Association of Hearing Loss and Nutrient Deficiencies

Jasmine Thai

ABSTRACT

Presbycusis is the age-related gradual development of hearing loss in the elderly. Hearing loss is an important component that contributes to the quality of life, making its loss an important public health concern. Age-related hearing loss is unavoidable, but early presbycusis may be reduced by further investigating factors that may contribute to the loss of sensorineural hearing. This paper investigates the association of presbycusis and antioxidant vitamins C, D, E, magnesium and folic acid. Diet warrants consideration because there is a strong correlation between hearing loss and type II diabetes or obesity. I used cross-sectional data from NHANES that were collected for 6612 participants between the years 2005-2010 to examine the relationship between hearing loss and nutrient deficiencies as defined by recommended daily allowance values dictated by the National Institute of Health. The data was compared using Pearson's Chi-squared tests, Fisher's exact tests, and adjusted for covariates using logistic regression. I found that participants categorized as deficient on RDA values had statistically significant higher odds of having hearing loss. My findings associating hearing loss to nutrient deficiencies suggest further implications of being aware of dietary intakes.

KEYWORDS

Presbycusis, age-related hearing loss, antioxidant vitamins, nutrition, NHANES

INTRODUCTION

Hearing, which allows us to communicate, connect with, and sense our surroundings, is one of our most important senses, intensifying the consequences of its loss. Age related hearing loss, also called presbycusis, describes the process of gradual hearing loss by the elderly. Presbycusis occurs in 80% of individuals over 70 years of age (Gates and Mills 2005) making it an important public health concern because hearing loss is always associated with changes in the quality of life and is sometimes even considered a disability that negatively affects physical, cognitive, behavioral, and social functions (Stig 2003). A correlation exists between hearing loss and increased frequency of dementia, indicating hearing helps maintain important neural connections (Lin et al. 2011). With an increasing average lifespan in the modern world and therefore an increasing elderly population (Gates and Mills 2005), hearing loss and its associated consequences is becoming a prevalent issue, making it important to understand the factors that may increase the risk of early presbycusis.

Although presbycusis is unavoidable to some degree, early presbycusis may be reduced by prediction using the examination of genetic, behavioral, and environmental risk factors that have been suggested to accelerate age-related hearing loss. In the case of gender, a genetic risk factor, males are more likely than females to have presbycusis before 70 years of age (Pearson et al. 1995). Behavioral risk factors include alcohol consumption and tobacco use and low alcohol consumption may offer some protective effect on presbycusis whereas tobacco use increases the risk for presbycusis (Nomura et al. 2005, Fransen et al. 2008). Alternatively, early damaging noise exposure in adolescents also increase the risk of early presbycusis (Kujawa et al. 2006). Unfortunately, other risks factors can be environmental which are often not deliberate or intentional but can have massive negative effects to hearing. Occupational hazards, an environmental risk factor, affect people in industrial jobs; where they are surrounded by loud machinery, have a demonstrated higher risk for hearing loss (Uimonen et al. 1998). Another of these environmental risk factors which most people may be unaware can be a risk factor is nutrition.

Diet and nutrition can be referred to as environmental risk factors because it can be affected by lack of access to food. Limited access, rather than the behavioral factor "choice," is often the cause of poor diet. Diet warrants consideration because there is a strong correlation between hearing loss and type II diabetes or obesity (Bainbridge et al. 2008). This correlation may be result

from the connection of these two illnesses to cardiovascular disease which constricts blood vessels and therefore may affect hearing (Liswoska et al. 2001). Because a correlation has been clearly established between obesity, type II diabetes, and hearing loss (REF), the next step to increase our understanding of presbycusis is to investigate the correlation between nutrition and hearing loss.

