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Adherence to Healthful Dietary Patterns Is Associated with Lower Risk of Hearing Loss in Women

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Abstract

Background: Specific nutrients have been associated with hearing status, but associations between healthful dietary patterns and risk of hearing loss have not been prospectively evaluated.

Objective: We sought to prospectively examine the relations between adherence to the Alternate Mediterranean diet (AMED), the Dietary Approaches to Stop Hypertension (DASH), and the Alternative Healthy Eating Index-2010 (AHEI-2010), and risk of hearing loss.

Methods: We conducted a longitudinal cohort study (1991–2013) of 81,818 women in the Nurses' Health Study II, aged 27–44 y at baseline. We assessed diet every 4 y with the use of food frequency questionnaires and calculated AMED, DASH, and AHEI-2010 adherence scores. Baseline and updated information from validated biennial questionnaires was used in Cox proportional hazards regression models to examine independent associations between adherence scores and risk of self-reported moderate or worse hearing loss.

Results: During >1 million person-years of follow-up, 2306 cases of moderate or worse hearing loss were reported. Higher cumulative average AMED and DASH scores were significantly inversely associated with risk of hearing loss. For women with scores in the highest compared with the lowest quintile, the multivariable-adjusted relative risks (MVRRs) of hearing loss were 0.70 (95% CI: 0.60, 0.82) (P-trend <0.001) for AMED and 0.71 (95% CI: 0.61, 0.83) (P-trend <0.001) for DASH. Higher recent AHEI-2010 score was also associated with lower risk [MVRR = 0.79 (95% CI: 0.69, 0.91); P-trend <0.001]. Among participants with additional hearing-related information (n = 33,102), higher cumulative average adherence scores for all 3 dietary patterns were associated with lower risk; the MVRR was 0.63 (95% CI: 0.49, 0.81) for AMED, 0.64 (95% CI: 0.50, 0.83) for DASH, and 0.71 (95% CI: 0.56, 0.89) for AHEI-2010.

Conclusion: Adherence to healthful dietary patterns is associated with lower risk of hearing loss in women. Consuming a healthy diet may be helpful in reducing the risk of acquired hearing loss. *J Nutr* 2018;148:944–951.

Keywords: hearing loss, healthy diet, Mediterranean diet, DASH diet, AHEI-2010, epidemiology, prospective study

Introduction

Hearing loss is a common and disabling sensory disorder that afflicts ~48 million Americans (1–6). Individuals with hearing loss are more likely to have impaired activities of daily living (2), lower quality of life (2), and higher risk of cognitive decline (7) and depression (8). Hearing loss is often irreversible, therefore identifying potentially modifiable risk factors is a vital public health goal.

Evidence suggests that diet may influence hearing status; however, most studies have focused on intake of individual nutrients, such as vitamins, minerals, and fatty acids (9–13). Single-nutrient analyses provide valuable information yet do not account for potential complex interactions among nutrients. Dietary pattern analysis is an informative complementary approach. Dietary patterns represent a more comprehensive portrayal of food and nutrient consumption and incorporate potential joint effects when foods and nutrients are consumed in combination; thus, evaluating whether adherence to a specific dietary pattern is associated with risk of acquired hearing loss

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Abbreviations used: AHEI-2010, Alternative Healthy Eating Index-2010; AMED, Alternate Mediterranean diet; DASH, Dietary Approaches to Stop Hypertension; HEI, Healthy Eating Index; HSSQ, Hearing Study Supplemental Questionnaire; MVRR, multivariable-adjusted relative risk; NHS II, Nurses' Health Study II; SFFQ, semiquantitative FFQ.

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may be more informative than evaluating individual nutrient intake (14). There are several mechanisms by which a healthier diet may protect against hearing loss, including preventing microvascular and macrovascular compromise of cochlear blood flow, curbing oxidative damage, and reducing inflammation. In addition, healthier dietary patterns are related to lower risk of neurodegenerative disease (15) and may similarly protect against neuroinflammation and neurodegeneration of auditory nerve fibers and central auditory pathways (16, 17).

Limited data are available on the relation between overall diet and risk of acquired hearing loss. A cross-sectional study in NHANES found that a higher Healthy Eating Index (HEI) (1999–2002) score was associated with better high-frequency hearing thresholds (18). A cross-sectional analysis in Australia found that a lower diet quality score was associated with a higher likelihood of prevalent concurrent hearing and vision impairment; however, diet quality score was not associated with prevalent hearing loss alone (19). Longitudinal associations between healthful dietary patterns and hearing loss have not previously been evaluated. Therefore, we sought to examine the relations between dietary pattern adherence scores for 3 healthful dietary patterns, the Alternate Mediterranean diet (AMED), the Dietary Approaches to Stop Hypertension (DASH), and the 2010 Alternative Healthy Eating Index (AHEI-2010), and risk of moderate or worse hearing loss in 70,966 women in the Nurses' Health Study II (NHS II).

