women (Table 1). The mean (SD) hearing threshold was 22.21 (17.17) dB on the right side and 23.16 (18.03) dB on the left side. Postural instability was identified in 127 participants (3.3%). There were no statistically significant differences in age or mean hearing thresholds between men and women.

Table 2 shows a comparison between participants with and without postural instability in condition 4. There were no statistically significant differences in age (Cohen $d = 1.31$; 95% CI, 1.13-1.49) or mean hearing thresholds (for right side mean [SD], pass: 21.7 [16.7] dB vs fail 38.6 [22.8] dB; Cohen $d = 1.00$; 95% CI, 0.83-1.18) between participants with or without postural instability.

Table 3 shows the number of participants identified in each hearing state category with the number of people who did not meet condition 4. The incidence of postural instability was high in the following order: bilateral moderate hearing loss group (33 of 280 [11.8%]), one mild and the other moderate hearing loss group (23 of 261 [8.8%]), and unilateral moderate hearing loss group (25 of 383 [6.5%]). The incidence of postural instability in severe hearing loss participants (hearing threshold between 71-90 dB, n = 156, unilateral or bilateral) and profound hearing loss participants (hearing threshold greater than 91 dB, n = 67, unilateral or bilateral) was 12.2% ($n = 19$) and 11.9% ($n = 8$).

Table 4 shows an OR of postural instability by hearing state, which is adjusted for age and sex. A total of 38.7% of participants had some form of hearing loss, and the proportion of unilateral mild hearing loss was the highest at 10.4%. Women had a 1.65-fold (95% CI, 1.12-2.42) increased odds of postural instability than men. For every 1 year increase in age, there was a 1.13-fold (95% CI, 1.10-1.16) increase in the odds of postural instability occurring. There was no increase in the odds of postural instability in unilateral and bilateral mild hearing loss. However, moderate hearing loss on at least 1 side was associated with an increase in postural instability: OR, 2.71 (95% CI, 1.20-6.10) in unilateral moderate hearing loss group; 2.18 (95% CI, 1.16-4.09) in one mild and the other moderate hearing loss group; and 2.34 (95% CI, 1.27-4.33) in the bilateral moderate hearing loss group.

**Discussion**

Age-related changes are associated with substantial medical costs, and such changes should no longer be neglected but actively managed. Hearing loss and postural instability are both common changes associated with aging and are both modifiable risk factors associated with a person’s survival, function, and medical care costs. Falls are the most obvious example of a serious medical problem and are factors associated with hospitalization.

Previous studies focused on the association between hearing loss and postural instability. A 2014 study reported the postural stability in bilateral hearing aid users older than 65 years in both aided and unaided conditions. Romberg examination on foam pads and tandem gait tests were conducted in a white-noise environment. There was better postural stability reported in the hearing aided conditions. A 2016 study reported the postural stability in 4 acoustic environments using a Nintendo Wii Balance Board and foam pad test. The researchers suggested that...
sound cues facilitate postural control in both normal hearing and aided hearing-impaired participants. Two studies have attempted to demonstrate the association between vestibular dysfunction and presbycusis through a vestibular evoked myogenic potentials test.\(^20,21\)

The present study investigated the association between hearing loss and postural instability. The analysis was based on large-scale data from the Korea National Health and Nutrition Examination Survey V, and the foam balance test used in the previous studies\(^18,19\) was selected as an assessment modality for postural stability. As reported in 2019,\(^22\) women and older persons were at higher odds for postural instability. We also examined the association of hearing loss with postural instability using a binomial logistic regression model. Although mild hearing loss was not associated with postural instability, higher odds of postural instability were associated with moderate hearing loss. The results were similar to those described by Lin et al\(^2\) in a 2012 study but different in that Lin et al\(^3\) used only self-reported falling history in the past 12 months and used only the hearing threshold of the better side. Those researchers did not include results from a combination of the left and right sides.

Currently, there are multiple criteria and standards regarding hearing loss, hearing aid use, and medical insurance coverage. The degree of hearing loss is also classified differently in different methods, but the classifications defined by the American Speech-Language-Hearing Association and World Health Organization are the most widely used.\(^23\) However, there are few studies of the association between hearing loss and postural instability. There is also a lack of criteria or indicators regarding associations of postural instability accompanying hearing loss. With a large number of participants, the results of this study suggest that the patient who has moderate hearing loss in at least 1 side is at higher odds of experiencing postural instability and may benefit from early rehabilitation.

This study confirmed an association between hearing loss and postural instability. Hearing rehabilitation is usually considered when troubled communication or failed hearing tests occur. A notable finding of this study is the possible role of and criteria for auditory rehabilitation for the purpose of modifying postural instability. With various levels and combinations of binaural hearing, the study may provide practical criteria for clinical practice.