Vitamins and minerals, essential to nutrition, are important factors that affect general health, not excluding hearing loss. For example, vitamins A, C, E and magnesium are free radical scavengers that decrease the effects of dangerous free radical formation that damages cells (Le Prell et al. 2007). Lack of these antioxidant vitamins is correlated with higher risk of cardiovascular disease which is an important health effect of type II diabetes (Yusuf 2000). Folic acid and B-12 vitamins found in leafy green vegetables have beneficial health effects and can prevent cardiovascular disease (Lonn et al. 2006). Based on these relationships, age-related hearing loss may be associated with poor intake of the vitamins A, C, E, magnesium, and folic acid but the range of studies that have investigated this correlation is limiting. Although significant associations have been found between age-related hearing loss and poor intake of these antioxidants, this association has not been compared to recommended daily allowances that may guide civilian intake of the same vitamins (Choi et. al 2013)

The purpose of this study is to determine if there is an association between low dietary intakes of vitamins A, C, E, magnesium, and folic acid as described by the recommended daily allowances (RDA) set by the National Institute of Health and early presbycusis. Based on the literature, I expected to find an association between low intakes of these compounds and hearing loss but less significant associations found by categorizing participants based on RDA values than previous studies. To test my hypothesis, I used data from the National Health and Nutrition Examination Surveys over three years: 2005-2006, 2007-2008, and 2009-2010 and performed statistical analysis on these variables to determine association.

METHODS

Participants

Participants were sampled by the National Health and Nutrition Examination Survey (NHANES) from 2005-2010. NHANES is a cross-sectional health survey conducted each year by

the National Center for Health Statistics (NCHS; CDC) to produce vital health information for epidemiological studies the United States. Each year, five thousand participants in fifteen different locations are given interviews and physical examinations including laboratory tests administered by medical personnel. To build a nationally representative sample, NHANES uses a complex study design to select participants of different demographic backgrounds; civilians over 60 years of age are over-sampled. Health interviews are given in participants homes while examinations are performed in mobile health centers equipped with the necessary technology for accurate data collection. To increase access to mobile health centers, transportation is provided for selected participants. My study included data from NHANES 2005-200, 2007-2008, 2009-2010. I did not use data from earlier years because of the difference in sampling procedures that began after 2005.

Definition of hearing loss

NHANES performed audiometry tests in four parts: an audiometric questionnaire, brief otoscopic screening, tympanometry, and pure tone air conduction audiometry. Audiometry examinations were performed in mobile examination centers in sound-isolating rooms by trained audiologists certified by the National Institute for Occupational Safety and Health. Otoscopic screening identified abnormalities in ear canals and ear drums; tympanometry exams identified abnormalities in middle ear pathologies. For pure tone air conduction audiometry, examiners tested for threshold hearing at seven frequencies from 500H to 8000 hertz (hz) at -10 to 100 decibels (dB) through insert earphones.

For this study, I defined hearing loss as any failure of a standard pure tone air conduction audiometry test at any one frequency at 25dB in either ear (Gates et al. 2003; McBride et al. 1994; Gelfand 2001). In order to isolate sensorineural hearing loss, I excluded participants who were using hearing aids that could not be removed for testing, had a damaged ear canal or ear drum as described by the otoscopic screening, and had tympanometry results that indicated damages to the middle ear.

Definition of vitamin deficiencies

NHANES determined dietary concentrations of energy, nutrients, and other food component intakes by an estimation based on two 24-hour dietary recall interviews for each participant. The dietary recall interviews are executed in person at a mobile examination center where each participant is asked to list all food and beverages consumed within the past 24-hours. Using the United States Department of Agriculture Food and Nutrient Database for Dietary Studies (USDA FNDDS), food and beverages were coded and nutrient values were calculated for each of the two days based on portion sizes. To monitor the quality of codes, coders were given certification tests and were routinely monitored.

I created a composite value for intakes of vitamin A, C, E, magnesium and folic acid based on the average of the two intakes calculated by the dietary recall interviews for each participant. I categorized the participants as having vitamin deficiencies for each examined nutrient if their intakes were below thresholds for recommended dietary allowances (RDA) for their gender determined by the National Institutes of Health (NIH). RDAs are calculated by the Food and Nutrition Board and represent the average daily level of intake sufficient to meet nutrient requirements of 98% of healthy people (NIH). Threshold values for 2013 are shown in Table 1.

