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Healthy Diets, Healthy Hearing: National Health and Nutrition Examination Survey, 1999–2002

C. Spankovich, AuD, PhD, MPH and C.G. Le Prell, PhD

Department of Speech, Language, and Hearing Sciences, University of Florida

Abstract

Objective—A significant relationship between dietary nutrient intake and susceptibility to acquired hearing loss is emerging. Variability in the outcomes across studies is likely related to differences in the specific metrics used to quantify nutrient intake and hearing status. Most studies have used single nutrient analysis. Although this analysis is valuable, interactions between nutrients are increasingly recognized and could modify modeling of single nutrient effects. Therefore, we examined the potential relationship between diet and hearing using a metric of overall dietary quality.

Design—This cross-sectional analysis was based on Healthy Eating Index data and audiological thresholds.

Study sample—Data for adults between the ages of 20 to 69 years of age were drawn from the National Health and Nutrition Examination Survey, 1999–2002.

Results—Controlling for age, race/ethnicity, sex, education, diabetes, and noise exposure, we found a significant negative relationship (Wald $F = 6.54$, $df = 4, 29$; $p = 0.05$) between dietary quality and thresholds at higher frequencies, where higher dietary quality was associated with lower hearing thresholds. There was no statistically significant relationship between dietary quality and threshold sensitivity at lower frequencies.

Conclusions—The current findings support an association between healthier eating and lower high frequency thresholds in adults.

Keywords

diet; nutrition; healthy eating index; hearing loss

Introduction

Individual variability for susceptibility to acquired hearing loss is not well understood. One of the most valuable resources to date for examining hearing loss covariates is the large epidemiological database generated by the CDC in 2-year cycle cross-sectional surveys, i.e. the National Health and Nutrition Examination Survey (NHANES) (<http://www.cdc.gov/nhanes>). Audiometry has been part of the NHANES since the first National Health

Examination Survey (NHES I) in 1960–1962. A second useful approach has been longitudinal studies. One longitudinal study worth note is the Baltimore Longitudinal Study on Aging, which started in 1958 and includes more than 1,400 men and women, in their 20's through their 90's (Moreira & Palladino, 2011; Brant & Fozard, 1990). Another large-scale longitudinal study that has provided valuable information is the Epidemiology of Hearing Loss cohort from Beaver Dam, WI, and, more recently, the Beaver Dam Offspring Study, which now includes 5,275 adults born between 1902 and 1962 (Cruickshanks et al., 1998; Nash et al., 2011). Finally, the Blue Mountain Hearing Study (BMHS) is a population-based survey of age-related hearing loss conducted during the years 1997–2004 in Sydney, Australia. The study is a spin-off of the Blue Mountain Eye Study and includes prospective 5 year assessments (Mitchell et al., 2011).

From the NHANES and these longitudinal studies, numerous variables have been indicated as modifying factors for age-related hearing loss (ARHL). Sex has commonly been a statistically significant factor, with males having worse thresholds than females, although the effects of sex are difficult to interpret given sex-based differences in noise history (see Marlenga et al., 2012). Other statistically significant covariates include race/ethnicity (Lin et al., 2012), education /socioeconomic status (Henderson et al., 2011; Agrawal et al., 2008; Zhan et al., 2011), noise exposure (Agrawal et al., 2009), smoking and second-hand smoke (Cruickshanks et al., 1998, Fabry et al., 2011), diabetes (Bainbridge et al., 2008), cardiovascular health (Agrawal et al., 2009; Nash et al., 2011), ototoxic drugs (Bainbridge et al., 2008), and genetics (for review, see Liu & Yan, 2007 and Uchida et al., 2011). One important observation across studies is the tremendous subject to subject variability with respect to both incoming threshold and rate of change (Pearson et al., 1995; Morrell et al., 1996). There is also evidence suggesting changes in risk factors across generations, with prevalence of hearing loss decreasing in more recent generations (Zhan et al., 2010). A complicating factor in understanding ARHL is the variability in exposure to noise, and also the individual variability in vulnerability to noise-induced hearing loss (NIHL). Like the effects of aging on hearing, the effects of noise on hearing also vary. The National Institute for Occupational Safety & Health (NIOSH) suggests up to 29% of those exposed to 90 dBA noise for 8 hrs/day over a working lifetime will suffer permanent hearing impairment (see table 3-1 in National Institute for Occupational Safety and Health, 1998), but it is not clear what makes that 29% more vulnerable than the other 71% of the population. Thus, there is a major gap in our understanding of individual variability in hearing thresholds, rate of change in hearing, and susceptibility to acquired hearing loss and factors that may contribute to this variability.

