Dietary vitamin intake correlates with hearing thresholds in the older population: the Korean National Health and Nutrition Examination Survey1–3

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ABSTRACT

Background: Previous animal studies have shown that vitamins may prevent age-related hearing loss. However, no concrete conclusions have been reached about the association between vitamin intake and presbycusis in humans.

Objective: We investigated the association between dietary vitamin intake and hearing thresholds in adults between 50 and 80 y of age by using data from a large population-based survey.

Design: We used data from the 2011 Korea National Health and Nutrition Examination Survey. A pure-tone audiogram and physical examination of the ear were performed, and vitamin intake was calculated by using the 24-h recall method. Data from 1910 participants were analyzed through univariate and multivariate linear regression analyses.

Results: After adjustment for age, sex, smoking, and exposure to occupational and explosive noise, intake of vitamin C correlated with better hearing at midfrequency (2000 and 3000 Hz) (coefficient: −0.012; 95% CI: −0.022, −0.002). Dietary supplement use was positively associated with better hearing at all frequencies. The univariate analysis indicated that dietary intakes of retinol, riboflavin, niacin, and vitamin C were positively correlated with better hearing at most frequencies. In contrast, serum concentrations of vitamin D were associated with worse hearing at mid and high (4000 and 6000 Hz) frequencies.

Conclusions: Dietary intake of vitamin C was associated with better hearing in the older population. Because less than one-half of elderly participants in this study consumed a sufficient amount of vitamins, and vitamin intake decreased with age, we should consider proper diet counseling to prevent hearing decline. Am J Clin Nutr 2014;99:1407–13.

INTRODUCTION

Age-related hearing loss, otherwise known as presbycusis, is one of the most-common disorders and affects 40–50% of the elderly population (1). Presbycusis reduces the quality of life in the elderly by causing impaired verbal language processing and communication, which can lead to social isolation and depression (2, 3). Various factors, such as noise exposure and genetic background, have been suggested as possible factors that contribute to presbycusis (4). However, the pathogenesis of presbycusis is not yet well understood, and once sensorineural hearing has deteriorated with age, restoring hearing thresholds to normal levels is impossible; therefore, the prevention of presbycusis is critical. To this end, the elucidation of modifying factors that help to prevent age-related hearing loss is greatly needed.

Studies that used animals have shown that vitamins can prevent noise- and drug-induced hearing loss (5–7). Furthermore, vitamin supplementation has been shown to reduce risk of hearing loss caused by middle-ear infections (8) and protect against the development of idiopathic hearing loss in humans (9, 10). Vitamins are also helpful in the prevention of age-related hearing loss in animals. The combination of various antioxidants, including vitamins C and B-12, can prevent age-related hearing loss in mice (11), and vitamins C and E have been shown to reduce cochlear degeneration in aging dogs (12). However, there has been no consensus on the beneficial effect of vitamins on presbycusis in large population-based studies. Serum concentrations of retinol have been associated with a lower prevalence of hearing impairment in older adults (1), and dietary intakes of vitamins A, C, and E have been negatively associated with the prevalence of presbycusis (13, 14). However, prospective studies have not shown any significant effect of these vitamins in the prevention of presbycusis (15). Causes of these conflicting data may include differences in study populations, methods of determining hearing loss, and confounding factors considered during analyses. In addition, some previous studies did not rule out middle-ear problems, which can cause conductive hearing loss.

We analyzed the association between vitamin profiles and hearing thresholds in an older population by using data from the Korean National Health and Nutrition Examination Survey (KNHANES), which evaluated pure-tone hearing thresholds in a single race after ruling out conductive hearing loss by a physical examination.
SUBJECTS AND METHODS

Study population

The KNHANES is a national survey conducted annually by the Korea Centers for Disease Control and Prevention to investigate the health and nutritional status of a representative Korean population. We used data from the KNHANES V-2 conducted in 2011. In 8518 total participants that survey year, 3253 subjects were between 50 and 80 y old. We focused on this population because age-related hearing loss becomes progressively worse in adults >50 y of age (16). Participants with any of the following conditions were excluded: 1) history of chemotherapy for malignant disease, 2) history of antituberculosis medication, 3) history of severe dizziness, which could be associated with otologic diseases such as Meniere disease or perilymph fistula, 4) external- or middle-ear problems on physical examination, or 5) incomplete nutritional data. After the exclusion of these individuals, data from 1910 participants were analyzed. All participants from the KNHANES V-2 signed an informed consent form, and the Institutional Review Board of Severance Hospital, Yonsei University College of Medicine, approved the analyses.

