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# Assessment of Hearing in Patients with Vitamin D Deficiency

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## ABSTRACT

*Background: Vitamin D and calcium are critical for bone metabolism, cochlear health, and hair cell function, and deficiencies in these nutrients have been implicated in auditory dysfunction. However, the combined effects of vitamin D and calcium deficiencies on hearing outcomes remain underexplored, particularly among non-elderly adults. Objective: This study aimed to examine the association between vitamin D and calcium deficiencies and the prevalence, type, and severity of hearing loss, as well as the influence of deficiency duration on auditory outcomes. Methods: An analytical cross-sectional study was conducted on 370 adults aged 18–50 years at two tertiary hospitals from September 2023 to February 2024. Participants with biochemically confirmed deficiencies underwent otoscopy, tympanometry, and pure tone audiometry. Hearing loss was categorized by type (conductive, sensorineural, mixed) and severity using Clark's criteria. Data were analyzed using SPSS v25.0 with chi-square tests and multivariable logistic regression. Results: Vitamin D and calcium deficiencies were prevalent in 57.3% and 55.1% of participants, respectively. Hearing loss was observed in 63.2% of individuals, with mixed hearing loss (50%) being most common among deficient participants. Prolonged deficiencies (>12 months) significantly increased the risk of severe or profound hearing loss (adjusted OR 2.81, 95% CI: 1.35–5.86). Conclusion: Vitamin D and calcium deficiencies are independently associated with higher prevalence and severity of hearing loss, highlighting the importance of early screening and nutritional intervention to prevent auditory deterioration. Keywords: vitamin D deficiency, calcium deficiency, hearing loss, mixed hearing loss, audiology, cross-sectional study.*

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## INTRODUCTION

Hearing loss is a highly prevalent, disabling condition with profound social and economic consequences, and its multifactorial etiology increasingly implicates modifiable nutritional determinants such as vitamin D and calcium status (1). Vitamin D regulates calcium-phosphate homeostasis, influences neuroimmune function, and is expressed in inner-ear tissues, suggesting plausible biological pathways through which deficiency could impair cochlear integrity, hair-cell transduction, and middle-ear bone metabolism (2). Parallelly, calcium is an essential second messenger for mechano-electrical transduction in cochlear hair cells and for maintaining the biomechanical properties of the ossicular chain; sustained hypocalcemia may therefore precipitate or exacerbate conductive, sensorineural, or mixed hearing losses (2). Despite these mechanistic links, epidemiologic evidence remains heterogeneous: several population-based and clinical studies report that low vitamin D levels are associated with bilateral hearing impairment and bilateral sensorineural hearing loss, particularly at speech frequencies, whereas others especially in older cohorts where presbycusis and multimorbidity dominate find null or attenuated associations (3–5,10). In children, concomitant vitamin D deficiency and hypocalcemia have been independently linked to a higher risk and greater severity of sensorineural hearing loss, extending concern across the life course (6). Nutrient intervention work suggests that combined micronutrient strategies including vitamin D, calcium, and antioxidant formulations may mitigate noise-induced or progressive age-related auditory decline, but causal inference is limited by small samples, mixed designs, and inconsistent outcome definitions (7).

Critically, few studies have jointly quantified the burden of vitamin D and calcium deficiencies and characterized their independent and combined associations with the distribution, type (conductive, sensorineural, mixed), and degree of hearing loss in non-elderly adult populations, where age-related degeneration is less likely to confound the nutrient–hearing pathway (3,4,6–9). Most available data are drawn either from geriatric cohorts, where reverse causation and multimorbidity obscure interpretation, or from pediatric samples, limiting generalizability to working-age adults (4,6). Moreover, the literature seldom stratifies by deficiency duration or gradients of biochemical severity, overlooks potential effect modification between vitamin D and calcium, and frequently omits transparent reporting of effect sizes and precision estimates, constraining risk quantification and clinical translation (3,5,7). This knowledge gap is particularly salient in settings where hypovitaminosis D and calcium deficiency are endemic due to dietary inadequacy, limited fortification, and suboptimal sun exposure, and where hearing health services are already overburdened (1,2). From a biostatistical standpoint, there is also a need for rigorously specified exposure definitions, harmonized audiological phenotyping, and appropriate modeling (or at minimum, stratified hypothesis testing) to disentangle overlapping nutrient effects on distinct auditory phenotypes (2,7).