One possibility is that dietary quality influences hearing status by mediating vulnerability of the inner ear to noise insult and to age-related changes. Review of the literature reveals mixed support regarding specific nutrients and the relationship between single nutrient intake and hearing (described in detail in Le Prell & Spankovich, 2012, in press). A brief overview of the human epidemiological literature is provided here. **Vitamin A.** In cross-sectional analyses increased serum levels of retinol and pro-vitamin A carotenoids (Michikawa et al., 2009) and increased dietary intake of vitamin A (Gopinath et al., 2011) were associated with decreased prevalence of hearing impairment in older individuals,

although one data set revealed small but statistically significant decreases in high-frequency sensitivity in those with the highest vitamin A intake (Spankovich et al., 2011). Beta-carotene is metabolized to vitamin A. Most data sets reveal no significant relationship between β -carotene and hearing outcomes (Michikawa et al., 2009; Shargorodsky et al., 2010; Gopinath et al. 2011). However, one recent analysis of the NHANES data did suggest a beneficial role for β -carotene in hearing (Choi, 2011). **Vitamin B.** Folic acid slowed progression of age-related hearing loss at low frequencies in a 3-year longitudinal study (Durga et al., 2007), although an earlier study showed no relationship between hearing loss and B vitamin levels in plasma (Berner et al., 2000). **Vitamin C.** Some cross-sectional data suggest a positive relationship between vitamin C intake and hearing sensitivity (Spankovich et al., 2011), although several studies failed to detect a statistically significant relationship (Shargorodsky et al., 2010; Gopinath et al. 2011; Choi, 2011). **Vitamin E.** Increased intake of vitamin E has been linked to better hearing in a cross-sectional analysis (Spankovich et al., 2011), although several other studies failed to detect a statistically significant relationship (Michikawa et al. 2009; Shargorodsky et al., 2010; Gopinath et al. 2011; Choi, 2011). **Magnesium (Mg).** Mg reduced development of new human NIHL in two double-blind placebo-controlled studies (Joachims et al., 1993; Attias et al., 1994; 2004); there are also cross-sectional data that suggest a positive relationship between Mg intake and hearing sensitivity (Spankovich et al., 2011). The study populations, the tools used to characterize diet and hearing, and the specific outcomes are summarized in table form in Appendix A.

In contrast to vitamins and minerals, higher carbohydrate intake, fat intake, and cholesterol intake are associated with negative hearing outcomes. **Carbohydrates.** Gopinath et al. (2010a) reported an increased risk for hearing loss in adults with higher glycemic index (an index of carbohydrate quality) and glycemic load (an index of both quality and quantity), as well as higher total carbohydrate intake. **Fat/Cholesterol.** A link between dietary fat, cardiovascular disease, and hearing loss was first suggested based on better than expected cardiovascular function and auditory sensitivity in the Mabaan tribe in Sudan (Rosen & Olin, 1965). The relationship between dietary fat, cardiovascular disease, and hearing loss was confirmed by Rosen et al. (1970), when they manipulated institutionalized patient diets (by replacing saturated fats with unsaturated fats) and demonstrated lower thresholds in patients on the low saturated fat diet. Polyunsaturated fatty acids have since been associated with better hearing outcomes in more recent studies as well (Dullemeijer et al., 2010; Gopinath et al., 2010b; Spankovich et al., 2011). Deficient high density lipoprotein (i.e., not enough “good” cholesterol) (Suzuki et al., 2000) and elevated triglycerides (i.e., too much “bad” cholesterol) are also associated with poorer hearing (Evans et al., 2006). Still, the relationship between hearing loss and total cholesterol remains unclear (Jones & Davis, 2000; Suzuki et al., 2000).