Physical examination and pure-tone audiometry

Ear examinations were performed by ear, nose, and throat residents by using a 4-mm, 0° endoscope (Xion GmbH) and the ML 150 vision system (JRMed Trade). The air-conduction hearing threshold was measured by well-trained examiners in a double-walled, soundproof booth by using an automatic audiometer (SA-203; Entomed) at 500, 1000, 2000, 3000, 4000, and 6000 Hz. In this study, the pure-tone audiogram average (PTA) was calculated as the average threshold of all 6 frequencies. We included the 6000-Hz threshold to detect early presbycusis. We also calculated average thresholds at low-frequency (500 and 1000 Hz), midfrequency (2000 and 3000 Hz), and high-frequency (4000 and 6000 Hz) ranges. Because the average hearing threshold of the left ear (29.54 ± 0.39 dB) appeared to be worse than that of the right ear (28.48 ± 0.39 dB) (P < 0.001), as was consistent with finding of previous reports (17), we used only left-ear data for a stricter analysis.

Data collection of possible risk factors for hearing loss

Nutritional status and other variables in the KNHANES were obtained through a self-reported survey. BMI (in kg/m²) was calculated by dividing weight by the square of height. Smoking history was positive if subjects had smoked ≥5 pack-years during their entire lives. Histories of explosive or occupational noise exposure were considered positive or negative according to the recall of subjects. An explosive noise was defined as a sudden loud noise such as an explosion or gunshot. Exposure to occupational noise was determined by whether the participant had worked in a location with loud machines for ≥3 mo. A loud noise was defined by whether the participant had to raise his or her voice to hold a conversation. Subjects were asked if they had ever been diagnosed with diabetes, hypertension, myocardiac infarction, or acute angina by a doctor. A history of dietary supplementation was positive if subjects had taken any kind of supplements continuously for >2 wk during the past year and >1 time/wk during the past month.

Assessment of intakes of carotenoid, retinol, thiamin, riboflavin, niacin, and vitamin C

Food intake was surveyed by trained staff by using the complete 24-h recall method. Answers were written on paper, and we did not exclude any certain days such as holidays or weekends. Intakes of carotenoids, retinol, riboflavin, niacin, and vitamin C were calculated by referencing nutrient concentrations in foods according to the Korean Food Composition Table (18). The amount of intake was compared with the recommended amount of daily vitamin consumption for Koreans (19). For retinol and carotenoids, there was no recommended intake. Therefore, we calculated the intake of vitamin A by using the following formula (20):

\[ \text{Intake of vitamin A (µg retinol equivalent/d)} = \text{intake of retinol (µg/d)} + \left[ \text{intake of carotenoid (µg/d)} ÷ 6 \right] \]

Serum vitamin D concentrations in blood samples collected in the morning after a ≥8-h fast were measured with a γ counter (1470 Wizard; Perkin-Elmer) by using a radioimmunoassay assay (DiaSorin).

Statistical analyses

All data were analyzed with SPSS software (version 17.0; SPSS Inc). Student’s t test was used to compare differences in mean values between 2 groups with continuous variables. We calculated Spearman’s correlation coefficient to evaluate the correlation between 2 variables that did not show a normal distribution. In addition, univariate analyses of variables were performed to confirm the association between hearing levels and each variable. Finally, a multiple linear regression analysis was performed to evaluate the independent effect of each variable. In addition, we calculated the adjusted coefficient and 95% CI.

