The Role of Dietary Intake of Certain Nutrients on the Prevention of Hearing Loss

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Abstract

Considering growing cities and portable audio devices, increasingly people have deviations in the threshold of hearing. Thus, hearing loss is a point of concern in modern society, being one of the most common causes of disability. Furthermore, it may cause social isolation, dependence, cognitive impairment among several other undesired effects that certainly limit the quality of life of individuals. The prevalent origin of hearing loss is sensorineural, caused by irreversible loss of hearing cells (hair cells in the organ of Corti and/or spiral ganglion neurons). Sensorineural hearing loss has a multifactorial etiology including genetic and environmental factors such as exposure to high levels of noise, pathologies, ototoxic substances, nutritional deficiencies and aging. Some recent studies have been shown a correlation between hearing loss and certain nutrients (such as folic acid and omega-3 fatty acids). This work focuses on the nutritional aspects detected in hearing loss studied thus far, and suggests that an adequate diet on specific nutrients may increase prevention of hearing loss.

Introduction

This work consists of an initial collaborative effort among acoustics, nutrition and medicine. It aims to identify previous studies and developments in the established literature regarding the relationship between hearing and aspects of nutrition. In the latter, the nutrients found are associated with food contained in the common dietary human intake.

Hearing loss (HL) and deafness are public health conditions that affect at least 5% of the World's population (WP) as announced by the World Health Organization (WHO) [1]. Following the contemporary devices phase, about 15% of young WP are found at risk of hearing loss due to exposure to noise during recreational activities (also known as noise-induced HL or NIHL). Thus, as one of the most common modern causes of disability, it is a point of concern. Depending on the HL severity (mild, moderate, severe and profound), it may cause social isolation, dependence, cognitive impairment, or several other undesired effects that certainly limit the quality of life of individuals. The prevalence of HL is usually higher among low- and middle-income countries [1]. The WHO has been publishing material to increase awareness, guidance, and care for those with HL.

The main origin of hearing loss is sensorineural (SNHL), caused by temporary and/or irreversible loss of hearing cells (hair cells in the organ of Corti and/or spiral ganglion neurons). SNHL has a multifactorial etiology including genetic and environmental factors such as exposure to high levels of noise (NIHL), pathologies, ototoxic substances, viral causes, nutritional deficiencies and aging (presbycusis or age-related HL, ARHL), among others.

Given the difficulty in accessing the inner ear and to fully comprehend its processes, the journey towards knowledge often brings together scientists from diverse areas. Some studies have investigated the correlation between nutrition and SNHL. They typically seek prevention and treatment. The nutrients with most relevance to this topic published in literature are: carotenoids, vitamin A, vitamin C, vitamin E, vitamin B12, vitamin B9 (folate), long-chain Polyunsaturated fatty acids (PUFAs, e.g. omega-3) and magnesium.

Vitamin A deficiency was associated with hearing loss only in situations of malnutrition, pregnancy and childhood. Therefore, it is not addressed over the course of this study. However, carotenes function as vitamin A precursors in the human body. Additionally, they are also antioxidants. The latter function was strongly associated with hearing loss related to aging and oxidative stress [5, 7].

Studies [5-7] have shown relationships between specific nutrition aspects and preventing hearing loss (HL). Like carotenoids, vitamin C also has antioxidant effects. In addition, omega-3 promotes an anti-inflammatory action. Nevertheless, work carried out by Curham et al. [5] found that vitamin C in high doses, i.e. exceeding the Upper Intake Level (UL) recommended for individuals [8], yields a greater association with hearing loss. These doses were reached with supplements and not with food, demonstrating that even antioxidant nutrients, considered to be beneficial, in excess may have deleterious effects.

The study by Choi et al [7] also showed the positive effects of magnesium in the prevention of hearing loss. Furthermore, the nutrients beta-carotene, vitamin C and magnesium were associated with better auditory health. It is interesting to note that the effect of the three nutrients in synergy was greater than the sum of individual benefits.