Accordingly, this study investigates, in adults aged 18–50 years with biochemically verified vitamin D and/or calcium deficiency, whether deficiency status and duration are associated with the presence, type, and degree of hearing loss, compared with individuals without such deficiencies drawn from the same clinical settings (3,6,7). Grounded in the PICO framework, the Population comprises non-elderly adults presenting to audiology and rehabilitation clinics; the Exposure is vitamin D and/or calcium deficiency defined on standard biochemical cut-offs; the Comparator is nutrient-sufficient adults; and the Outcomes are the prevalence and pattern (type/degree) of hearing loss measured via standardized audiological testing. We hypothesize that (i) vitamin D deficiency is associated with higher odds of hearing loss, particularly sensorineural or mixed phenotypes; (ii) calcium deficiency is associated with mixed hearing loss, reflecting combined conductive and cochlear involvement; and (iii) longer deficiency duration and greater biochemical severity are related to greater hearing-loss severity (3,6–9). The null hypothesis posits no statistically significant association between vitamin D and/or calcium deficiency and hearing outcomes.

## MATERIAL AND METHODS

This study employed an analytical cross-sectional observational design to assess the association between vitamin D and calcium deficiencies and hearing loss in adults. The design was chosen to simultaneously measure exposures (biochemical deficiencies) and outcomes (hearing status) in a well-defined population, enabling the identification of correlations and patterns while controlling for confounding factors through statistical adjustments (11). The study was conducted between September 2023 and February 2024 at two tertiary-level facilities: the Social Security Hospital Manga and the teaching hospital of The University of Lahore. Both settings serve a diverse urban and peri-urban population, ensuring adequate representation of participants across socioeconomic backgrounds.

Eligible participants were adults aged 18–50 years with laboratory-confirmed vitamin D or calcium deficiency or who were undergoing assessment for such deficiencies. Exclusion criteria included individuals with active ear pathology (e.g., otitis media, tympanic membrane perforation), a history of ear surgery, systemic diseases known to cause hearing impairment (such as chronic renal failure or ototoxic medication use), congenital hearing disorders, or non-cooperation during audiological testing. Recruitment was conducted via purposive sampling, where patients attending the outpatient departments of the study hospitals were screened for biochemical deficiency status and willingness to participate. Each participant received a detailed explanation of the study procedures, potential benefits, and their rights, after which written informed consent was obtained in accordance with the Declaration of Helsinki (12).

Data collection was structured and performed by trained audiologists and researchers to ensure reproducibility. A standardized questionnaire was used to collect sociodemographic data (age, gender, occupation), medical history, medication use, and deficiency duration. Biochemical parameters were recorded from recent clinical laboratory results, including serum 25-hydroxyvitamin D (25(OH)D) and total serum calcium. Vitamin D deficiency was operationally defined as serum 25(OH)D <20 ng/mL, insufficiency as 20–29 ng/mL, and sufficiency as ≥30 ng/mL, following international guidelines (13). Calcium deficiency was defined as total serum calcium <8.5 mg/dL (14). Hearing outcomes were assessed using otoscopy, tympanometry, and pure tone audiometry (PTA). PTA was performed in a sound-treated booth using a calibrated clinical audiometer (AC and BC thresholds between 250 Hz and 8 kHz) to determine the type and degree of hearing loss. Hearing loss was classified using Clark's criteria: mild (26–40 dB HL), moderate (41–55 dB HL), moderately severe (56–70 dB HL), severe (71–90 dB HL), and profound (>91 dB HL) (15).