Taken together, the mixed outcomes from single nutrient studies may reflect the mixed contributions of “healthy” nutrients and dietary components that have detrimental effects when consumed at higher than recommended levels. The vast majority of the epidemiological studies described above used a single nutrient analysis method (for review of single nutrient analysis, see Tucker, 2010). In this type of analysis, the nutrient information is derived from weighed food records, 24-hour recall, and/or a food frequency

questionnaire used to estimate dietary intake. Based on reported food choices, the foods are separated into their respective caloric and nutrient intake (i.e. amount of vitamin C, vitamin E, magnesium, fat, etc). The individual nutrients derived are then entered into a statistical model to examine the relationship between the individual nutrient and the health outcome of interest. Although, this type of analysis is valuable, it has several limitations. First, the effect of any single nutrient may be too small to detect. Second, it is difficult to draw conclusions regarding individual nutrients when significant relationships are detected for multiple nutrients (as in Gopinath et al., 2011; Spankovich et al., 2011). Third, type I error rates are increased by performing multiple single nutrient analyses (Hu, 2002). Finally, there are interactions between nutrients, both functionally and biochemically (see for example, Le Prell et al., 2007; Choi, 2011).

Given the limitations of single nutrient analysis, the use of overall dietary pattern as an alternative approach has been adopted by many (for review, see Tucker, 2010). A dietary pattern is not measured directly, but rather relies on statistical methods to characterize diet from collected information. One approach for analyzing dietary pattern is to look at indices of diet quality. These indices are typically constructed based on dietary recommendations. An example is the Healthy Eating Index (HEI). The HEI was developed by the U.S. Department of Agriculture's (USDA) Center for Nutrition Policy and Promotion. The HEI estimates overall quality of a person's diet by assessing the degree to which an individual's diet conforms to the U.S. Dietary Guidelines for Americans (Kennedy et al., 1995). The use of dietary patterns allows a parallel that better matches "real world" dietary intake, where nutrients are consumed as combinations of food rather than individual nutrients. In addition, dietary patterns could have important public health implications by simplifying recommendations for the public to interpret and translate into their diets (Hu, 2002).

In this study, we used data from the 1999 to 2002 NHANES to evaluate associations between a measure of dietary quality, the HEI, and hearing sensitivity. A clearer understanding of factors that may modify susceptibility to hearing loss could inform novel strategies to prevent this highly prevalent and potentially disabling disorder.

Methods

The NHANES is an ongoing cross-sectional survey of the civilian non-institutionalized population of the United States. Every 2 years, approximately 10,000 individuals are selected at random within specific demographic distributions so as to be representative of the US population. Between 1999 and 2002, NHANES collected data on 21,004 individuals of all ages (9,965 in 1999–2000 and 11,039 in 2001–2002). Further details on NHANES sampling, data collection, and analysis methods are available (Curtin et al., 2012). Effects of dietary quality on hearing thresholds were explored using a cross-sectional analysis of 1999–2002 NHANES data, including the HEI and pure tone average (PTA) thresholds for low and high frequencies (LFPTA and HFPTA respectively).

Participants, Demographics, and Variables

Of the 21,004 participants, there were 8,143 between the ages of 20 to 69 years of age. Audiometric data were available for 3,853 participants (1,807 participants in the 1999–2000

cycle and 2,046 in the 2000–2002 cycle). Of the 3,853 participants with audiometric data, there were 2,366 participants included in the final analysis. The exclusionary criteria applied to reduce the 3,853 with audiometric data to the final included 2,366 participants are described under Inclusion/Exclusion (in the next section).

Trained interviewers administered detailed questionnaires. Age at interview was binned into 5 age groups (20–29, 30–39, 40–49, 50–59 and 60–69 years of age) comparable with other NHANES studies (Agrawal et al., 2008; Bainbridge et al., 2011). Race/ethnicity was grouped as non-Hispanic White (hereafter, white), non-Hispanic Black (hereafter, black), Mexican American, or Other. Education was coded as Less than High School, High School Diploma (including general equivalency diploma), and More than High School. Participants were asked if they were “Ever told by a doctor that they have diabetes” (Yes or No). Smoking history was reported as having smoked at least 100 cigarettes in entire life (Yes or No). Exposure to occupational noise was defined as noise exposure in the workplace (requiring speaking in a raised voice) for at least 3 months (Yes or No). Veteran status for service in the United States Armed Forces was also considered (Yes or No). Sex was categorized into male and female.