Table 1. Recommended dietary allowances for vitamins A, C, E, magnesium, and folic acid in 2013. RDAs (reported in grams/day) are calculated by the Food and Nutrition Board to be 20% higher than the estimated average requirements expected to satisfy needs of 50% of people based on scientific literature.

Nutrients	Average RDA for Males	Average RDA for Females
Vitamin A	900 (µg/d)	700 (µg/d)
Vitamin C	15 (mg/d)	15 (mg/d)
Vitamin E	15 (mg/d)	15 (mg/d)
Folic Acid	400 (µg/d)	400 (µg/d)
Magnesium	400 (mg/d)	300 (mg/d)

Definition of covariates and other sociodemographic factors

I accounted for covariates and sociodemographic factors that could affect association. These variables included gender, ethnicity, obesity, household income and education status and have been associated to hearing loss in other studies (Pearson et al., Jerger et al. 1993, Garsteki et al. 1998, Helzner et al. 2005). NHANES classified participants into ethnicities of Mexican American, other Hispanic, non-Hispanic white, non-Hispanic black, and multiracial. Obesity was determined by body max index (BMI) which is a ratio calculated by using height and weight, usually correlated with body fat. I categorized participants as obese if their BMI was above 25 kg/m2 (NIH). Annual household income was adjusted based on number of people in each household. I determined participants' poverty level from numbers from the U.S. Bureau of the Census: below 35,000 was defined as below poverty level, 35,000-75,000 was defined as middle class, and above 75,000 was defined as upper class. I classified educational status for each participant by examining the highest education level achieved by entire household. Participants households were separated into four groups: no high school diploma, high school diploma, some college, and college graduate and above.

Statistical analyses

I tested for association by using chi-squared tests and logistic regression. I used Perason's Chi-squared tests for bivariate analysis to determine association between positive hearing loss and positive deficiencies of antioxidant vitamins A, C, E, magnesium, and folic acid categorized as described above. A P-value < 0.05 was considered to be statistically significant. I used Fisher's exact test to determine odds ratios for significant associations determined by the Pearson's Chi-squared tests.

To account for sociodemographic factors, I used multivariate logistic regression to test for independent associations between hearing loss and covariates including gender, ethnicity, obesity, household income, and education status with the covariates predicting for hearing loss. All analyses were conducted with R statistical software (version 3.0.2; R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Participants

I examined a total number of 6,612 participants with a 30.28 percentage of participants with hearing loss for the years 2005, 2007, and 2009 after participants with damages to the ear canal were removed (Table 2).

Table 2. Total number of participants with hearing loss. Participants were taken from NHANES 2006-2007, 2008-2009, 2010-2011.

Hearing Loss (# of participants)	Total # of Participants	Hearing Loss (% of participants)
2002	6612	30.28%

The demographic characteristics of participants with audiometry information were representative of the United States population. Participants with higher percentages of impaired hearing were characterized by being non-Hispanic White and having of middle class or lower. For all other relevant demographics, percentages showed no large difference (Table 3).

Table 3. Aggregate demographics of participants with hearing loss data. NHANES 2005-2006, 2007-2008, 2009-1010, N=6612.

	Total	Hearing - Normal (#)	Hearing - Impaired (#)	Hearing - Impaired (%)
Gender				
Male	3369	2319	1050	31.17
Female	3243	2291	952	29.36
Ethnicity				
Mexican American	1530	1285	245	16.01
Other Hispanic	439	371	68	15.49
Non-Hispanic White	2682	1387	1299	48.36
Non-Hispanic Black	1647	1325	322	19.55
Other Race – Including Multi-Racial	310	242	68	21.94
Body Mass Index				
Not Overweight	3604	690	1312	43.62
Overweight	2914	2914	1696	56.38
Income Level				
Below 35000	2988	1972	1016	34.00
35000-75000	1822	1272	550	30.19
75000 and Above	553	439	114	20.61

Education Status				
No Diploma	3562	2428	1134	31.84
High School Diploma	1535	1028	507	33.03
Some College	1744	1275	469	26.89
College Graduate and Above	1068	710	358	33.52

Association of hearing loss with nutrient deficiency

Chi-squared tests showed significant associations between hearing loss and vitamin A, C, E and magnesium. Folic Acid, however, had no significant association with hearing loss (Table 4).