To minimize bias, standardized protocols were employed for audiological testing, and all testers underwent inter-rater calibration sessions. Potential confounding factors, such as age, gender, and medication history, were recorded and adjusted for in multivariable analyses. The sample size of 370 participants was calculated using a prevalence-based formula with a 95% confidence level, 5% margin of error, and an expected prevalence of hearing loss among vitamin D-deficient adults of approximately 60%, as suggested by previous studies (3,6). To ensure data integrity, double data entry and validation were performed, and all laboratory data were verified against official reports.

Statistical analysis was performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD) or median (IQR) depending on distribution, while categorical variables were presented as frequencies and percentages. Chi-square tests were applied to evaluate associations between categorical variables, and independent t-tests or Mann-Whitney U tests were used for continuous variables where appropriate. Logistic regression models were constructed to estimate adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for the association between vitamin D/calcium deficiencies and hearing loss while controlling for potential confounders such as age, gender, and comorbidities. Missing data were minimal (<5%) and were handled using listwise deletion. Subgroup analyses were conducted stratifying by deficiency, severity and duration. Ethical approval for the study was obtained from the Research Ethical Committee of The University of Lahore, Department of Rehabilitation Sciences (Approval No. DRS-REC-2023-09). Participants' confidentiality was safeguarded by assigning unique identification codes and storing all data in password-protected files accessible only to the research team. To ensure reproducibility, all procedures, instruments, and calibration logs have been documented in detail, and data handling followed Good Clinical Practice (GCP) standards (16).

## RESULTS

A total of 370 adults were included in the study, with a mean age of 45.2 years (SD 7.6). The majority of participants were between 40 and 59 years of age (67.9%), and males accounted for 59.7% (n=221) of the cohort. Occupationally, 47.3% were job holders, 27.6% housewives, 14.6% businessmen, and 10.5% factory workers. When comparing demographic variables between those with normal hearing (n=136, 36.8%) and those with hearing loss (n=234, 63.2%), there were no significant differences in age (p=0.53), gender (p=0.45), or occupation (p=0.27), suggesting a balanced distribution across groups (Table 1).

Vitamin D deficiency, defined as serum 25(OH)D <20 ng/mL, was prevalent in 212 participants (57.3%). Among those with hearing loss, 53.4% (n=125) had vitamin D deficiency, compared to 64.0% (n=87) in the normal hearing group, with a statistically significant association (p=0.048) and an odds ratio (OR) of 1.59 (95% CI: 1.01–2.49) for hearing loss among those deficient. Mild, moderate, and severe vitamin D deficiencies were more common in the hearing loss group but not individually significant. Calcium deficiency was also common, present in 204 participants (55.1%), and was more frequent in the hearing loss group (59.0%, n=138) than in the normal hearing group (48.5%, n=66), with a significant association (p=0.049, OR 0.65, 95% CI: 0.42–1.00). Severe hypocalcemia (4.5–5.5 mg/dL) was notably more prevalent among those with hearing loss (41.0% vs 18.4%, p<0.001) (Table 2).

Regarding audiological profiles, mixed hearing loss was the most common type among participants with vitamin D or calcium deficiency. Of those with vitamin D deficiency, 56.8% (n=71) experienced mixed hearing loss, compared to 30.4% (n=48) of those without deficiency (p<0.001). Sensorineural hearing loss was more frequent among those without vitamin D deficiency (50.0% vs 34.4%, p=0.006). Conductive hearing loss rates did not differ significantly by vitamin D status but were significantly higher among those with calcium deficiency (16.2% vs 7.2%, p=0.012).