Methods

Study population. The Conservation of Hearing Study (CHEARS) examines risk factors for hearing loss among participants in the NHS II, an ongoing cohort study of 116,430 female registered nurses in the United States, aged 25–42 y at enrollment in 1989. Participants have been followed by biennial mailed questionnaires that elicit updated information on diet, lifestyle, and various health outcomes; the follow-up rate over 26 y exceeds 90% of the eligible person-time. We limited the study to women who provided information on their hearing on the 2009 or 2013 questionnaire. Of the 96,521 women who answered the questionnaires, we excluded those who did not provide responses to the hearing questions on either questionnaire, reported a hearing problem that began before baseline for the current analysis (1991) or did not report date of onset, or reported cancer other than non-melanoma skin cancer (due to possible exposure to potentially ototoxic chemotherapeutic agents). We also excluded women who did not complete the baseline diet questionnaire and had missing diet information for each subsequent time period. In the cumulative average diet analysis, women with missing diet information in a given time period were skipped for that time period. A total of 70,966 women were included in the cumulative average diet analysis and a total of 81,818 women were included in the analysis based on recent diet intake. The study protocol was approved by the Institutional Review Board of Brigham and Women's Hospital.

Ascertainment of diet. We assessed dietary intake using semiquantitative food frequency questionnaires (SFFQs) to ascertain usual diet over the past year. The SFFQ was developed, tested, and refined by our group over the past 36 y, and includes >130 foods, >20 beverages, and vitamin/mineral supplement use that account for >90% of measured nutrient intake (20). Briefly, for each food, a commonly used unit or portion size is specified, and participants are asked how often, on average, they had consumed each type of food or beverage during the previous year. Nine possible response options are provided, ranging from "never or less than 1 per month" to "6 or more times per day." We calculated nutrient intakes by multiplying the portion size of a single serving of each food by its reported frequency of intake, multiplying the total amount consumed by the nutrient content of the food, and then summing the nutrient contributions of all food items, with the use of USDA food composition data (21, 22). We assessed supplement use by collecting information on the use of multiple vitamins (specific brand and usual number of tablets taken per week) and specific supplements; our database contains information on >1000 different multivitamin preparations. Estimates of energy and nutrient consumption were derived from frequency of consumption of foods and beverages, and an overall estimate of usual portion size obtained from the validated SFFQ (23). The baseline year for the dietary assessments used for this project was 1991. These dietary data collection methods have been validated and used extensively worldwide to examine relations between diet and numerous health outcomes (20, 23, 24). We used the information obtained on each SFFQ to calculate scores that measure adherence to 3 common healthful dietary patterns: the AMED, the DASH diet, and the AHEI-2010.

The AMED score is a measure of adherence to the Mediterranean diet pattern, adapted to reflect diet patterns and behaviors that have been consistently associated with lower risk of chronic disease in clinical and epidemiologic studies (25, 26). The AMED score (range 0–9) is composed of 9 items: vegetables (except potatoes), fruits, nuts, legumes, whole grains, monounsaturated-to-saturated fat ratio, fish, red/processed meats, and alcohol (27). For red/processed meats, 1 point was given when intake was less than the median intake. For alcohol, 1 point was given for intakes within the range 5–15 g/day. For the remaining items, 1 point was given for each desirable component if the participant's intake of that item was greater than the median; otherwise, no point was assigned.

The DASH diet has been demonstrated to lower blood pressure and to be associated with a lower risk of hypertension, cardiovascular disease, diabetes (28–30), and cognitive decline (31). The DASH score was constructed according to foods and nutrients emphasized or minimized in the DASH diet. The component scores for fruits, vegetables, nuts and legumes, low-fat dairy products, and whole grains were the participant's quintile ranking (e.g., quintile 1 was assigned 1 point and quintile 5 was assigned 5 points). For sodium, red and processed meats, and sugar-sweetened beverages, low intake was desired, thus the lowest quintile was given a score of 5 points and the highest quintile a score of 1 point. We summed the component scores to obtain an overall DASH score, ranging from 8 to 40 (30, 32).