The audiological examination consisted of four parts: an audiometric questionnaire, otoscopic examination, tympanometry and pure-tone air-conduction threshold measures at 0.5, 1.0, 2.0, 3.0, 4.0, 6.0, and 8.0 kHz (National Health Examination Survey, 2001). Testing was performed in mobile examination centers (MEC) equipped with sound-isolated rooms. Audiometry was completed by health technicians trained by a certified audiologist from NIOSH. NIOSH conducted performance monitoring of technicians on a routine basis. Instrumentation for audiometry included an audiometer (AD226; Interacoustics AS, Assens, Denmark) with standard headphones (TDH-39; Telephonics Corporation, Farmingdale, NY) and insert earphones (EarTone 3A; Etymotic Research, Elk Grove Village, IL). Tympanometry was performed using an acoustic impedance tympanometer (Earscan, Micro Audiometric, Murphy, NC). Further details on audiometric testing procedures are available online (<http://www.cdc.gov/nchs/nhanes/au.pdf>).

Inclusion/Exclusion

Of the 3,853 participants selected for audiometric testing, a subset was excluded as they had incomplete auditory data and/or missing dietary data (540 excluded). Additional exclusions were applied based on present ear tubes, abnormal otoscopy, impacted cerumen, abnormal tympanometry (peak pressure -150 daPa; compliance 0.3 ml), and/or more than 10-dB difference between test and retest thresholds at 1 kHz (635 excluded). Finally, LFPTA (0.5, 1, and 2 kHz) and HFPTA (3, 4, 6, and 8 kHz) were calculated for each ear. NHANES does not survey for congenital/genetic or sudden hearing loss; therefore, participants with LFPTAs or HFPTAs > 3 standard deviations (SD) above the mean for their age group (186 excluded), or > 15 dB difference between ears on either LFPTA or HFPTA (126 excluded), were excluded from further analysis. This left a final sample size of 2,366 participants available for inclusion in the reported analyses. Based on β -coefficients 0.80 for right vs left ear comparisons, the PTAs for right and left ears were averaged such that each subject contributed a single HFPTA and a single LFPTA to the analysis.

Healthy Eating Index (HEI)

The HEI estimates overall dietary quality based on an overall score across dietary components. The overall score is a sum of 10 equally weighted components for the five food groups (meat, dairy, fruits, vegetables, and grains), four nutrients (total fat consumption as a percentage of total caloric intake, saturated fat consumption as a percentage of total caloric intake, total cholesterol intake, and total sodium intake), and a measure of variety in food intake. Each component has a maximum score of 10 and a minimum score of zero, resulting in a maximum HEI score of 100. For each of the five food group components, individuals who consumed the recommended number of servings (based on their caloric intake and age) received a maximum score of 10. If they consumed less than recommended intake, the score was decreased proportionately, with no additional adjustment for consuming higher than the recommended servings. Fat and saturated fat intakes were examined in proportion to total caloric intake. Fat and saturated fat intakes less than or equal to 30% of total caloric intake were assigned a score of 10. Higher than recommended intake decreased the score, and the score declined to zero when the value reached 45% or greater. Cholesterol and sodium intake were based on milligrams (mg) consumed. If cholesterol (300 mg = max recommended) and sodium (2,400 mg = max recommended) intake were less than the maximum recommended intake values, the participant received a score of 10. If the participant consumed greater than 300 mg cholesterol or 2,400 mg sodium, the scores decreased, with a score of zero assigned for cholesterol 450 mg and sodium 4800 mg. Dietary variety was assessed by totaling the number of different foods eaten by an individual over a 3-day period. A score of 10 was given if at least 16 different foods were consumed and a score of zero was assigned if 6 or less different foods were consumed. HEI thus provides an overall assessment of the type and quantity of foods people eat, their compliance with specific dietary recommendations, and the variety in their diets. Further details on the HEI are available (United States Department of Agriculture, 1995).

Trained interviewers conducted dietary recall interviews using automated data collection systems during the MEC evaluation of the 1999–2002 NHANES. A 24-hour dietary recall was used to estimate intakes from food and beverages. USDA calculated HEI component and overall scores from these recalls for individuals with complete food intake records. The data file for the HEI 1999–2002 was downloaded from the USDA Center for Nutrition Policy and Promotion website (www.cnpp.usda.gov/HealthyEatingIndex-Archive.htm). Table 1 provides an overview of these data for the 2,366 participants. Initially, the HEI data were used to rank participants into quintiles, with the lowest (worst) 20% of HEI scores assigned to quintile 1 and the highest (best) 20% of HEI scores assigned to quintile 5. The use of quintiles is a common method in nutritional epidemiology and provides a simple presentation of quantitative relationships while allowing for greater generalizability and decreasing influence of outlier data points (Willett, 1990; Willett et al., 1997). Subsequent analyses were based on the top three HEI quintiles (HEI scores ≥ 62) compared to the bottom 2 quintiles (with average HEI scores ≤ 61). A final analysis was based on USDA cut points for good, needs improvement, and poor.