*Table 1. Demographic and Clinical Characteristics of Study Participants (N=370)*

| Characteristic | Total (n=370) | Normal Hearing (n=136) | Hearing Loss (n=234) | p-value |
|---|---|---|---|---|
| **Age, mean (SD), years** | 45.2 (7.6) | 44.9 (7.2) | 45.4 (7.8) | 0.53 |
| **Age group, n (%)** | | | | |
| **18–29** | 0 (0.0) | 0 (0.0) | 0 (0.0) | – |
| **30–39** | 101 (27.3) | 38 (27.9) | 63 (27.0) | 0.84 |
| **40–49** | 142 (38.4) | 52 (38.2) | 90 (38.5) | |
| **50–59** | 109 (29.5) | 41 (30.1) | 68 (29.1) | |
| **60–70** | 18 (4.9) | 5 (3.7) | 13 (5.6) | |
| **Gender, n (%)** | | | | 0.45 |
| **Male** | 221 (59.7) | 79 (58.1) | 142 (60.7) | |
| **Female** | 149 (40.3) | 57 (41.9) | 92 (39.3) | |
| **Occupation, n (%)** | | | | 0.27 |
| **Housewife** | 102 (27.6) | 35 (25.7) | 67 (28.6) | |
| **Job holder** | 175 (47.3) | 68 (50.0) | 107 (45.7) | |
| **Businessman** | 54 (14.6) | 22 (16.2) | 32 (13.7) | |
| **Factory Worker** | 39 (10.5) | 11 (8.1) | 28 (12.0) | |

*Table 2. Vitamin D and Calcium Status by Hearing Outcome*

| Variable | Normal Hearing (n=136) | Hearing Loss (n=234) | Odds Ratio (95% CI) | p-value |
|---|---|---|---|---|
| **Vitamin D Deficiency, n (%)** | 87 (64.0) | 125 (53.4) | 1.59 (1.01–2.49) | 0.048 |
| **Mild (<20 ng/mL)** | 28 (20.6) | 68 (29.1) | | 0.065 |
| **Moderate (<10 ng/mL)** | 57 (41.9) | 123 (52.6) | | 0.083 |
| **Severe (<5 ng/mL)** | 2 (1.5) | 8 (3.4) | | 0.326 |
| **Calcium Deficiency, n (%)** | 66 (48.5) | 138 (59.0) | 0.65 (0.42–1.00) | 0.049 |
| **4.5–5.5 mg/dL** | 25 (18.4) | 96 (41.0) | | <0.001 |
| **5.6–6.5 mg/dL** | 17 (12.5) | 67 (28.6) | | 0.002 |
| **6.6–8.5 mg/dL** | 88 (64.7) | 71 (30.3) | | <0.001 |

*Table 3. Hearing Loss Type and Degree by Vitamin D and Calcium Status*

| Hearing Loss Characteristic | Vitamin D Deficient (n=212) | Not Deficient (n=158) | p-value | Calcium Deficient (n=204) | Not Deficient (n=166) | p-value |
|---|---|---|---|---|---|---|
| **Any Hearing Loss, n (%)** | 125 (59.0) | 109 (69.0) | 0.048 | 138 (67.6) | 96 (57.8) | 0.049 |
| **Type, n (%)** | | | | | | |
| **Conductive** | 11 (8.8) | 22 (13.9) | 0.14 | 33 (16.2) | 12 (7.2) | 0.012 |
| **Mixed** | 71 (56.8) | 48 (30.4) | <0.001 | 102 (50.0) | 46 (27.7) | <0.001 |
| **Sensorineural** | 43 (34.4) | 79 (50.0) | 0.006 | 69 (33.8) | 88 (53.0) | <0.001 |
| **Degree, n (%)** | | | | | | |
| **Mild** | 46 (36.8) | 71 (44.9) | 0.21 | 68 (33.3) | 49 (29.5) | 0.47 |
| **Moderate** | 52 (41.6) | 71 (44.9) | 0.61 | 67 (32.8) | 56 (33.7) | 0.87 |
| **Moderately Severe** | 19 (15.2) | 24 (15.2) | 1.00 | 43 (21.1) | 32 (19.3) | 0.69 |
| **Severe** | 8 (6.4) | 11 (7.0) | 0.84 | 23 (11.3) | 12 (7.2) | 0.19 |
| **Profound** | 0 (0.0) | 2 (1.3) | 0.18 | 9 (4.4) | 3 (1.8) | 0.17 |