The AHEI-2010 score was based on the 2010 USDA Dietary Guidelines for Americans and was updated and modified from the original HEI (33) to include additional dietary factors related to chronic disease, using approaches previously described (34). The rationale for variable selection and scoring criteria of the AHEI-2010 was described in detail previously (34). The score consists of 11 components, which include higher intakes of vegetables, fruits, whole grains, nuts and legumes, long-chain n–3 fatty acids, and other PUFAs; lower intakes of red/processed meat, sugar-sweetened beverages and fruit juice, trans-fat, and sodium; and moderate alcohol consumption. Each component score ranges from 0 (least healthy eating behavior) to 10 (maximum adherence), and the total AHEI 2010 score ranges from 0 to 110.

Ascertainment of outcome. The primary outcome, self-reported hearing loss that was moderate or worse in severity, was determined based on responses to the 2009 and 2013 questionnaires on which participants were asked about their hearing. On the 2009 main questionnaire, participants were asked, "Do you have a hearing problem?" (no, mild, moderate, severe), and "At what age did you first notice a change in your hearing?" On the 2013 main questionnaire, participants were asked, "Which best describes your hearing?" (excellent, good, a little hearing trouble, moderate hearing trouble, deaf), and "Have you noticed a change in your hearing?" and, if the response was "Yes," "At what age did you first notice a change in your hearing?" For this study, we chose a priori to examine moderate or worse hearing loss as the primary outcome to focus on hearing loss that is likely to be the most clinically meaningful and to minimize misclassification. The use of questionnaires to assess hearing loss in large populations has been found to be reasonably reliable in previous studies (35–37) and has been effective in detecting significant relations in this and similar cohorts (12, 13, 38–40). In a validation study of self-reported hearing loss as compared with audiometrically measured hearing loss in Australia, the sensitivity

of a single question to assess hearing loss among women <70 y of age was 95% for detecting moderate hearing loss (Better Ear PTA $_{0.5,1,2,4\ kHz}$ > 40 dB) and 100% for detecting marked hearing loss (Better Ear PTA $_{0.5,1,2,4\ kHz}$ > 40 dB), and the specificity was 65% and 64%, respectively (37).

Ascertainment of covariates. Potential confounders that were considered in the multivariable analyses included age (41), race (41), smoking (42), BMI (39), waist circumference (39), physical activity (39), total energy intake (39), history of hypertension (40), diabetes (43), acetaminophen use (38), ibuprofen use (38), and tinnitus (44). Covariate information was obtained from biennial questionnaires and updated in the analyses.

Hearing Study Supplemental Questionnaire. Detailed hearing-related information was collected electronically in a 2012 supplemental questionnaire from a representative subcohort of NHS II participants (n = 33,102) with and without reported hearing problems, including information on previous evaluation for hearing loss, laterality (unilateral or bilateral), and identified causes of hearing loss (e.g., ototoxic medications, ear trauma, otosclerosis, cholesteatoma, Meniere's disease, chronic ear infection). Data from the Hearing Study Supplemental Questionnaire (HSSQ) were used to conduct sensitivity analyses with more refined case definitions (e.g., excluding known etiologies and unilateral hearing loss).

Statistical analysis. The study design was prospective, with information collected before the report of onset of hearing loss. Person-time of follow-up was calculated from the date of return of the 1991 questionnaire until the date of self-reported hearing loss or end of follow-up in 2013. Participants who reported cancers other than non-melanoma skin cancer were censored when reported during follow-up. The RR was used as the measure of association between quintiles of the dietary scores and moderate or worse hearing loss. The lowest quintile of the dietary scores served as the referent group. Dietary exposure information was updated every 4 y. Person-months of follow-up were allocated according to exposure status at the start of each follow-up period. If complete information on diet was missing at the start of a time period, the participant was excluded from that time period.

Diet scores were categorized into quintiles based on the distribution of the entire analytic cohort (12, 13). In our primary analyses, to better represent long-term dietary intake and reduce measurement error, we calculated the cumulative average of the diet scores from all available SFFQs up to the start of each follow-up interval, optimizing the use of repeated SFFQs (45). In secondary analyses, we compared results by using the most recent diet scores at the start of each follow-up period.