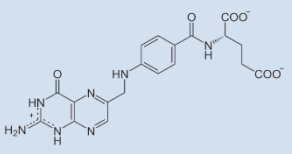
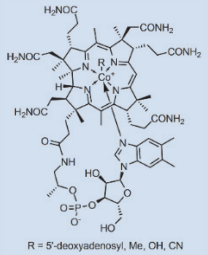
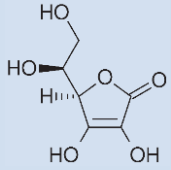
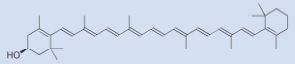
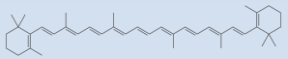
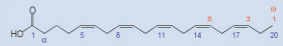
Concurrently, an important relationship between HL and homocysteine metabolism was found. Homocysteine is an amino acid, an intermediate product in methionine metabolism that requires the presence of vitamin B6, B9 (folate) and B12 to complete its cycle. In the absence of one of these vitamins, homocysteine accumulates within the body, and this accumulation is associated with various cardiovascular and neurological diseases. Some studies have shown that folate and vitamin B12 deficiencies are related to HL, suggesting that the accumulation of homocysteine in the cochlea caused these losses.

Table 1 summarizes the six selected studies, including each study's design and main findings, respectively. The criteria for choosing the studies were to cover all nutrients that had a significant relationship with SNHL, as well as to include different types of study and methods.

Table 1: Literature review regarding nutrients and HL [2-7]. Selected studies including the participants, type/study design, outcome measures and the main findings.

Study	Participants (origin)	Type/ Study Design (duration)	Outcome Measures	Findings
Houston et al (1999) [2]	55 healthy women aged 60-71 years (USA)	**Cross-sectional**	• *Serum vitamin B-12* • *Red cell folate* • *Thorough audiometric assessment*	*Women with impaired hearing had 38% lower serum vitamin B-12 and 31% lower red cell folate than women with normal hearing. Among participants who did not take supplements containing vitamin B-12 or folate, women with impaired hearing had 48% lower serum vitamin B-12 and 43% lower red cell folate than women with normal hearing.*
Durga et al (2007) [3]	728 older men and women (Netherlands)	**Intervention trial:** Double-blind, randomized, placebo-controlled trial conducted from September 2000 to December 2004.	*Intervention:* *Daily oral folic acid (800 µg) or placebo supplementation for 3 years. Three-year change in hearing thresholds, assessed as the average of the pure-tone air conduction thresholds of both ears of the low (0.5 kHz, 1 kHz, and 2 kHz) and high (4 kHz, 6 kHz, and 8 kHz) frequencies.*	*Slower progression of age related hearing loss in individuals receiving folate supplement.* *At the time, Netherlands had no program of folic acid fortification of food.*
Martínez-Vega et al (2015) [4]	Experimental study in mouse models (Spain)	Two-month old C57BL/6J mice were randomly divided into two groups (n = 65 each) that were fed folate-deficient (FD) or standard diets for 8 weeks.	*High-performance liquid chromatography (HPLC) analysis demonstrated a 7-fold decline in serum folate and a 3-fold increase in tHcy levels. FD mice exhibited severe hearing loss measured by auditory brainstem recordings and TUNEL-positive apoptotic cochlear cells.*	*On average, mice in the normal folate group had normal hearing, whereas animals in the folate deficiency group had moderate (34%) or profound (66%) hearing loss.*
Curhan et al (2015) [5]	65521 women in the Nurses' Health Study II (USA)	**Prospective** cohort study from 1991 to 2009.	*Baseline and updated information obtained from validated biennial questionnaires was used in Cox proportional hazards regression models to examine independent associations between nutrient intake and self-reported hearing loss.*	*Higher intakes of β-carotene, β-cryptoxanthin, and folate, whether total or from diet, are associated with lower risk of hearing loss, whereas higher vitamin C intake is associated with higher risk (up to 1 g from supplements). There was no significant trend between intake of vitamin E intake and risk.*
Gopinath et al (2010) [6]	2956 participants, aged 50 years (Australia)	The Blue Mountains Hearing Study (BMHS) is a population based survey of age-related HL conducted during the years 1997-2004.	*Presbycusis, defined by the author as the pure-tone average of frequencies 0.5 kHz, 1.0 kHz, 2.0 kHz, and 4.0 kHz >25 decibels of hearing loss, was measured. Dietary data was collected by using a semiquantitative food-frequency questionnaire and calculated PUFA and fish intakes.*	*There was an inverse association between higher intakes of long-chain n-3 PUFAs and hearing loss. The study suggests that dietary intervention with n-3 PUFAs could prevent or delay the development of age-related hearing loss.*
Choi et al (2014) [7]	2592 participants, aged 20 - 69 years from NHANES 2001–2004 (USA)	NHANES is an ongoing series of **cross-sectional** surveys conducted by the National Center for Health Statistics (NCHS).	*Cross-sectional data from participants who were submitted to Audiometry Examination was analyzed. Hearing thresholds as pure tone averages (PTAs) at speech (0.5, 1, 2, and 4 kHz) and high frequencies (3, 4, and 6 kHz) were computed. Dietary b-carotene, vitamin C, vitamin E, and magnesium intakes in NHANES were estimated by 24-h dietary recall (DR) interview.*	*Higher intakes of β-carotene, vitamin C, and magnesium were associated with lower (better) PTAs at both speech and high frequencies. The estimated joint effects were borderline significantly larger than the sums of the individual effects. Conclusion: Dietary intakes of antioxidants and magnesium are associated with lower risks of hearing loss, and there are additional effects with the synergy of these nutrients.*