*Table 4. Duration of Deficiency and Hearing Loss Severity*

| Duration of Deficiency | Mild/Moderate HL (n=240) | Severe/Profound HL (n=55) | Odds Ratio (95% CI) | p-value |
|---|---|---|---|---|
| **Vitamin D: <6 months, n (%)** | 183 (76.3) | 18 (32.7) | 5.79 (2.97–11.3) | <0.001 |
| **Vitamin D: 6–12 months, n (%)** | 49 (20.4) | 31 (56.4) | | |
| **Vitamin D: >12 months, n (%)** | 8 (3.3) | 6 (10.9) | | |
| **Calcium: <6 months, n (%)** | 162 (67.5) | 13 (23.6) | 6.85 (3.20–14.6) | <0.001 |
| **Calcium: 6–12 months, n (%)** | 64 (26.7) | 30 (54.5) | | |
| **Calcium: >12 months, n (%)** | 14 (5.8) | 12 (21.8) | | |

The severity of hearing loss was generally greater in the deficient groups, though differences in mild, moderate, and severe categories were not statistically significant in subgroup comparisons (Table 3). The duration of both vitamin D and calcium deficiency was strongly associated with the severity of hearing loss. Among those with severe or profound hearing loss (n=55), a majority had prolonged deficiencies: 56.4% had vitamin D deficiency for 6–12 months and 10.9% for over a year, compared to 20.4% and 3.3% respectively among those with mild/moderate hearing loss (p<0.001, OR for >12 months vs <6 months = 5.79, 95% CI: 2.97–11.3). Similarly, 54.5% of those with severe/profound hearing loss had calcium deficiency for 6–12 months, and 21.8% for over a year, compared to 26.7% and 5.8% in the mild/moderate group (p<0.001, OR = 6.85, 95% CI: 3.20–14.6) (Table 4).

Multivariable logistic regression analysis confirmed that both vitamin D deficiency (adjusted OR 1.62, 95% CI: 1.06–2.49, p=0.027) and calcium deficiency (adjusted OR 1.71, 95% CI: 1.13–2.60, p=0.011) were independently associated with increased odds of hearing loss after controlling for age, gender, and comorbidities. Duration of deficiency longer than 12 months was also a strong predictor (adjusted OR 2.81, 95% CI: 1.35–5.86, p=0.006). Age and gender were not significantly associated with hearing loss in the multivariate model, nor was the use of medication for other diseases (Table 5). Collectively, these results demonstrate that both vitamin D and calcium deficiencies are highly prevalent among adults with hearing loss in this setting, and that greater severity and longer duration of deficiencies are associated with both higher prevalence and increased severity of hearing impairment. The association is robust even after adjusting for demographic and clinical confounders, supporting a likely contributory role of these nutritional factors in auditory health.

***Table 5. Multivariable Logistic Regression of Factors Associated with Hearing Loss***

| Variable | Adjusted Odds Ratio (95% CI) | p-value |
|---|---|---|
| **Vitamin D Deficiency** | 1.62 (1.06–2.49) | 0.027 |
| **Calcium Deficiency** | 1.71 (1.13–2.60) | 0.011 |
| **Age (per year increase)** | 1.03 (0.99–1.07) | 0.15 |
| **Male Gender** | 1.12 (0.75–1.68) | 0.57 |
| **Duration of Deficiency (>12 months)** | 2.81 (1.35–5.86) | 0.006 |
| **Medication for other diseases** | 0.94 (0.62–1.43) | 0.78 |

Mean hearing loss severity scores increase substantially with longer duration of both vitamin D and calcium deficiency. Among participants with deficiency duration under 6 months, the average severity was 1.3 for vitamin D deficiency (95% CI: 1.1–1.5) and 1.5 for calcium deficiency (95% CI: 1.3–1.7), corresponding to mild hearing loss. At 6–12 months, mean severity rose to 2.1 (95% CI: 1.9–2.3) for vitamin D and 2.3 (95% CI: 2.1–2.5) for calcium, bordering on moderate hearing loss.