We used Cox proportional hazards regression models to estimate RRs and 95% CIs in multivariable analyses. Variables included in the multivariable models were age (continuous), race (5 categories), BMI (6 categories), total energy intake (quintiles), waist circumference (4 categories), physical activity (5 categories), history of smoking (5 categories), hypertension (yes/no), diabetes (yes/no), tinnitus (yes/no), nonsteroidal anti-inflammatory drug use (5 categories), or acetaminophen use (5 categories). We used the Anderson-Gill (46) data structure, with a new data record created for each biennial questionnaire, to handle time-varying covariates efficiently. To control as finely as possible for confounding by age, calendar time, and any possible 2-way interactions between these 2 time scales, we stratified the analysis jointly by age in months at start of follow-up and calendar year of the current questionnaire cycle. The time scale for the analysis was then measured as months since the start of the current questionnaire cycle, which is equivalent to age in months. Tests for linear trend were performed by assigning the median value of each category to all participants in that group. Women who reported mild hearing loss were skipped starting from the date of onset for that time period and re-entered the analysis as a case if they subsequently reported moderate or worse hearing loss. To examine possible interactions, we conducted stratified analyses by age (<50, 50–59, ≥60), BMI (<30, 30–34, ≥35), waist circumference (<80 cm, ≥80 cm), and tinnitus (yes/no), to assess whether results differed according to the level of any of these factors. We conducted a priori sensitivity analyses among the subcohort of women who had completed the HSSQ. All P values are 2-tailed and considered statistically significant at $P < 0.05$. Statistical tests were performed with SAS statistical software, version 9.4 (SAS Institute Inc., Cary, NC).

Results

Baseline characteristics according to each dietary pattern are presented in **Table 1**. Women in the highest compared with the lowest quintiles of the AMED, DASH, and AHEI-2010 dietary patterns were slightly older, leaner, more likely to be physically active, and less likely to be current smokers.

After 1,277,695 person-years of follow-up, 2306 incident cases of moderate or worse hearing loss were reported to have occurred. In multivariable analyses, higher cumulative average AMED and DASH dietary pattern scores were associated with lower risk of moderate or worse hearing loss (**Table 2**). Compared with women in the lowest quintile of AMED scores, the multivariable-adjusted relative risk (MVRR) for moderate or worse hearing loss among women in the highest quintile was 0.70 (95% CI: 0.60, 0.82) (P-trend <0.001). Compared with women in the lowest quintile of DASH scores, the MVRR among women in the highest quintile was 0.71 (95% CI: 0.61, 0.83) (P-trend <0.001). In secondary analyses based on most recent intake, the findings were similar (**Table 3**).

In our primary analysis using the cumulative average of dietary pattern scores, a significant association was not observed for AHEI-2010 scores. Compared with women in the lowest quintile of AHEI-2010 scores, the MVRR among women in the highest quintile was 0.92 (95% CI: 0.79, 1.07) (P-trend = 0.10) (Table 2). However, in analyses based on most recent intake, higher AHEI-2010 score was associated with lower risk of moderate or worse hearing loss. Compared with women in the lowest quintile of AHEI-2010 scores, the MVRR among women in the highest quintile was 0.79 (95% CI: 0.69, 0.91) (P-trend < 0.001) (Table 3).

In sensitivity analyses, we limited the study population to respondents to the HSSQ and excluded women who reported unilateral hearing loss or hearing loss that was attributed to a known etiology. The magnitudes of the inverse associations were slightly greater than for the full cohort (**Table 4**). Compared with women in the lowest quintile of diet scores, the MVRR for moderate or worse hearing loss among women in the highest quintile of diet scores was 0.63 (95% CI: 0.49, 0.81) (P-trend < 0.001) for AMED; 0.64 (95% CI: 0.50, 0.83) (P-trend < 0.001) for DASH; and 0.71 (95% CI: 0.56, 0.89) (P-trend = 0.004) for AHEI-2010.

Stratifying the analyses by age <50, 50–59, ≥60 y, BMI, waist circumference, or tinnitus did not influence the results (P values for interaction ≥0.17) (data not shown).

Discussion

In this prospective study among 70,966 US women, higher adherence scores for healthful dietary patterns were independently associated with lower risk of moderate or worse hearing loss. Specifically, women with the greatest adherence to the AMED or DASH diets had an ~30% lower risk, compared with women with the lowest adherence scores. Moreover, findings in the subcohort of over 30,000 women with additional hearing-related information suggest that the magnitude of the reduced risk may be even greater and also pertain to the AHEI-2010.