Statistical Analysis

All analyses were performed in SPSS version 20. Data were entered into the Complex Samples Analysis incorporating 4-year sample weights. General linear models were performed to assess the effect of dietary quality on hearing. The independent variable in the general linear model was HEI quintile; dependent variables were HFPTA and LFPTA. Covariates adjusted in the final models included: age, sex, race/ethnicity, loud job and veteran status, diabetes, recreational noise exposure, firearm noise exposure, and education. Other covariates previously shown to be related to hearing status were considered, including history of hypertension, history of high cholesterol, smoking, and poverty-to-income ratio. However, these variables did not meet statistical significance criteria ($p < 0.05$) in preliminary multiple regression analyses when adjusting for all other covariates, and were therefore excluded from final model. Wald F statistics were performed and $\alpha = 0.05$ was considered significant; mean and standard error (SE) data are provided. There were no significant differences between included and excluded participants with respect to sex, age, and race/ethnicity.

Results

HEI scores varied across the population, ranging from 24 to 95 across participants. The USDA classifies HEI scores greater than 80 as “good” and scores less than 51 as “poor”. The majority of our sample, 73.5 %, had intermediate scores (ranging from 51 to 80), which are classified as “needs improvement”, while 14.8% had “poor” scores and 11.7% had “good” scores. That distribution is consistent with other population based evaluations of HEI (United States Department of Agriculture, 1995). The average HEI score was 64.33 (see Table 1).

There was a statistically significant negative relationship between HEI and HFPTA (Wald $F = 6.542$, $df = 4, 26$; $p < 0.05$) when participants were broken into quintiles based on HEI (see Figure 1A). Participants that had diets that more closely met US Dietary Guidelines for Americans (i.e., quintiles 4 and 5) had better hearing at higher frequencies (3, 4, 6, and 8 kHz). Comparable results were found when HFPTA was compared across HEI scores categorized as good [14.55 dB HL (SE= .66)], needs improvement [15.97 dB HL (SE= .27)], and poor [17.49 dB HL (SE=.62)], (Wald $F = 7.96$, $df = 2, 28$; $p < 0.05$); the small sample size at the extremes (good and poor) limited further analyses with this categorization. There was a similar trend for LFPTA with HEI quintiles, but the relationship was not statistically significant (see Figure 1B); thus, all subsequent analyses were limited to HFPTA data.

Pair-wise comparisons revealed a discrete break point between the bottom two and top three quintiles with respect to HFPTA (see Figure 1A). Therefore, two subsequent analyses exploring the relationship between diet and HFPTA stratified by age and sex were based on comparisons of participants with the bottom HEI scores (poorer 40%) with participants having the top HEI scores (better 60%). Combining quintiles increased power to detect differences in the secondary analyses, by maintaining larger sample sizes within dietary subgroups. Figure 2A depicts the overall model, comparing HFPTA scores of those with the top 60% of HEI scores to those with the bottom 40% of scores (Wald $F = 28.5$, $df = 1, 29$, $p < 0.05$).

Data were analyzed for subsets of subjects stratified by age group (Figure 2B: 20–29 years, Figure 2C: 30–39 years, Figure 2D: 40–49 years, Figure 2E: 50–59 years, and Figure 2F: 60–69 years). As shown in Figure 2, HFPTA thresholds increased (worsened) as age increased. Within the oldest group (see Figure 2F), there was approximately 5 dB difference in HFPTA thresholds in higher vs lower dietary quality subsets; this difference was statistically significant (Wald $F = 4.174$, $df = 1, 29$; $p = 0.05$). Differences were smaller (~2–3 dB), but still statistically significant, for age groups 40–49 years (see Figure 2D; Wald $F = 5.310$, $df = 1, 29$; $p = 0.05$) and 20–29 years (see Figure 2B; Wald $F = 12.297$, $df = 1, 29$; $p = 0.05$). There was no statistically significant relationship between HEI and HFPTA in the 30–39 and 50–59 year age categories, although the trend for lower thresholds in subgroups with better dietary quality was seen in all age groups.