Table 2: Food nutrients related to hearing, recommendations for adults from the Dietary Reference Intakes (DRIs): recommended intakes for individuals [8] and food sources from Krause's food & the nutrition care process [9].

Nutrient	Folate (folic acid or vitamin B9)	Vitamin B12 (cobalamin)	Vitamin C (ascorbic acid)	Carotenoids (they can be converted to vitamin A and also act as antioxidants)	Omega-3 (long-chain Polyunsaturated fatty acids or PUFAs)	Magnesium (Mg)
Food Sources	Dark green leafy vegetables, lentils, beans, papaya, orange, asparagus and Brussels sprouts. (Folic acid is added to grain products in many countries)	Found in animal products, including fish, meat, poultry, eggs, milk and milk products. Vegetarians should consume plant-based products fortified with B12 or take a supplement.	Citrus fruits and juices, such as orange, lemon, and grapefruit, pineapple cantaloupe, watermelon, kiwi fruit, mango, papaya, acerola, strawberries, raspberries, blueberries and cranberries. Bell peppers, broccoli, cauliflower and spinach are also good sources.	The carotenoids in general are organic pigments found in yellow and orange fruits and vegetables, such as cantaloupe, mangoes, pump kin, and papayas, carrots and sweet potatoes. Cryptoxanthin is also found in egg yolk and butter.	ALA can be found in seed oil, Flaxseed (or linseed) is on the top of the list, but also in several types of nuts and hemp seeds. EPA and DHA is only found in fish oil or some seaweed.	Banana, avocado, grape, grains and derivatives, wheat germ and oats, seeds and nuts such as sesame, peanuts, sunflower, Brazilian nuts and peanuts, milk, soybeans, chickpeas, bread, fish, potatoes, beets, kale and spinach.
Dietary Reference Intakes (DRI)	The Recommended Dietary Allowances (RDA) is 400 µg/day for adults. Supplement for pregnancy is recommended.	RDA is 2.4 µg/day for adults.	The female RDA is 75 mg (for non-pregnant or lactating adults) and 90 mg for males. The tolerable upper intake level (UL) is 2000 mg.	No DRIs are established for beta-carotene or other carotenoids. However, existing recommendations for consumption of carotenoid-rich fruits and vegetables are supported.	The Adequate Intake (AI) of α-linolenic acid varies from 1.1 to 1.6 g/day, or 0.6 – 1.2% of energy from diet, or up to 10% from EPA and DHA.	The RDA vary from 310 mg/day to 420 mg/day for adults depending on age range and gender.
Chemical Structure or Symbol				Beta-Carotene  Cryptoxanthin 	Alpha-linolenic acid (ALA)  Eicosapentaenoic acid (EPA)  Docosahexaenoic acid (DHA) 	