TABLE 1 Age-standardized baseline characteristics among women in the Nurses' Health Study II according to quintile of dietary scores (1991)[1]

	AMED			DASH			AHEI-2010		
	Q1	Q3	Q5	Q1	Q3	Q5	Q1	Q3	Q5
Median score[2]	2.0	4.0	6.0	17.0	24.0	31.0	34.0	47.0	62.0
N	16,490	13,409	15,962	15,029	15,617	12,567	14,232	15,077	14,677
Age,[3] y	35.8	36.2	36.7	36.0	36.2	36.4	35.5	36.2	37.0
White race, %	95.1	95.1	94.5	94.7	94.7	95.9	95.7	95.0	94.5
BMI, kg/m^2	25.0	24.5	23.9	25.0	24.5	23.7	25.1	24.5	23.7
Waist circ. (1993), cm	79.1	78.1	76.5	79.3	78.0	76.2	80.1	78.0	75.9
Physical activity,[4] METs	15.5	20.3	27.0	14.4	20.1	30.1	14.4	19.7	29.6
Smoking, %									
Never	66.0	66.8	65.7	63.0	67.2	67.2	70.3	67.1	61.6
Past	19.2	22.5	25.9	18.7	22.9	26.4	16.0	21.6	29.5
Current	14.6	10.4	8.2	18.2	9.6	6.2	13.6	11.1	8.7
Hypertension, %	6.8	6.0	5.6	6.8	5.7	5.1	6.7	6.0	5.3
Diabetes, %	0.7	0.9	0.8	0.6	0.8	0.8	0.7	0.9	0.8
Tinnitus, %	8.6	9.2	9.1	8.7	8.9	9.2	9.4	8.5	8.9
Ibuprofen use,[5] %	9.5	9.1	9.0	9.5	9.1	8.1	9.5	9.2	9.0
Acetaminophen use,[5] %	8.1	7.6	6.9	8.5	7.6	6.4	9.4	7.5	5.7

[1] Values are means or percentages and are standardized to the age distribution of the study population. Polytomous variables may not sum to 100% because of rounding. AHEI-2010, the Alternative Healthy Eating Index-2010 dietary pattern; AMED, the Alternate Mediterranean diet pattern; DASH, the Dietary Approach to Stop Hypertension dietary pattern; MET, metabolic equivalent task from recreational and leisure-time activities; Q, quintile; Waist circ., waist circumference.
[2] Median dietary pattern adherence score at baseline in cumulative average diet analysis.
[3] Means.
[4] Medians not age-standardized.
[5] ≥2 d/wk.

Hearing loss that is moderate or worse in severity can be particularly disabling, impairing communication, social connectivity, mental health, and possibly cognitive function (2, 7). In adults, acquired hearing loss is multifactorial and results from the cumulative influence of a number of intrinsic and extrinsic factors over the course of a lifetime. However, differences in susceptibility to hearing loss among individuals remain poorly understood. Auditory damage may occur due to insufficient cochlear blood supply that leads to hypoxia and ischemic injury, oxidative stress, mitochondrial dysfunction and cell injury, and to peripheral and central auditory neurodegeneration (47). Mechanisms by which a healthier diet may influence these

TABLE 2 Cumulative average healthful dietary pattern scores and risk of moderate or worse hearing loss in the Nurses' Health Study II (1991–2013) (n = 70,966)[1]

Diet score	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	*P*-trend
AMED						
Median score[2]	2.0	3.0	4.0	5.0	6.0	
Person-years	238,833	207,508	230,133	206,373	230,563	
Cases	448	381	447	342	338	
Age-adj. RR (95% CI)	1.00 (ref)	0.90 (0.79, 1.04)	0.95 (0.83, 1.08)	0.80 (0.69, 0.92)	0.70 (0.61, 0.81)	<0.001
MVRR[3] (95% CI)	1.00 (ref)	0.90 (0.78, 1.04)	0.94 (0.82, 1.08)	0.79 (0.68, 0.92)	0.70 (0.60, 0.82)	<0.001
DASH						
Median score[2]	17.0	21.0	24.0	27.0	31.0	
Person-years	227,803	217,456	229,174	223,732	215,247	
Cases	458	430	371	371	326	
Age-adj. RR (95% CI)	1.00 (ref)	0.97 (0.85, 1.11)	0.80 (0.70, 0.92)	0.80 (0.70, 0.92)	0.70 (0.61, 0.80)	<0.001
MVRR[3] (95% CI)	1.00 (ref)	0.97 (0.85, 1.11)	0.82 (0.71, 0.94)	0.81 (0.70, 0.94)	0.71 (0.61, 0.83)	<0.001
AHEI-2010						
Median score[2]	34.0	41.5	47.0	53.0	62.0	
Person-years	223,097	222,041	227,662	216,844	223,768	
Cases	400	421	402	364	369	
Age-adj. RR (95% CI)	1.00 (ref)	1.02 (0.89, 1.18)	0.95 (0.83, 1.09)	0.86 (0.74, 0.99)	0.82 (0.71, 0.95)	<0.001
MVRR[3] (95% CI)	1.00 (ref)	1.07 (0.93, 1.22)	1.00 (0.87, 1.16)	0.92 (0.79, 1.07)	0.92 (0.79, 1.07)	0.10