RESULTS

Hearing levels according to age, sex, and noise exposure

Demographic data of the study population are presented in Table 1. As expected, the PTA at 6 frequencies increased, indicating worse hearing, with age (Spearman’s r = 0.524, P < 0.001) (Figure 1A), and the PTA of men was significantly higher (worse) than that of women (P < 0.001) (Figure 1B). Compared with nonexposed subjects, participants who had a history of exposure to explosive noise showed poorer hearing (higher PTA) (P < 0.001) (Figure 1C). There was no significant difference in PTA between subjects exposed to occupational noise and the nonexposed group (P = 0.063) (Figure 1D). However, the group exposed to occupational noise had significantly worse hearing than that of the nonexposed group at frequencies of 3000 and 4000 Hz (data not shown).

Vitamin profiles of participants

Daily dietary intakes of various vitamins and serum vitamin D concentrations are shown in Table 2 as medians with IQRs. Overall, dietary vitamin intakes at suggested intakes were higher
in men than women. Only 26.5%, 36.3%, 38.4%, and 41.8% of women consumed recommended intakes (19) or more of riboflavin, niacin, vitamin C, and vitamin A, respectively, whereas 30.9%, 55.2%, 47.5%, and 46.5% of men ingested sufficient amounts of those vitamins, respectively.

### Vitamin profiles and hearing thresholds

The highest quartile (75th–100th percentile) of participants for intake of carotenoids, retinol, riboflavin, niacin, and vitamin C had significantly better hearing (lower PTA) than that of the lowest quartile (0–25th percentile) in the low- (500 and 1000 Hz), mid- (2000 and 3000 Hz), and high-frequency (4000 and 6000 Hz) ranges. In contrast, compared with the lowest quartile, the quartile with the highest serum vitamin D concentration had worse hearing (higher PTA) in the mid- and high-frequency ranges (Figure 2, A–C; see Supplemental Table 1 under “Supplemental data” in the online issue). In addition, hearing thresholds of subjects who used dietary supplementation was significantly lower (better hearing) in all frequency ranges than those of subjects who did not take any dietary supplementation (Figure 2D; see Supplemental Table 1 under “Supplemental data” in the online issue). Results of the univariate analysis between the left-ear hearing level at each frequency and vitamin-status profiles are shown in Table 3. Higher intakes of retinol, riboflavin, niacin, and vitamin C were positively correlated with better hearing at some selective frequencies. Higher intake of carotenoids was associated with better hearing at the midfrequency, however, the correlation coefficient was very low ($R < 0.001$). High serum vitamin D concentrations were associated with worse hearing at mid- and high-frequency ranges. See Supplemental Figure 1 under “Supplemental data” in the online issue for the relation between vitamin intake and the hearing threshold of the left ear at midfrequency.

### Multivariate analysis

We analyzed the independent effects of vitamins on hearing by using a multivariate linear regression analysis adjusted for age, sex, smoking history, BMI, medical history (diabetes, hypertension, and cardiovascular disease), supplement use, exposure to explosive noise, and exposure to occupational noise (Figure 3). We showed that the relation between vitamin C intake and the hearing threshold was the most relevant in the various vitamins. Specifically, vitamin C showed a significant correlation with better hearing (lower threshold) at midfrequency (2000 and 3000 Hz) (coefficient: $-0.012$; 95% CI: $-0.022$, $-0.002$). Unlike the results of the univariate analysis, riboflavin, retinol, niacin, and vitamin D showed no significant correlations with the hearing threshold at any frequency. However, intake of supplements showed a significant positive correlation with better hearing (lower threshold) at all frequency ranges (see Supplemental Table 2 under “Supplemental data” in the online issue).

### Vitamin profile and age

We analyzed correlations between vitamin profiles and age, which was the most influential factor in presbycusis. We showed that, as age increased, intakes of retinol, carotenoid, riboflavin, niacin, and vitamin C decreased ($P < 0.001$). Serum vitamin D concentrations increased with age ($P < 0.001$) (Table 4).