Table 4. Prevalence of hearing loss with and without vitamin deficiencies. NHANES 2005-2006, 2007-2008, 2009-2010, N=6612. Significant p-values are denoted with "*".

Nutrients	% without Hearing Loss	% with Hearing Loss	X^2	P-value
Vitamin A	55.6	22.2	52.114	5.237e-13*
Vitamin C	8.1	2.4	24.0923	9.183e-07*
Vitamin E	68.8	30.4	4.9921	0.02546*
Folic Acid	42.4	19.5	2.9138	0.08782
Magnesium	60.1	25.3	20.5976	5.667e-06*

The Fisher's exact tests for the odds ratios of nutrients that had statistically significant associations (vitamins A, C, E, and magnesium) all had odds ratios higher than 1 (Table 5). The odds of having hearing loss are therefore increased by having deficiencies in vitamins A, C, E, and magnesium.

Table 5. Vitamin deficiencies independently associated with hearing loss. NHANES 2005-2006, 2007-2008, 2009-2010, N=6612. Significant p-values are denoted with "*".

	Odds Ratio	95% CI	P-value

Vitamin A	1.577407	1.389946 1.789442	1.116e-12
Vitamin C	1.608687	1.325286 1.961631	5.621e-07
Vitamin E	1.372326	0.7782184 2.3707614	0.03212
Magnesium	1.400982	1.206643 1.624994	8.357e-06

Association of Hearing Loss, Nutrient Deficiency, and Demographic Factors

Some covariates were also independently associated with early presbycusis. Gender was not statistically significant and was not independently associated with hearing loss. However, ethnicity, obesity, household income and education were significantly associated with early presbycusis (Table 6). Participants with obesity had significant odds ratio of 3.266; being obese largely increases the odds of testing positive for hearing loss. Participants that were non-Hispanic white and mixed race also had significant associations to hearing loss; odds ratios for participants that fit these categories were greater than one so the odds of having hearing loss are greater for these participants. Participants with no diploma, some college, and college and above also had greater odds of having hearing loss. These were statistically significant as well. Household incomes of below upper class also increased odds of having hearing loss. Participants with household incomes of upper class were also significantly associated with hearing loss but had an odds ratio of less than one; having household incomes categorized as upper class decreases the odds of having hearing loss.

Table 6. Risk factors independently associated with hearing loss. NHANES 2005-2006, 2007-2008, 2009-2010, N=6612. Significant p-values are denoted with "*".

Risk Factor		P-value	Odds Ratio	Confidence interval
Gender		0.06374	1.089613	0.9942766 - 1.1938066
Obesity		1.571e-09*	3.266158	2.922633 3.652772
Ethnicity	Mexican American	0.7915	0.6785306	0.5040417 0.9225562
	Other Hispanic	0.0249	0.6522911	0.4487540 0.9478181
	Non-Hispanic White	<2e-16 *	3.3330294	2.5350128 4.4378055
	Non-Hispanic Black	0.3354	0.8648613	0.6468726 1.1688407
	Other Race – Including Multi-Racial	0.01176 *	1.4737730	1.0840732 1.9837429
Education	No Diploma	1.71e-05 *	2.1518990	1.5335289 - 3.0897136
	High School Diploma	0.18345	1.1012232	0.9552497 - 1.2692207

	Some College	0.00155 *	1.7674414	1.2550626 - 2.5455018
	College Graduate & Higher	1.42e-06 *	2.4227413	0.1466964 - 0.2880305
Household Income	Less than 35000	1.67e-07 *	1.4832374	0.5852819 - 0.9498286
	35000-75000	0.00787 *	1.2447996	1.0597100 - 1.4638198
	75000 and above	0.01843 *	0.7475912	0.5852819 - 0.9498286

DISCUSSION

In this study of a representative sample of the United States population, I found that hearing loss is associated with nutrient deficiencies in diet, even by categorizing participants as nutrient deficient only based on above or below RDA values. Participants who were categorized as deficient in vitamins A, E, C, and magnesium had higher odds than their counterparts who were categorized as deficient of the same vitamins suggesting that vitamins A, E, C, and magnesium are important contributing factors to hearing loss and RDA values are considerable guidelines to follow in preventing hearing loss.