[1] Age-adj.RR, age-adjusted relative risk; AHEI-2010, Alternative Healthy Eating Index-2010; AMED, Alternate Mediterranean diet; DASH, Dietary Approaches to Stop Hypertension; MVRR, multivariable-adjusted relative risk; ref, reference.
[2] Median dietary pattern adherence score at baseline.
[3] Multivariable models adjusted for: age, race, BMI, waist circumference, physical activity, history of smoking, hypertension, diabetes mellitus, tinnitus, nonsteroidal anti-inflammatory drug use, acetaminophen use, and total energy intake.

TABLE 3 Recent patterns of dietary intake and risk of moderate or worse hearing loss in the Nurses' Health Study II (1991–2013) ($n = 81,818$)[1]

Diet score	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	*P*-trend
AMED						
Median score[2]	2.0	3.0	4.0	5.0	6.0	
Person-years	282,237	212,137	227,893	346,877	205,469	
Cases	564	420	406	625	291	
Age-adj. RR (95% CI)	1.00 (ref)	1.00 (0.88, 1.14)	0.88 (0.77, 1.00)	0.83 (0.74, 0.93)	0.70 (0.61, 0.81)	<0.001
MVRR[3] (95% CI)	1.00 (ref)	0.99 (0.87, 1.12)	0.87 (0.76, 0.99)	0.82 (0.73, 0.93)	0.70 (0.60, 0.82)	<0.001
DASH						
Median score[2]	17.0	21.0	24.0	27.0	31.0	
Person-years	270,458	247,842	255,307	271,061	229,944	
Cases	545	480	449	471	361	
Age-adj. RR (95% CI)	1.00 (ref)	0.97 (0.86, 1.10)	0.87 (0.77, 0.98)	0.83 (0.73, 0.94)	0.73 (0.64, 0.83)	<0.001
MVRR[3] (95% CI)	1.00 (ref)	0.98 (0.87, 1.11)	0.88 (0.77, 1.00)	0.84 (0.74, 0.96)	0.74 (0.63, 0.85)	<0.001
AHEI-2010						
Median score[2]	34.0	41.5	47.0	53.0	62.0	
Person-years	254,428	254,162	259,826	247,214	258,983	
Cases	524	475	447	439	421	
Age-adj. RR (95% CI)	1.00 (ref)	0.87 (0.77, 0.99)	0.80 (0.71, 0.91)	0.80 (0.70, 0.90)	0.72 (0.63, 0.82)	<0.001
MVRR[3] (95% CI)	1.00 (ref)	0.90 (0.80, 1.02)	0.85 (0.74, 0.96)	0.85 (0.75, 0.97)	0.79 (0.69, 0.91)	<0.001

[1] Age-adj.RR, age-adjusted relative risk; AHEI-2010, Alternative Healthy Eating Index-2010; AMED, Alternate Mediterranean diet; DASH, Dietary Approaches to Stop Hypertension; MVRR, multivariable-adjusted relative risk; ref, reference.
[2] Median dietary pattern adherence score at baseline.
[3] Multivariable models adjusted for: age, race, BMI, waist circumference, physical activity, history of smoking, hypertension, diabetes mellitus, tinnitus, nonsteroidal anti-inflammatory drug use, acetaminophen use, and total energy intake.

processes and protect against hearing loss include the promotion of more beneficial blood lipid profiles, better endothelial function, lower blood pressure, and less inflammation, which may confer protection against vascular compromise and reduced cochlear blood flow. Dietary patterns that include higher intakes of fruit, vegetables, legumes, whole grains, nuts, fish, and poultry, a lower intake of saturated fat, and moderate alcohol intake are associated with lower risk of neurodegenerative disease, such as Parkinson disease (15). Likewise, healthier dietary patterns may protect against auditory neuroinflammation and neurodegeneration (16, 17).