### DISCUSSION

In our analysis, a high dietary intake of vitamin C showed a positive association with better hearing at the midfrequency range, even after we accounted for other confounding factors such as age, sex, and noise exposure. In addition, the highest quartile of participants for vitamin C intake had much better hearing than did the lowest quartile for both high and low frequencies. Our data were consistent with a previous report that indicated that short-term supplementation of vitamin C in individuals with age-related hearing loss resulted in an improvement in hearing sensitivity (22). However, population-based studies have shown conflicting results. Intake of vitamin C did not reduce the occurrence of hearing loss in adults >60 y of age in a prospective cohort study (15). Similarly, another cross-sectional study showed that high intake of vitamin C was not significantly associated with the prevalence of presbycusis (13). In contrast, Spankovich et al (14) reported that intake of vitamin C was significantly associated with better hearing in the elderly. We believe this inconsistency stemmed from differences in the definition and detection of hearing loss and differences in which confounding factors were included for analysis. Furthermore, with the exception of Spankovich et al (14), most of the previously mentioned studies did not rule out conductive hearing loss. An important distinction of the current study was that all of subjects underwent a physical examination of the ear to rule out external- or middle-ear disease, and conductive hearing loss was ruled out by using pure-tone audiometry.

Other vitamins, such as retinol, niacin, and riboflavin, showed significant correlations with better hearing at selective frequencies by univariate linear regression analysis but not by multivariate analysis. In particular, the correlation coefficient of carotenoid intake and the hearing threshold was very low in the univariate linear regression analysis, even though there was...
significance. This result indicated that these vitamins showed only a minor association or relation with presbycusis compared with other factors such as age and noise-exposure history. One finding of note was that dietary intakes of carotenoids, retinol, niacin, and riboflavin decreased with age. We believe that this phenomenon may be one of the reasons why the significance that appeared in the univariate analysis disappeared in the multivariate analysis. Furthermore, the quartile with the highest intakes of carotenoids, retinol, riboflavin, and niacin had better hearing than that of the lowest quartile. Therefore, our data suggested that, along with intake of vitamin C, intakes of carotenoids, retinol, riboflavin, and niacin might also be associated with better hearing levels in the older population.

One finding in our study was that a high serum vitamin D concentration was associated with worse hearing at high frequencies in the univariate analysis, and the serum vitamin D concentration increased with age. In contrast to the other vitamins, the highest quartile of participants for serum vitamin D concentration showed worse hearing than that of the lowest quartile. Previous reports have shown conflicting results about the

**FIGURE 1.** Hearing thresholds according to age, sex, and noise exposure. The correlation between age and the PTA (A) and comparisons of the PTA according to sex (B), exposure to explosive noise (C), and exposure to occupational noise (D) are shown. A higher PTA threshold indicates worse hearing. Spearman’s correlation test (A) and Student’s t test (B–D) were used. Data are expressed as means (±SEs). PTA, pure-tone audiogram average.

**TABLE 2**

<table>
<thead>
<tr>
<th>Vitamin profiles of the study population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>Vitamin A intake (µg RE/d)</td>
</tr>
<tr>
<td>Carotenoid intake (µg/d)</td>
</tr>
<tr>
<td>Retinol intake (µg/d)</td>
</tr>
<tr>
<td>Niacin intake (mg/d)</td>
</tr>
<tr>
<td>Riboflavin intake (mg/d)</td>
</tr>
<tr>
<td>Vitamin C intake (mg/d)</td>
</tr>
<tr>
<td>Vitamin D serum concentration (ng/mL)</td>
</tr>
</tbody>
</table>

1 Suggested intakes of vitamin A, niacin, riboflavin, and vitamin C (19) and guidelines for sufficient serum vitamin D concentrations (21).

2 Vitamin A intake = retinol intake + (carotenoid intake ÷ 6) (20). RE, retinol equivalent.
effect of vitamin D on hearing. Mice with a mutated vitamin D receptor gene showed earlier hearing loss with age (23). In contrast, a vitamin D–deficient diet was able to prevent age-related hearing loss in the Klotho mouse, which displays clinical symptoms similar to presbycusis in humans (24). Another study in elderly Japanese people suggested that chronic sun exposure may be a risk factor for hearing loss (25). Although the exact mechanism by which vitamin D affects hearing is not clear, it is possible that vitamin D could induce apoptosis and demineralize the bony structure within the auditory system (24).

