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REVIEW ARTICLE

ROLE OF VITAMIN D IN OTOLOGICAL AND NEUROTOLOGICAL DISORDERS: A REVIEW

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ABSTRACT

Demineralization of labyrinth and, in particular, otoconia dislodgment can result from low serum vitamin D levels. Vitamin D regulates expression of pro-inflammatory mediators and has a potent immunomodulatory effect. Increased inflammatory responses in inner ear have been linked to vitamin D deficiency. Patients with Meniere's illness, sensorineural hearing loss (SNHL), and paroxysmal positional vertigo are frequently deficient in vitamin D. The commonest peripheral etiology of vertigo is benign paroxysmal positional vertigo (BPPV). One of the possible causes of BPPV development is a vitamin D deficiency. Low mineral density and vitamin D deficiency are also risk factors for vestibulocochlear diseases, including age-related hearing loss. Supplementation of vitamin D may improve the auditory recovery and vestibular disorders like BPPV. The recurrence of BPPV can be significantly reduced with vitamin D treatment alone. The present narrative review will consider the role of vitamin D in otological and neurotological disorders.

KEYWORDS

Vitamin D, benign paroxysmal positional vertigo, sudden sensorineural hearing loss, Meniere's disease.

1. INTRODUCTION

Nowadays, vitamin D has drawn a lot of attention since it has been shown to be crucial for both acute and chronic illness (Rebelos et al., 2023). Due to the complex metabolism of vitamin D, there are several risk factors for vitamin D deficiency. Reduced or restricted sun exposure decreased cutaneous synthesis, inadequate food intake, malabsorption syndrome, and chronic liver and kidney disorders are important causes of vitamin D insufficiency (Płudowski et al., 2023). The calcium concentration necessary for proper hearing and vestibular functions may be disrupted by deficiency of vitamin D or metabolic byproducts of vitamin D (Yamauchi et al., 2010). Vitamin D regulates the pro-inflammatory mediator's expression and plays a powerful immunomodulatory impact.

It was suggested that otoconia had grown into enormous crystals that were no longer attached to the otoconial membrane, losing their comparatively fine stony appearance (Jeong et al., 2013). Serum 25-hydroxyvitamin-D levels lower than 20 ng/ml are considered to be a sign of insufficiency of vitamin D. Vitamin D deficiency is defined as 21–29 ng/ml, whereas vitamin sufficiency is defined as 30 ng/ml or more in both adults and children (Hossein-nezhad and Holick, 2013). To make up for a vitamin D deficit, a daily intake of 1000 IU is sufficient (Jeong et al., 2022). The purpose of this review is to discuss how vitamin D affects otological and neurotological conditions such Meniere's disease, tinnitus, sudden sensorineural hearing loss, benign paroxysmal positional vertigo, and presbycusis.

2. METHODS OF LITERATURE SEARCH

A search was done for research articles on the role of Vitamin D in otological and neurotological disorders using various methods. This began with searching online databases such as Google Scholar, PubMed, Scopus, and Medline. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) served as the foundation for the development of a search strategy. This method located published article abstracts, and more research articles were manually located using citations. Evaluations were conducted to determine whether observational studies, case series, comparative studies, case reports, and randomized controlled trials were appropriate for this review. Across databases, a total of 82 papers (27 case reports, 21 case series, and 34 original articles) were located; 51 of them were included in this evaluation (Figure 1).

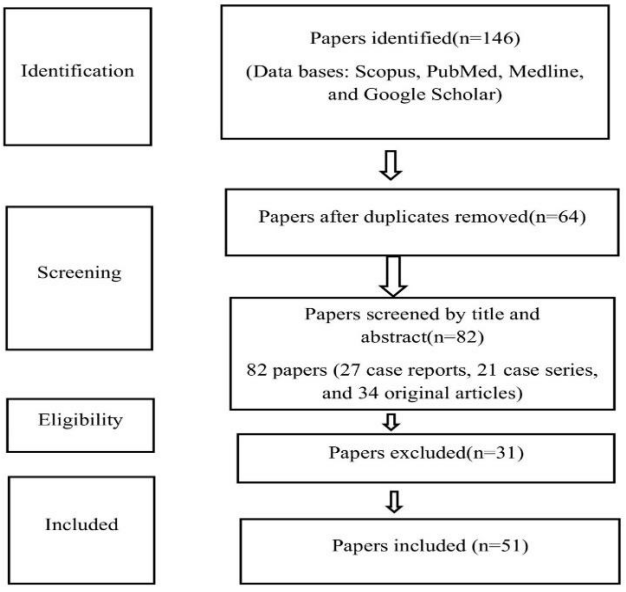

Figure 1: Methods of literature search.