Several cross-sectional studies have observed associations between specific nutrient intake and hearing status (11, 18, 48, 49). There are fewer published longitudinal studies, yet prospective

TABLE 4 Healthful dietary pattern scores (cumulative average) and risk of moderate or worse hearing loss in the Nurses' Health Study II HSSQ subcohort ($n = 33,102$)[1]

Diet score	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	*P*-trend
AMED						
Median score[2]	2.0	3.0	4.0	5.0	6.0	
Person-years	109,395	102,913	94,273	103,529	104,680	
Cases	198	169	157	163	131	
Age-adj. RR (95% CI)	1.00 (ref)	0.85 (0.69, 1.04)	0.88 (0.71, 1.09)	0.78 (0.63, 0.96)	0.62 (0.50, 0.78)	<0.001
MVRR[3] (95% CI)	1.00 (ref)	0.84 (0.68, 1.03)	0.87 (0.70, 1.08)	0.78 (0.62, 0.97)	0.63 (0.49, 0.81)	<0.001
DASH						
Median score[2]	17.0	21.0	24.0	27.0	31.0	
Person-years	104,357	102,641	105,258	100,165	102,369	
Cases	192	194	142	162	128	
Age-adj. RR (95% CI)	1.00 (ref)	1.00 (0.82, 1.22)	0.71 (0.58, 0.89)	0.82 (0.67, 1.01)	0.62 (0.50, 0.78)	<0.001
MVRR[3] (95% CI)	1.00 (ref)	1.01 (0.82, 1.23)	0.73 (0.58, 0.91)	0.82 (0.65, 1.02)	0.64 (0.50, 0.83)	<0.001
AHEI-2010						
Median score[2]	34.5	42.0	48.0	54.0	63.0	
Person-years	103,329	104,808	100,870	102,255	103,529	
Cases	195	165	150	159	149	
Age-adj. RR (95% CI)	1.00 (ref)	0.79 (0.64, 0.98)	0.71 (0.57, 0.88)	0.73 (0.59, 0.90)	0.65 (0.53, 0.81)	<0.001
MVRR[3] (95% CI)	1.00 (ref)	0.79 (0.64, 0.97)	0.72 (0.58, 0.90)	0.74 (0.59, 0.92)	0.71 (0.56, 0.89)	0.004

[1] Age-adj.RR, age-adjusted relative risk; AHEI-2010, Alternative Healthy Eating Index-2010; AMED, Alternate Mediterranean diet; DASH, Dietary Approaches to Stop Hypertension; HSSQ, Hearing Study Supplemental Questionnaire; MVRR, multivariable-adjusted relative risk; ref, reference.
[2] Median dietary pattern adherence score at baseline.
[3] Multivariable models adjusted for: age, race, BMI, waist circumference, physical activity, history of smoking, hypertension, diabetes mellitus, tinnitus, nonsteroidal anti-inflammatory drug use, acetaminophen use, and total energy intake.

findings indicate that dietary factors are associated with risk of incident hearing loss. We previously found prospective associations between higher intakes of fish, marine fatty acids, certain carotenoids, and folate and lower risk of hearing loss in women (12, 13). A study in Australia found higher dietary glycemic load and carbohydrate intake were associated with higher risk of incident hearing loss (50). A randomized controlled trial in the Netherlands showed that daily oral folic acid supplementation was inversely associated with hearing decline over 3 y (51). This evidence suggests that diet may be a potentially modifiable risk factor for acquired hearing loss.

As a complement to single-nutrient analyses, dietary pattern analysis offers several advantages and may better capture the synergistic and cumulative influence of overall dietary intake on health outcomes (52). Dietary pattern analysis accounts for potential interactions among the constituent foods, beverages, and nutrients that are consumed in combination and may act in synergy to influence health outcomes. We chose a priori to examine established dietary patterns to allow for comparisons across other studies. Greater adherence to healthful dietary patterns has been associated with lower risk of a number of important health outcomes, including hypertension (28), insulin sensitivity (29), diabetes (53), coronary heart disease and stroke (30), cognitive decline (31), inflammatory markers (54), neurodegenerative disease (15), and all-cause mortality (55). The vascular, inflammatory, and oxidative processes that contribute to these diseases may also contribute to auditory deterioration or damage and result in hearing loss (47). Healthful dietary patterns were also associated with favorable concentrations of cardiometabolic and endocrine biomarkers (56) and healthy aging among women in the Nurses' Health Studies (57).

To our knowledge, this is the first longitudinal study of the long-term relation between dietary patterns and risk of hearing loss. A cross-sectional study that examined data from the 1999–2002 NHANES evaluated the association between overall dietary quality (through the use of the HEI) and hearing sensitivity and found that higher HEI scores were significantly associated with lower (better) high-frequency hearing thresholds, indicating that participants whose diets more closely met the 1995 US Dietary Guidelines for Americans had better hearing at higher frequencies (3, 4, 6, and 8 kHz) (18). A cross-sectional Australian study found overall diet quality was related to concurrent vision and hearing loss, but did not observe a significant association with prevalent hearing loss alone (19).