Vitamins

Participants categorized as deficient in vitamins A, C, E, and magnesium had higher odds of hearing loss than participants categorized as not deficient. These results were statistically significant.

Vitamins A, C, E and magnesium are free radical scavengers that are acknowledged to decrease the effects of dangerous free radical formation that damages cells (Le Prell et al. 2007). Free radical formation, which can stunt cochlear blood flow, is one of the major contributors to hearing loss (Le Prell et al. 2007). It is triggered by aging, noise, and other environmentally medicated trauma. Mice treated with antioxidant vitamins showed dramatic decrease formation of free radicals and therefore a decrease in the incidence of hearing loss (Seidman 2000). However, studies on humans investigating this same relationship have been less suggestive of positive association (Shargorodsky et al. 2010) perhaps due to measurement errors or biased self-reporting.

My investigation of the positive association between nutrient deficiency and hearing do suggest that vitamins A, C, E and magnesium have the same protective effects in hearing loss in

humans as they do in mice (Seidmann 2000). My study determined that participants above RDA values of vitamin C had lower odds of hearing loss which is consistent with a mouse study that determined lack of vitamin C accelerated hearing loss by causing loss of signal ganglion neurons which are important in the hearing pathway (Kashio et al. 2009). The positive association of vitamin C and hearing loss is supported by the clear benefits in antioxidant treatment to mice with age-induced hearing loss (Heman-Ackah et al. 2010). However, nutrient therapy does not always provide a healing effect (Bielefeld et al. 2008 and Bielefeld et al. 2008) and it cannot be concluded, even with the results of this study that nutrients can be used to treat presbycusis. Although antioxidant vitamins are important in the hearing loss formula somewhere, they may not be a direct cause of presbycusis.

Disease

Participants categorized as obese had significant positive associations to hearing loss in my study. Cardiovascular disease and type II diabetes could also be variables in the hearing loss formula that could link nutrient deficiencies to hearing loss, specifically associations between obesity and hearing loss (Hwang et al. 2009 and Lalwani et al. 2013). This association may be because of obesity and type II diabetes induced cardiovascular disease which causes vasoconstriction of blood vessels (Frisinia et al. 2006). Furthermore, abundance of free radicals which exponentially increase oxidative stress in the human body has been affirmatively associated with risk of cardiovascular disease (Halliwell and Gutteridge 2007). The lack of antioxidant vitamins has been found to be correlated for higher risk of cardiovascular disease (Yusuf et al. 2000) because antioxidant vitamins decrease abundance of free radicals. Therefore, antioxidant nutrient deficiencies, type II diabetes, and cardiovascular disease could all be factors contributing to presbycusis. However, we should be wary of the limitations of these conclusions.

Limitations and Future Directions

Although comprehensive, the NHANES data set is cross-sectional and not an experimental study and causal inferences cannot be made. First of all, my sample size was limiting. My population size for this study was 6612 people. Even though sampling was comprehensive and the

data included spanned six years, the participants sampled are still a small representative sample of the United States. Moreover, NHANES did not collect audiometry data for children under 12 years of age and further investigation could include samples of under below 12 years of age and include more participants over more years.

The nutrient information acquired by NHANES was not exhaustive and could represent bias in personal characteristics. NHANES collected information from participants for only two days which may not be representative of what a person may eat on a day-to-day basis. To improve this study, information could be collected for participants with a more detailed focus on nutrient deficiencies, including collecting blood samples in general or performing interviews for a greater amount of time.