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3. Prevalence

Through oral consumption and skin photosynthesis, vitamin D is kept at a sufficient level. Globally, almost one billion people are deficient in vitamin D (Botros et al., 2015). In Egypt, 30.1% of people had severe vitamin D deficiency and 36.9% had vitamin D deficiency (Botros et al., 2015). The percentages of insufficient and sufficient types are 15.6% and 17.2%, respectively (Botros et al., 2015). To inform future approaches, however, few research have evaluated vitamin D deficiency across various age groups, genders, incomes, and geographic areas. According to one study, all age categories and genders had high levels of vitamin D inadequacy: 38% had severe shortage, 29% had moderate deficiency, and 25% had mild deficiency, with only 8.6% having normal levels (Sheikh et al., 2012; Riaz et al., 2016).

4. Vitamin D

A fat-soluble vitamin with multiple functions in the body, vitamin D (25(OH)D) is made photochemically in the skin from 7-dehydrocholeseterol (DeLuca, 2004). Cholecalciferol is the most prevalent kind of vitamin D present in food and food supplements (Navarro-Triviño et al., 2019). Typically, vitamin D plays an important role in skin health, antimicrobial, anti-inflammatory, anti-allergy, and plasma calcium ion levels (Navarro-Triviño et al., 2019). Plasma calcium ion levels, antibacterial activity, anti-inflammatory activity, anti-allergy, and skin health are all typically regulated by vitamin D (Navarro-Triviño et al., 2019). Vitamin D may also serve as an antioxidant, helping to maintain the equilibrium between oxidants and antioxidants. This balance is important as oxidative stress can result from an imbalance that is typified by either an excess of reactive oxygen species or lack of antioxidants. Numerous diseases' onset and progression have been linked to this type of oxidative stress (Nuszkiewicz et al., 2020).

However, one study showed no association between reactive oxygen species and pathogenesis of SSNHL (Elias et al., 2021). Hyperbaric oxygen treatment is one of the unique therapeutic procedures that can increase the body's generation of reactive oxygen species, especially when 100% oxygen is used. Another study showed that vitamin D supplements can help stop lipid peroxidation in erythrocytes in patients with SSNHL receiving hyperbaric oxygen therapy (Paprocki et al., 2021). Although the underlying mechanism is still unknown, animal investigations have shown that vitamin D influences both bone metabolism and the metabolism of calcium carbonate-based otoconia, which contributes to otoconial regeneration (Jeong et al., 2022). One of the recognized concepts for the pathophysiology of BPPV is the dislodgement of calcium carbonate crystals (otoconia) from utricle into semicircular canals, most frequently posterior canal. The density and matrix of calcium carbonate crystals (otoconia) may be impacted by vitamin D's significant involvement in calcium metabolism (Mohsin et al., 2019). Research has verified that the vitamin D receptor is present on the labyrinth's calcium channel transport systems and functions to maintain appropriate calcium balance. The function of vitamin D in preserving healthy auditory function may be better understood through this approach (Szeto et al., 2021).

5. Defeicncy of Vitamin D

Numerous factors affect vitamin D's photosynthesis and bioavailability, which may raise the danger of low vitamin D levels. These variables include age, obesity, and the prevalence of chronic illness, as well as variations in sunlight exposure caused by geographic latitude, time of day, solar radiation exposure, season, weather, air pollution, clothing, sunscreen use, and skin pigmentation (Tsiaras and Weinstock, 2011). Cochlear deafness and demineralization have been linked to vitamin D insufficiency. Since calcium ions are crucial for membrane permeability, the vitamin D shortage may have an impact through altered calcium metabolism. The production of action potentials in the cochlea may be impacted by ionized calcium shortage, which is necessary for optimal neuron activity. Low levels of calcium and vitamin D can cause degenerative changes in the spiral ligament, stria vascularis, cochlear hair cells, and demineralization of the otic capsule (Lee et al., 2024). According to one study, hearing improves after serum vitamin D levels are restored (Carpinelli et al.,2011). Grading of vitamin D deficiency is given in Table 1.