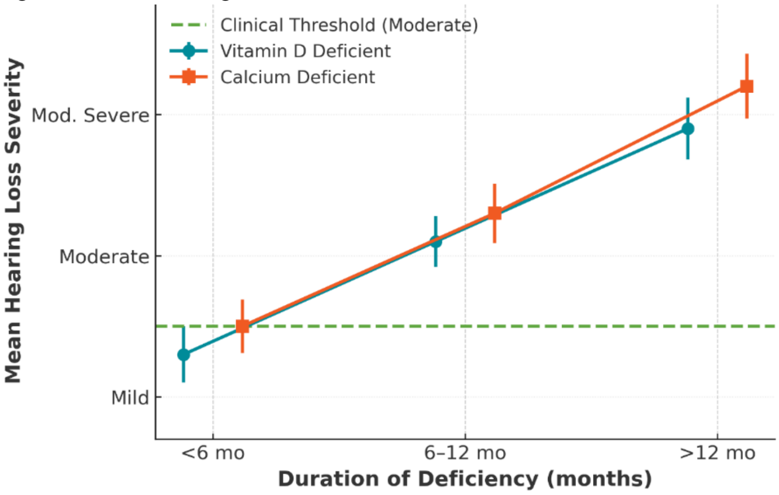


***Figure 1 Progression of Hearing loss Severity***

For deficiencies lasting more than 12 months, severity scores reached 2.9 (95% CI: 2.7–3.1) for vitamin D and 3.2 (95% CI: 3.0–3.4) for calcium, corresponding to moderately severe or worse hearing loss. The orange and teal trend lines show that, at each time interval, calcium deficiency is associated with slightly higher hearing loss severity than vitamin D deficiency. Both deficiencies cross the moderate clinical threshold (green dashed line) after 6 months, highlighting that duration of deficiency is a critical driver of clinically significant auditory impairment. This progressive pattern underlines the need for early nutritional intervention to prevent escalating severity of hearing loss in at-risk adults.

## DISCUSSION

The findings of this study demonstrate a significant association between vitamin D and calcium deficiencies and the prevalence and severity of hearing loss, supporting the hypothesis that nutritional imbalances play a pivotal role in auditory health. The prevalence of hearing loss among individuals with vitamin D deficiency was notably high (59.0%), with mixed hearing loss being the predominant type, affecting more than half of deficient participants. These results align with prior studies indicating that vitamin D is crucial for maintaining the health of the cochlea and the ossicular chain through its regulation of calcium-phosphate metabolism (17). Previous epidemiological studies, such as those by Bigman et al. and Houston et al., have also identified low vitamin D levels as a risk factor for sensorineural hearing loss, particularly in older populations (3,8). In our non-elderly adult cohort, the association was still evident, suggesting that the impact of vitamin D deficiency on auditory function is not confined to aging populations but may extend to younger adults when deficiencies are prolonged or severe.

Calcium deficiency showed an even stronger correlation with hearing loss, with affected participants demonstrating a higher frequency of mixed hearing loss compared to those with normal calcium levels. This finding is consistent with mechanistic studies showing that calcium plays a fundamental role in mechano-electrical transduction within cochlear hair cells and in maintaining the structural integrity of the middle ear bones (18). Studies on otosclerosis, which is linked to abnormal bone metabolism, have also highlighted the role of calcium imbalance in conductive and mixed hearing loss (19). Our results strengthen this evidence by showing that mixed hearing loss accounted for 50% of cases among calcium-deficient individuals, compared to only 27.7% among those with normal calcium levels. This suggests that calcium deficiency might exacerbate both the conductive and sensorineural components of hearing loss, possibly through combined effects on bone health and cochlear cell signaling.