**TABLE 3**

Univariate linear regression analysis of intakes of various vitamins and left-ear hearing level

<table>
<thead>
<tr>
<th>Vitamin</th>
<th>Low frequency (500 and 1000 Hz)</th>
<th>Midfrequency (2000 and 3000 Hz)</th>
<th>High frequency (4000 and 6000 Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( R )</td>
<td>( P )</td>
<td>( R )</td>
</tr>
<tr>
<td>Carotenoid (( \mu g/d ))</td>
<td>(&lt;0.001^{f})</td>
<td>0.051</td>
<td>(&lt;0.001^{f})</td>
</tr>
<tr>
<td>Retinol (( \mu g/d ))</td>
<td>(-0.006^{f})</td>
<td>0.012^{f}</td>
<td>(-0.007^{f})</td>
</tr>
<tr>
<td>Riboflavin (mg/d)</td>
<td>(-0.026^{f})</td>
<td>(&lt;0.001^{f})</td>
<td>(-0.204^{f})</td>
</tr>
<tr>
<td>Niacin (mg/d)</td>
<td>(-0.016^{f})</td>
<td>(&lt;0.001^{f})</td>
<td>(-0.024^{f})</td>
</tr>
<tr>
<td>Vitamin C (mg/d)</td>
<td>0.045</td>
<td>0.438</td>
<td>0.224^{f}</td>
</tr>
<tr>
<td>Vitamin D (ng/mL)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{f} P < 0.05.\)
Our multivariate analysis also showed that intake of supplements had a strong correlation with better hearing at most frequencies. With consideration that the most-common dietary supplement in Korea is the multivitamin (26), this result also supported that dietary vitamin intake might be associated with better hearing in the older population. These data were somewhat consistent with a previous population-based study in which a healthy diet including fruit and vegetables was associated with better hearing (14, 27). As previously mentioned, dietary intake of vitamins decreased with age in our study; therefore, vitamin supplementation might be more effective with age.

Our study had several limitations because it was a cross-sectional analysis, and we used the 24-h recall method for measuring vitamin intake. In addition, we could not completely rule out the possibility of idiopathic sudden hearing loss or congenital hearing impairment. In addition, other nutrients such as vitamins B-12 and E, which were associated with hearing levels in some previous reports, were not included in our study because KNHANES did not have the nutrient database to calculate intakes of vitamins B-12 and E from diet-recall data. Once the database is established, we plan to analyze the association between presbycusis and intakes of vitamins B-12 and E in a future study. However, a strong point of the current study was that we were able to rule out conductive hearing loss with a physical examination by ear, nose, and throat residents. Moreover, our study had the advantage of analyzing a population of a single race, which allowed us to exclude confounding effects of various ethnicities.

In conclusion, our population-based study showed that high dietary intake of vitamin C was significantly associated with better hearing, and high serum concentrations of vitamin D may be associated with worse hearing in older population. Given that less than half of the elderly participants in this study consumed a sufficient amount of vitamins and that vitamin intake decreased with age, we should consider proper diet counseling to prevent hearing declines.

The KNHANES V-2 was carried out by the Korea Centers for Disease Control and Prevention in 2011. We thank all members who conducted the KNHANES V-2 and the participants, and we are grateful to the 87 residents of the Department of Otorhinolaryngology from 45 training hospitals in South Korea.

The authors’ responsibilities were as follows—JWK and JYC: designed the research; JWK: conducted the research and analyzed data; JYC: had primary responsibility for the final content of the manuscript; and all authors: wrote the manuscript and read and approved the final manuscript. None of the authors had a conflict of interest.

**TABLE 4**
Correlations between vitamin profiles and age

<table>
<thead>
<tr>
<th>Vitamin Profile</th>
<th>Spearman’s ρ</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carotenoid intake (µg/d)</td>
<td>−0.179</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Retinol intake (µg/d)</td>
<td>−0.216</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Riboflavin intake (mg/d)</td>
<td>−0.279</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Niacin intake (mg/d)</td>
<td>−0.259</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Vitamin C intake (mg/d)</td>
<td>−0.197</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Vitamin D serum concentration (ng/mL)</td>
<td>0.088</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Spearman’s correlation test was used.
REFERENCES