Table 1: Grading of vitamin D deficiency

Grading of vitamin D deficiency	Serum values of 25-OH vitamin D(ng/m)
Normal	>30 ng/ml
Insufficiency	20-29.9 ng/ml
Deficiency	< 20ng/ml

6. Otoconia

There are two parts to otoconia crystals: the center core and the periphery zone. The exterior zone is often inorganic (mostly a polymorph of calcium carbonate) with a higher level of calcium, whereas the inner core is primarily organic (mostly glycoprotein) with a lower level of Ca (Lins et al., 2000). The otoconia's external surface, periphery, and central core are all made of interconnected fibrous material with different sizes and arrangements. Otoconia crystals are attached to hair cells by protein fiber and are partially imbedded in a fibrous matrix (Lundberg et al., 2006). The mechanism of calcium and phosphate deposition in the teeth, bones, and vestibular system's otoconial particle creation is directly impacted by vitamin D (Pillai and Gopinath, 2019). Otoconia and bone biomineralization share certain characteristics. In otoconia, biomineralization entails precise control over the development of an organic matrix at particular sites and the organized deposition of mineral crystallites, much like in teeth and bone (Xu et al., 2011).

7. Benign Paroxysmal Positional Vertigo

Benign paroxysmal positional vertigo (BPPV) is the most common type of peripheral vertigo. Rotational vertigo that happens abruptly when the head moves while lying down or turning head in supine position is a defining feature of BPPV (Swain, 2025). Vertigo with head movement is caused by calcium carbonate crystals termed otoconia, which are adhered to utricular macula and can become dislodged for a variety of causes. They can either become lodged in the cupula or enter the semicircular canal (Kim and Zee, 2014). Low vitamin D levels and the BPPV did not correlate, according to a systematic review. Nonetheless, a detrimental vitamin D imbalance is present in certain BPPV patients (AlGarni et al., 2018). Seasonal factors are known to have an impact on BPPV, especially exposure to sunlight, which in turn alters the levels of vitamin D (Whitman and Baloh, 2015). In BPPV, vitamin D dramatically lowers the likelihood of vertigo recurrence (Swain et al., 2020). However, it is still unclear what precise benefits and processes vitamin D supplementation has in preventing BPPV recurrence in cases of vitamin D deficiency.

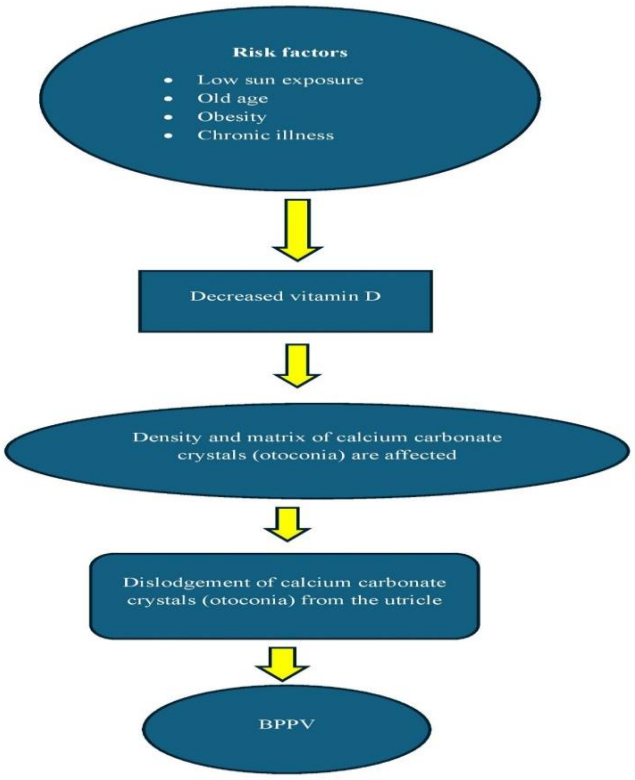

Figure 2: Pathophysiology for development of BPPV due to deficiency of vitamin D.

In osteoporosis, there is defective vitamin and calcium metabolism, which is likely a major contributor to the pathophysiology of BPPV. The otoconia matrix and density are influenced by calcium crystal deposition and vitamin D levels in a manner akin to that of bone structures (Figure 2) (Yang et al., 2011). The severity and recurrence of BPPV are associated with vitamin deficiencies (Talaat et al., 2015). The recurrent episodes of BPPV may be reduced by supplementation of vitamin D. Following vitamin D supplementation trials, many patients achieved a full remission (Talaat et al., 2016). Vitamin D supplementation lowers the incidence of bone fractures, but vitamin deficiency raises the risk (Mosekilde, 2005).

Numerous investigations have found that vitamin D has a significant role in the development and recurrence of BPPV based on this pathophysiology (Rhim, 2016). A study using data from the Korean National and Nutritional Examination Survey compared the serum vitamin D levels of 100 patients with idiopathic BPPV with 192 normal individuals (people from same community who had never experienced vertigo or imbalance) revealed that the BPPV group had lower levels.