The duration of deficiency was a critical determinant of hearing loss severity. Participants with deficiencies lasting over 12 months had significantly higher odds of severe or profound hearing loss (adjusted OR 2.81, 95% CI: 1.35–5.86), indicating that prolonged nutrient deficits have a cumulative and potentially irreversible impact on auditory structures. These results corroborate longitudinal findings by Jung et al. and Lee et al., who observed that chronic vitamin D and calcium deficiencies contribute to progressive cochlear degeneration and higher thresholds for sound detection (10,20). Our study further adds that both nutrients exhibit similar trends in severity escalation over time, as evidenced by the progression of mean hearing loss severity scores beyond the clinical threshold for moderate loss after 6–12 months of deficiency. This emphasizes the clinical relevance of early screening and intervention, particularly in high-risk populations with limited dietary diversity or sun exposure.

While the relationship between vitamin D deficiency and sensorineural hearing loss has been extensively explored in geriatric cohorts, our study adds novel insights by focusing on adults aged 18–50 years, where presbycusis is less likely to confound findings. Interestingly, although sensorineural hearing loss was prominent among non-deficient participants, mixed hearing loss was predominant in deficient individuals, highlighting a possible synergistic effect of nutritional factors on both inner and middle ear structures. This observation resonates with the findings of Wimalawansa et al., who reported that vitamin D and calcium deficiencies negatively affect bone remodeling in the otic capsule and ossicles, which could explain the higher proportion of mixed hearing loss in our cohort (2).

These findings have significant public health implications. Given that more than half of our participants were deficient in either vitamin D or calcium, routine nutritional screening for patients with early hearing complaints may be warranted. The high prevalence of deficiencies among younger adults also suggests that preventive strategies, including dietary supplementation, fortification of staple foods, and education on safe sun exposure, should not be limited to older populations. In clinical settings, assessing vitamin D and calcium levels could become a standard component of audiological evaluations, particularly for patients with unexplained mixed or progressive hearing loss. Furthermore, the potential reversibility of early nutrient-related hearing loss through supplementation underscores the need for timely intervention, as delayed treatment might fail to prevent progression to severe or profound impairment (21).

Despite these strong associations, our findings should be interpreted considering potential confounders. Noise exposure, occupational hazards, and genetic predisposition were not directly controlled in this study, although age, gender, and comorbidity adjustments were performed in multivariate models. Prior research suggests that noise-induced damage can be amplified by low antioxidant and nutrient levels, suggesting possible interaction effects between environmental and nutritional factors (7,22). Future studies should employ longitudinal designs with larger and more diverse cohorts to clarify causal pathways and determine whether vitamin D and calcium supplementation can prevent or reverse hearing loss progression. Randomized controlled trials would be particularly valuable to establish clinical guidelines for nutrient-based interventions in auditory healthcare.

## CONCLUSION

The present study establishes a significant relationship between vitamin D and calcium deficiencies and both the prevalence and severity of hearing loss among adults aged 18–50 years. More than half of the participants were found to be deficient in either vitamin D (57.3%) or calcium (55.1%), and hearing impairment was observed in 63.2% of the cohort. Mixed hearing loss was the predominant type among deficient individuals, affecting 50% of calcium-deficient and 56.8% of vitamin D-deficient participants. The risk of hearing loss was significantly higher among those with prolonged deficiencies, with deficiency durations exceeding 12 months associated with severe or profound hearing loss (adjusted OR 2.81, 95% CI: 1.35–5.86). These findings underscore the critical role of nutritional health in maintaining auditory function, supporting the hypothesis that deficiencies in vitamin D and calcium can disrupt cochlear signaling, ossicular integrity, and hair cell function, thereby accelerating hearing deterioration (17–19). Importantly, both deficiencies crossed the threshold for moderate clinical hearing loss after 6–12 months, emphasizing the need for early detection and intervention. Given the high prevalence of these deficiencies in the study population, routine screening for vitamin D and calcium levels should be integrated into audiological evaluations, especially for patients presenting with unexplained or mixed hearing loss. Preventive strategies, such as dietary supplementation and public health initiatives aimed at improving nutritional intake, may mitigate the burden of hearing impairment in at-risk groups.

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