Data were also analyzed stratified by sex (Figures 3A, 3B). The comparison of HFPTA across HEI scores was statistically significant in both males (Wald $F = 14.603$, $df = 1, 29$; $p = 0.05$) and females (Wald $F = 8.258$, $df = 1, 29$; $p = 0.05$), although the effect size was smaller in females.

The primary analysis was based on overall dietary quality metrics. Sub-scales are also of potential interest, given that single nutrient approaches have suggested statistically reliable relationships between hearing status and single nutrients including vitamins and minerals (micronutrients), and fat, protein, and carbohydrates (macronutrients). In post-hoc analyses, we explicitly considered the potential relationship between HFPTA thresholds and scores on the dietary subscales. There was a statistically significant negative relationship in which higher (healthier) fruit intake (Wald $F = 5.01$, $df = 1, 29$; $p = 0.05$), vegetable intake (Wald $F = 4.30$, $df = 1, 29$; $p = 0.05$), dairy intake (Wald $F = 9.82$, $df = 1, 29$; $p = 0.05$), and variety (Wald $F = 20.19$, $df = 1, 29$; $p = 0.05$) were related to lower (better) HFPTA thresholds. There was no statistically significant relationship between fat, saturated fat, cholesterol, sodium, grain, or meat intake and HFPTA thresholds, see Table 2.

Discussion

This report describes the relationship between *overall dietary quality* and hearing status; there was a statistically significant negative relationship between HEI score and HFPTA, with higher HEI scores being significantly associated with lower high frequency hearing thresholds. Although the majority of nutritional epidemiological studies have used a single nutrient analysis method, a variety of nutrients may influence hearing outcomes, and there are both known and potentially unknown biochemical interactions across nutrients. Here, we specifically excluded NHANES participants with unilateral hearing loss (asymmetry > 15 dB), which might reflect many underlying pathologies, including, for example, sudden sensorineural hearing loss (SSHL). However, dietary quality has the potential to influence SSHL as well, based on two studies from Japan that examined overall dietary pattern and susceptibility to SSHL. First, Nakashima et al. (1997) demonstrated decreased odds of SSHL with increased intake of fresh vegetables. The same group of investigators then compared participants who ate a traditional Japanese diet to those who ate a Western diet. An increased risk of hearing loss was seen among those on a Western diet and a decreased

risk of hearing loss was observed among those eating a Japanese diet (Nakamura et al., 2001).

The cross-sectional data presented here are consistent with the cross-sectional data from others. Cross-sectional designs are a limitation common to epidemiological analyses assessing potential relationships between diet and health. Though NHANES data are comprehensive and nationally representative, cause and effect cannot be determined from cross-sectional data. Second, the dietary tool used in NHANES is a single self-reported 24-hour dietary recall. This limited snapshot may not reflect regular eating habits and provides no insight into variability in a subject's eating habits. Food reports may be susceptible to over and under-reporting. Despite these concerns, the HEI has been utilized in numerous studies and has a demonstrated correlation with nutrient intake and biomarkers of nutrient intake (Kennedy et al., 1995; Weinstein et al., 2004). The HEI is one measure of dietary quality, and there are others that could be considered. The major limitation of applying indices of dietary quality to health outcomes is that the index quality is limited by the current knowledge and understanding of the diet-health relationship; i.e., what food and nutrients are considered "healthy" and at what levels. An advantage of the analysis of overall diet quality with respect to health outcomes, however, is the simple interpretation and translation into a person's diet. It is easier to follow USDA guidelines for a diet that is high in vegetable, fruit, and variety, and low in saturated fat, rather than tracking specific levels of individual nutrients (Hu, 2002). It is, however, noteworthy that the subscales that demonstrated significant relationships with HFPTA (fruits, vegetables, dairy, and variety) closely follow single nutrient analyses that suggest benefit from intake of single nutrients commonly found in fruits and vegetables (such as vitamin C, vitamin E, magnesium, etc.). Numerous noise exposure metrics assessed as part of NHANES were included in our model. The noise measures are limited relative to other available surveys and the overall analysis may be strengthened by the addition of additional noise information. Finally, we cannot exclude the possibility that missing and/or excluded data may introduce bias, or that other undetermined confounding variable(s) may exist, such as analgesic use, which has recently emerged as a possible covariate (Curhan et al., 2010 and 2012).