Additionally, to access whether these dieting habits where by choice or by circumstance, researchers could record the location of the participants and calculate their proximity to food deserts which are determined by their lack of access to healthy food (Walker et. al 2010). Participant samples including location data would enrich our understanding about the negative impacts of food insecurity.

Broader Implications

Age-related hearing loss is a complex disease that affects tens of millions of people worldwide. With an increasing elderly population in the modern world, Presbycusis is a prevalent issue especially because of its profound societal costs and negative influences on quality of life. Age-related hearing loss can cause individuals to become isolated and depressed (Mohr et al. 2000). Hearing loss is even considered as a disability; negatively affecting physical, cognitive, behavioral, and social functions (Stig 2003). Hearing loss can accelerate dementia due to its relationship to signal ganglia neurons (Lin et al. 2011).

Ultimately, because my study strengthens the positive association between nutrient deficiencies and hearing loss, it calls to attention the importance of nutrition education to promote healthy diets. Additionally, my study also supports the legitimacy of RDA values for the vitamins of interest since results the results were similar to a study that investigated average threshold values rather than categorizing the participants, bolstering the importance of pursing RDA values in daily eating habits. It is commonly known that the lack of a balanced diet can cause decreases to the

quality of life through obesity and disease. Coupled with the association to increased hearing loss, lacking nutrients has even more profound societal impact and should encourage the general public should be more vigilant about eating healthily.

ACKNOWLEDGEMENTS

I would like to thank Patina Mendez (UC Berkeley Department Environmental Science, Policy and Management) for her ongoing support, statistical expertise, commentary, and helpful revisions of my research and writing, Kurt Spreyer (UC Berkeley Department Environmental Science, Policy and Management) for his advice and guidance on research topics, and Maureen Lahiff (UC Berkeley Department of Public Health) for her assistance in statistical analysis. Finally, my environmental science workgroup Kyle Caberjal, Kathryn Liu, Danielle Ngo, and Rebecca Samuel, as well as my friends and family were essential their moral support, feedback, and edits of my manuscript.

REFERENCES

Bainbridge, K.E., Hoffman, H.J, and C.C. Cowie. 2008. Diabetes and hearing impairment in the United States using audiometric evidence from the National Health and Nutrition Examination Survey 1999-2004. Annals of Internal Medicine 149:1-10.

Bielefeld, E.C., Coling, D., Chen, G.D., and D. Henderson. 2008. Multiple dosing strategies with acetyl L-carnitine fail to alter age-related hearing loss in the Fischer 344/NHsd rat. Journal of Negative Results in Biomedicine 7:4.

Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Questionnaire. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2005-2010

Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Examination Protocol. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2005-2010.

Choi, Y.H., Miller, J.M., Tucker, K.L., Hu, H., and S.K. Park. 2014. Antioxidant vitamins and magnesium and the risk of hearing loss in the US general population. The American Journal of Clinical Nutrition 99:148-154.

Frisina, S. T., F. Mape, S. H. Kim, D. R. Frisina, and R. D. Frisina. 2006. Characterization of hearing loss in aged type II diabetes. Hearing Research 211: 103-113.

Garstecki, D.C., and S.F. Erler. 1998. Hearing loss, control, and demographic factors influencing hearing aid use among older adults. Journal of Speech, Language and Hearing Research 41:527-537.

Gates, G. A. and J. H. Mills. 2005. Presbycusis. The Lancet 366: 111-1120.

Halliwell, B., and J. Gutteridge. 2007. Free radicals in biology and medicine. 4th ed. New Yor: Oxford University Press.

Helzner, E.P., Cauley, J.A., Pratt, S.R., Wisniewski, S.R., Zmuda, J.M., Talbott, E.O., DeRekeneire, N., Harris, T.B., Rubin, S.M., Simonsick, E.M., Tylavsky, F.A., and A.B. Newman. 2005. Journal of American Geriatrics 53:2119-2127.

Heman-Ackah, S.E., Juhn, S.K., Huang, T.C., and T.S. Weidmann. 2010. A combination antioxidant therapy prevents age-related hearng loss in C57BL/6 mice. Otolaryngology, Head, and Neck Surgery 143:429-434

Hwang, J.H., Wu, C.C., Hsu, C.J., Liu, T.C., and W.S. Yang. 2009. Association of central obesity with the severity and audiometric configurations of age-related hearing impairment. Obesity 17: 1796-1801.