Nomenclature: ALA = Alpha-linolenic acid, AI = Adequate Intake, BMHS = Blue Mountains Hearing Study, DHA = Docosahexaenoic acid, DR = Dietary Recall, DRI = Dietary Reference Intakes, EPA = Eicosapentaenoic acid, FD = Folate-Deficient, Hcy = Homocysteine, HL = Hearing Loss, HPLC = High-performance liquid chromatography, Mg = Magnesium, NHANES = National Health and Nutrition Examination Survey, PTAs = Pure Tone Averages, PUFAs = Polyunsaturated Fatty Acids, RDA = Recommended Dietary Allowances, tHcy = Total Plasma Homocysteine, UL = Upper Intake Level and WHO = World Health Organization.

Table 2 lists the six nutrients in which a relationship was found with HL [2-7]. It also contains the food sources and daily intake recommendation [8, 9].

Folate (vit. B9) is found in the plant kingdom, as in dark-green leafy. In many countries, there is a folate food fortification program. It is a key nutrient in the first trimester of pregnancy when supplementation is strongly indicated. Cobalamin (vit. B12) is synthesized by bacteria. Nevertheless, it is found in foods only from animal sources such as meats, fish, milk and eggs or in fortified foods. Vitamin C is widely found in the plant kingdom, especially in fruits. These three are from the group of vitamins.

Carotenoids are organic pigments that function as pro-vitamin A and also have antioxidant activity. They color the yellow-orange vegetables. There are several carotenoids, and the most famous is beta-carotene. Magnesium is a mineral found in vegetables such as fruits, grains and nuts and acts in various biological processes.

Omega-3 is a long-chain polyunsaturated fatty acid family in which the first unsaturation appears on carbon number 3. It is very important for neurological and vascular health and is a strong anti-inflammatory agent. The body uses Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA), which are found primarily in fish oils. In vegetables like walnuts and flaxseed Alpha-linolenic acid (ALA) is found, which undergoes various enzymatic reactions to be transformed within the human body to EPA and DHA.

The amount of these nutrients found in food varies greatly depending on the local climate, nutrient richness of the soil, fertilizers and pesticides, planting and harvesting time, time elapsed from harvesting to consumption, exposure to sunlight and temperature among other factors, making it difficult to measure the amount of food needed to reach the Recommended Dietary Allowances (RDA) of each nutrient. Therefore, regular ingestion of the food sources of these nutrients is suggested, since an adequate and varied diet provides all the necessary nutrients for the maintenance of life and hearing health, as regards the nutritional causes involved in SNHL.

In case of suspicion of deviation in the threshold of hearing, medical/nutritional evaluation must be sought. Self-medication and/or self-fortification of nutrients may lead to undesired effects, including the worsening of the scenario.

Final Considerations

This paper has identified previous studies in the literature that correlate hearing and nutrition aspects. It belongs to an initial cooperative research among nutrition, medicine and acoustics.

The main nutrients found to be related to hearing loss are carotenoids, vitamin C, omega-3, magnesium, vitamin B9 and vitamin B12. Furthermore, this paper presents the foods where they can be found, as well as DRIs for adults.

Apparently, there are two main causes that relate these nutrients to hearing loss: oxidative stress and homocysteine metabolism. Oxidative stress may be generated in several situations such as poor eating habits, pathologies, intense physical exercise, emotional or physical stress, and is a natural effect of aging. To circumvent these metabolic situations, the body needs antioxidants, and antioxidant deficiency has been shown to be associated with HL in varying degrees, as well as hearing threshold deviation. The second cause identified in the studies refers to the accumulation of cochlear homocysteine, caused by the deficiency of vitamins B9 and B12.

In view of these findings, it is important to note that an adequate and balanced ingestion of nutrients is relevant for hearing health. Moreover, the excess of nutrients, exceeding DRIs, may lead to negative hearing effects. That is, in this case, the consumption of too much of certain food (aiming to obtain a nutrient) will not prevent or solve hearing problems.

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