Taken together, the current findings suggest that 1) HEI is a useful metric for assessing associations between diet and hearing; 2) significant relationships are primarily limited to higher frequencies; 3) significant relationships with healthy eating are seen across lifespan; and 4) significant relationships with healthy eating are seen in both males and females. Cross-sectional data, such as those presented here, do not confirm a specific cause and effect relationship between diet and hearing loss. However, it is noteworthy that cross-sectional findings are consistent with animal data that more directly support cause and effect relationships (Seidman, 2000; Someya et al., 2009; Heman-Ackah et al., 2010). A detailed review of the animal literature is available in Le Prell and Bao (2011).

Summary and Conclusions

Audiologists and hearing conservation technicians do not routinely provide guidance that healthy eating strategies might help preserve auditory function over the lifespan. The data presented here suggest healthy eating strategies may benefit patients with respect to

preserved higher frequency thresholds, although the correlations presented here do not establish causal relationships. If healthier eating habits do confer benefit, it is reasonable to believe the relative benefit may accumulate over the course of the lifespan, given that the greatest differences were observed at older ages. If benefit does accrue, a large population could benefit (for discussion of possible folate benefits, see Dobie, 2007). By ages 60–69, the prevalence of LFPTA 25 dB HL is 44–54% and the prevalence of HFPTA 25 dB HL is 74–80% (95% C.I.'s from Agrawal et al., 2008). The potential effects of healthy eating on the auditory system require additional evaluation in prospective studies. If the relationships between diet and hearing function suggested here are confirmed, clinicians may be able to improve patient care via the integration of advice on healthy eating into this clinical dialogue.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Figure 1.

Figure 2.

Figure 3.

Table 1

Descriptive data for demographics of NHANES 1999–2002 with sample weights applied.

Demographics NHANES 1999–2002 (Mean data)	
Variable	Mean (SEM)
Age	40.18 (.30)
HFPTA	16.07 (.41)
LFPTA	9.25 (.20)
HEI	63.04 (.37)
Demographics NHANES 1999–2002 (Percent data)	
Variable	Percent (SEM)
Male	42.8 (1.3)
Female	57.2 (1.3)
Diabetes (Yes)	5.5 (.60)
Loud Job (Yes)	23.9 (1.0)
Recreational Noise (Yes)	25.0 (1.1)
Firearm noise (Yes)	6.3% (.80)
Smoker (Yes)	47.8 (1.6)
Veteran (Yes)	10.3 (.90)
Race/Ethnicity	
White	68.2 (2.2)
Black	11.3 (1.3)
Mexican	7.7 (.90)
Other	12.8 (2.3)
Education	
Less than High School	17.8 (1.1)
High School or Equiv.	24.3 (1.3)
More than High School	57.9 (1.8)

Table 2

HFPTA comparison for HEI subscales of NHANES 1999 – 2002 with sample weights applied.

Subscales of HEI	HFPTA threshold: Bottom 40% (SEM, CI)	HFPTA threshold: Top 60% (SEM, CI)
Fruit intake *	16.51 (.33, 15.84 – 17.18)	15.53 (.38, 14.7 – 16.32)
Vegetable intake *	16.44 (.35, 15.75 – 17.16)	15.72 (.32, 15.07 – 16.37)
Dairy intake *	16.76 (.37, 15.98 – 17.52)	15.38 (.32, 14.72 – 16.04)
Variety *	16.94 (.35, 16.23 – 17.66)	15.32 (.31, 14.70 – 5.95)
Fat intake	16.52 (.42, 15.65 – 17.38)	15.81 (.33, 15.12 – 16.49)
Saturated fat intake	16.41 (.41, 15.56 – 17.25)	15.81 (.35, 15.09 – 16.53)
Cholesterol intake	16.22 (.53, 15.14 – 17.32)	16.01 (.31, 15.37 – 16.64)
Sodium intake	15.64 (.33, 14.95 – 16.32)	16.43 (.33, 15.76 – 17.11)
Grain intake	16.35 (.36, 15.61 – 17.08)	15.75 (.30, 15.14 – 16.36)
Meat and meat alternative intake	16.08 (.36, 15.35 – 16.81)	16.06 (.34, 15.37 – 6.76)

* indicates significant difference.