Jerger, J., Chimiel, R., Stach, B., and M. Spretnjak. 1993. Gender affects audiometric shape in presbycusis.

Kashio, A., Amano, A., Konodo, Y., Sakamoto, T., Iwamura, H., and M. Suzuki. 2009. Effect of vitamin C depletion on age-related hearing loss in SMP30/GNL knockout mice. Biochemistry and Biophysiology Research Communications: 390: 394-398.

Kujawa, S.G., and M. C. Liberman. 2006. Acceleration of age-related hearing loss by early noise exposure: evidence of a misspent youth. Journal of Neuroscience 26: 2115-2123.

Lalwani, A. K., K. Katz, Y. H. Liu, S. Kim, and M. Weitzman. 2013. Obesity is associated with senisorineural hearing loss in adolescents. The Laryngoscope 10.

Le Prell, C.G., Hughes, L.F., and J.M. Miller. 2007. Free radical scavengers' vitamins A, C, and E plus magnesium reduce noise trauma. Free Radical Biology and Medicine 42:1454-1463.

Lin, F. R., J. Metter, R. J. O'Brien, S. M. Resnick, A. B. Zonderman, and L. Ferrucci. 2011. Hearing loss and incident dementia. Archives of Neurology 68: 214-220.

Lisowska, G., Namyslowski, G., Morawski, K., and K. Strojeck. 201. Cochlear dysfunction and diabetic microangiopathy. Scandinavian Audiology 52: 199-203.

Lonn, E., Yusuf, S., Arnold, M.J., Pogue, S.P, McQueen, M.M., Probstfield, J., Fodor, G., Held, C., and J. Genest. 2006. Homocysteine lowering with folic acid and B vitamins in vascular disease. New England Journal of Medicine 352:1567-1577.

Mohr, P. E., J. J. Feldman, J. L. Dunbar, A. McConkey-Robbins, J. K. Niparko, R. K. Rittenhouse, and M. W. Skinner. 2000. The Societal costs of severe to profound hearing loss in the United States. Internal Journal of Technological Assessment in Health Care 16: 1120-1135.

National Institutes of Health (NIH), Office of Dietary Supplements Nutrient Recommendations: Dietary Reference Intakes, Bethsda, MD: U.S. Department of Health & Human Services, National Institutes of Health.

Nomura, K., Nakao, M., and T. Morimoko. 2005. Effect of smoking on hearing loss: quality assessment and meta-analysis. Preventative Medicine 40: 138-144.

Pearson, J.D, Morrell, C.H, Gordon-Salant, S., Brant, L.J., Metter, E.J, Klein, L.L., and J.L. Fozard. 1995. Gender differences in a longitudinal study of age-associated hearing loss. Journal of the Acoustical Society of America 97: 1196

R Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/

Seidman, M.D., 2000. Effects of dietary restriction and antioxidants on presbycusis. Laryngoscope: 110:737-738.

Shargorodsky, J., Curhan, S. G., Eavey, R., and G. C. Curhan. 2010. A prospective study on vitamin intake and the risk of hearing loss in men. Otolaryngology – Head and Neck Surgery 142:231-236.

Stig, A. 2003. Negative consequences of uncorrected haring loss – a review. Internal Journal of Audiology 42:17-20.

Uimonen, S., Maki-Torkko, E., and M. Sorri. 1998. Hearing and occupation. International Journal of Circumpolar Health 57:156-161.

U.S. Department of Agriculture (USDA), Food and Nutrient Database for Dietary Studies (FNDDS),Washington, DC: U.S. Department of Health and Human Services, U.S. Department of Agriculture.

Yusuf, S., Dagenais, G., Pogue, J., Bosch, J., and P. Sleight. 2000. Vitamin E supplementation and cardiovascular events in high-risk patients. New England Journal of Medicine 342: 154-160.