This disparity provided evidence for a link between BPPV and lower serum vitamin D levels (Jeong et al., 2013). When compared to those who did not experience a relapse, 41 patients (17.7%) who experienced a relapse during an average ten-month follow-up had lower serum 25-OH vitamin D concentrations, according to another retrospective research of 232 BPPV patients. Age, sex, length of follow-up, and kind of BPPV were among the variables that had no effect on the results (Rhim, 2016).

To make up for the vitamin D deficit, 1000 IU of vitamin D supplements should be taken daily (Jeong et al., 2022). It is unknown, nevertheless, if this vitamin D dosage is the lowest that can effectively prevent vertigo from recurring. The minimum recommended dosage of vitamin D supplementation in non-randomized trial designs was 5000 IU (Jeong et al., 2022).

8. Sudden Sensorineural Hearing Loss

A sudden loss of hearing of more than 30 dB across three successive frequencies within 72 hours is known as sudden sensorineural hearing loss (Swain et al., 2018). Steroid therapy is now used to treat idiopathic SSNHL (Kuhn et al., 2011). Despite this, the precise causes of SSNHL remain unclear and are frequently regarded as idiopathic. Disorders of the central nervous system, vascular pathology, tumors, autoimmune diseases, infections, and trauma are some of the potential causes of SSNHL (Bul˘gurcu et al., 2018). Patients with idiopathic SSNHL have different levels of vitamin D than healthy persons (Szeto et al., 2021; Bigman, 2022).

Among individuals with SSNHL, vitamin D deficiency is more common. By changing of calcium metabolism, inner ear fluid balance, nerve transmission, and bone formation, vitamin D deficiency may have both direct and indirect effects on hearing. Deficiency of vitamin D can cause degeneration of auditory tissues and increased susceptibility of cochlea to effects of chronic ischemia due to its crucial involvement in calcium homeostasis. Hearing loss, demineralization of cochlea, and changes in otic capsule's bone remodelling could result from these modifications (Lee et al., 2024).

9. Meniere's Disease

Recent studies showed that correction of vitamin D deficiency in newly diagnosed patients of Meniere's disease reduced requirement of ablative treatment by intra-tympanic gentamycin. As per the hypothesis, if the symptoms of Meniere's illness are brought on by a local post-viral autoimmune reaction, treatment with vitamin D may in fact be helpful (Swain 2023). [41] Vitamin D controls expression of pro-inflammatory mediators and has a potent immunomodulatory effect (Buki et al., 2018).

10. Otosclerosis

The tendency for osteoporosis is more prevalent in patients with otosclerosis (Swain, 2022). Although otosclerosis patients had a lower mean 25(OH)D3 level than controls, this difference is not statistically significant. There have been reports linking three polymorphic markers in the collagen 1A1 gene (COL1A1) to otosclerosis (McKenna et al., 1998). The same marker, COL1A1, has been linked to osteoporosis in a similar way (Jin et al., 2011).

11. Tinnitus

Tinnitus is a prevalent disabling condition where the possible etiological mechanisms is unclear (Swain et al., 2016). Tinnitus has a complicated and frequently multiple etiology (Swain et al., 2017). Recent studies have provided solid evidence linking sensorineural hearing loss and balance issues to decreased serum vitamin D levels. Therefore, it is not surprising that tinnitus may be linked to reduced serum vitamin D levels. Whether or if vitamin D supplements can assist avoid underlying medical conditions that increase the chance of developing tinnitus, they may also be useful in reducing impairment leading to tinnitus (Nocini et al., 2023).

12. Presbycusis

Age related hearing loss is a highly prevalent, disabling condition with profound social and economic consequences among elderly people (Swain, 2021). Vitamin D regulates calcium-phosphate homeostasis, influences neuroimmune function, and is expressed in inner ear tissues, suggesting biological pathways through which deficiency can impair the cochlear integrity, hair cell transduction, and metabolism of middle ear bone (Wimalawansa et al., 2018). There is a significant relationship between Vitamin D and calcium deficiency and both have prevalence and severity of hearing loss among adults and older people (Mehboob et al., 2025). Vitamin D and calcium deficiencies negatively affect remodelling of the bone in otic capsule and ossicles, which can explain the higher proportion of mixed hearing loss Wimalawansa et al., 2018).

13. Conclusion

Vitamin D regulates the expression of pro-inflammatory mediators and plays a powerful immunomodulatory effect. Mneieres' disease, otosclerosis, sudden sensorineural hearing loss, benign paroxysmal positional vertigo, and other cochlear and vestibular disorders can all be improved by vitamin D. Low bone mineral density and vitamin D insufficiency are additional risk factors for age-related hearing loss. Larger-scale clinical trials are need for additional confirmation, though.

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