### Table 3. Number of Study Participants in Each Hearing Group and the Number of Participants With Postural Instability

<table>
<thead>
<tr>
<th>Hearing group</th>
<th>Total No.</th>
<th>Participants with postural instability, No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilateral normal</td>
<td>2370</td>
<td>26 (1.1)</td>
</tr>
<tr>
<td>Hearing loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unilateral</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>402</td>
<td>11 (2.7)</td>
</tr>
<tr>
<td>Moderate group</td>
<td>383</td>
<td>25 (6.52)</td>
</tr>
<tr>
<td>Bilateral mild</td>
<td>168</td>
<td>9 (5.35)</td>
</tr>
<tr>
<td>Hearing loss group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One mild and the other moderate</td>
<td>261</td>
<td>23 (8.81)</td>
</tr>
<tr>
<td>Bilateral moderate</td>
<td>280</td>
<td>33 (11.78)</td>
</tr>
</tbody>
</table>

### Table 4. Logistic Regression Analysis of the Odds Ratio of Postural Instability Associated With Hearing Loss

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR (95% CI)</th>
<th>Unadjusted</th>
<th>Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1.39 (0.97-2.01)</td>
<td>1.65 (1.12-2.42)</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>1.15 (1.13-1.18)</td>
<td>1.13 (1.10-1.16)</td>
<td></td>
</tr>
<tr>
<td>Bilateral normal</td>
<td>1 [Reference]</td>
<td>1 [Reference]</td>
<td></td>
</tr>
<tr>
<td>Hearing loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unilateral</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>2.54 (1.24-5.18)</td>
<td>1.22 (0.59-2.54)</td>
<td></td>
</tr>
<tr>
<td>Moderate group</td>
<td>6.30 (3.60-11.02)</td>
<td>2.71 (1.20-6.10)</td>
<td></td>
</tr>
<tr>
<td>Bilateral mild</td>
<td>5.10 (2.35-11.08)</td>
<td>1.70 (0.92-3.11)</td>
<td></td>
</tr>
<tr>
<td>Hearing loss group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild + moderate*</td>
<td>8.71 (4.89-15.51)</td>
<td>2.18 (1.16-4.09)</td>
<td></td>
</tr>
<tr>
<td>Bilateral moderate</td>
<td>12.05 (7.09-20.47)</td>
<td>2.34 (1.27-4.33)</td>
<td></td>
</tr>
</tbody>
</table>

* One mild and the other moderate hearing loss.

Although the exact mechanism is less clear, the association between hearing loss and postural instability has been demonstrated in several studies. In addition, hearing loss is considered to be associated with other dysfunctions such as dementia and depression.\(^24-26\) Hearing loss should be considered not just a matter of hearing, but an important risk factor affecting overall quality of life. Future research in this area is warranted to identify more precise interrelationships and preventive measures.

### Limitations
This study has several limitations. First, this cross-sectional study did not exclude temporary dizziness because the design did not sufficiently reflect changes over time. In addition, evaluation through the foam pad test included in the fifth edition of the Korea National Health and Nutrition Examination Survey requires attention to interpretation because it has the disadvantage that it can be affected by physical ability as well as vestibular function. In terms of research design, it may be a limitation to divide the hearing loss grade into mild and moderate. The moderate hearing loss group included moderate, severe, and profound hearing loss because the study was designed to ascertain the degree of hearing loss associated with postural instability. Hearing loss was not further subcategorized into severe or profound categories because with fewer participants, subcategorization could result in too many combinations of hearing loss status, which could have hindered statistical analysis.

### Conclusions
In this study, age, being female, and having moderate hearing loss were associated with postural instability among participants 40 years and older. It may be helpful to consider these findings when making recommendations or research on hearing rehabilitation to prevent postural instability.
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**ARTICLE INFORMATION**

Accepted for Publication: February 18, 2020.

Published Online: April 23, 2020.

Author Contributions: Drs Bang and Chae had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Bang, Lee, Choi, Song, Chae.

Acquisition, analysis, or interpretation of data: Bang, Jeon, Chae.

Drafting of the manuscript: Bang, Jeon, Lee, Choi, Song.

Critical revision of the manuscript for important intellectual content: Bang, Jeon, Chae.

Statistical analysis: Bang, Jeon, Song.

Obtained funding: Chae.

Administrative, technical, or material support: Lee, Song.

Supervision: Choi, Song.

Conflict of Interest Disclosures: Dr Chae reported receiving grants from the National Research Foundation of Korea during the conduct of the study. No other disclosures were reported.

Funding/Support: This study was supported by a National Research Foundation of Korea grant funded by the Korean government (2017M3A9G1027929).

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; and decision to submit the manuscript for publication.

REFERENCES