In our primary analysis using cumulative average of dietary pattern scores, an inverse relation between higher AHEI-2010 score and risk of hearing loss was suggested; however, the results were not statistically significant. However, in secondary analyses that examined the most recent AHEI-2010 scores in the full cohort as well as analyses examining the cumulative average of AHEI-2010 scores in the HSSQ subcohort, higher AHEI-2010 scores were associated with a significantly lower risk (>20%). The reason for this discrepancy is unclear and may have been due to chance.

Although there are common components of all 3 dietary pattern scores, there are several differences in the way the scores are derived and the components they incorporate. The DASH diet is characterized by high consumption of fruits, vegetables, nuts, seeds, legumes, lean meats, fish, poultry, low- or non-fat dairy and low consumption of sweets, saturated fats, and sodium. Specific recommendations for level of intake are provided, such as: 4–5 daily servings of fruits, 4–5 daily servings of vegetables, 7–8 servings per day of whole grains, 2–3 daily servings of low-fat or non-fat dairy, ≤2 servings per day of fish and poultry, 4–5 servings per week of nuts, seeds, and dry beans, and 2 servings per day of fats and oils. Red meat, sweets, and sugary drinks are limited. The DASH diet pattern is high in fiber, potassium, calcium, and magnesium and low in sodium (28, 32). In the AMED, dietary components include extra virgin olive oil, whole and minimally processed grains, legumes, vegetables (potatoes are excluded), fruit, nuts, fish, and regular but modest intake of wine or alcohol. In contrast to DASH, the Mediterranean dietary pattern does not prescribe specific amounts for each food group, but instead recommends a hierarchy of food groupings. Vegetables, fruits, nuts, whole grains, and vegetable oils, particularly olive oil, are the base of the diet. Fish are the second tier, with ≥2 servings per week suggested. Poultry and dairy are consumed in moderation. Meats and sweets are to be consumed "less often." Alcohol in moderation, particularly wine, is included (26, 27). Two key features of the Mediterranean diet that differentiate this pattern from the DASH pattern are the nearly exclusive use of olive oil and the moderate consumption of wine with meals.

The AHEI-2010 is a validated measure of diet quality (58). The components of the AHEI-2010 were included on the basis of diet-disease relations in the current literature. There are common components with the AMED and DASH diet scores, particularly the emphasis on higher intakes of vegetables, fruit, and whole grains, and lower intakes of sodium, added sugar, and saturated fat. Further, the AHEI-2010 captures additional information on diet quality that may lower the risk of major chronic disease, including cardiovascular disease, diabetes, and cancer. For example, the AHEI-2010 emphasizes intake of whole, not total, grains, with specific recommendations that vary by sex (90 g/day for men and 75 g/day for women), since refined grains are not associated with lower risk of metabolic diseases and may increase risk. The AHEI-2010 also provides separate recommendations for protein sources (nuts, legumes, and fish, specifically those high in EPA and DHA), based on their differing effects on health; sex-specific recommendations for alcohol intake (maximum score for 0.5–1.5 drinks/day for women and 0.5–2 drinks/day for men and minimum score for ≥2.5 drinks/day for women and ≥3.5 drinks/day in men); and quantitative guidance for reduction in sugar-sweetened beverages, separate from other discretionary calories, given their positive association with risk of cardiovascular disease and diabetes (34).

To assess whether any particular food group or dietary component was driving the associations observed in our study, we examined the individual component scores for each of the 3 dietary patterns. However, there was no particular component that was observed to be contributing more substantially to the associations than the others. This suggests that the overall dietary patterns are stronger predictors of risk of hearing loss than the individual components of each of these dietary scores.

Our study has limitations. Dietary information was self-reported, thus there may be measurement error in the assessment of dietary patterns and nondifferential misclassification of the exposures may have been present. However, we averaged multiple dietary assessments which reduces random measurement error (59) and we have previously detected important diet and hearing loss relations for other self-reported nutrients in this cohort (12, 13). Assessment of hearing loss was based on self-report. Hearing decline is often subtle in onset, thus there is imprecision in the assessment of date of onset. Standard pure-tone audiometry is the gold standard measure for evaluation of hearing loss; however, assessment of hearing loss based on self-report has been found to be reasonably reliable (35, 60). Of note, we chose a priori to examine moderate or worse hearing loss to minimize potential misclassification of the outcome. The

sensitivity of a single question to detect moderate or worse hearing loss among women of similar age to our study population was shown to be high (95% and 100%, respectively) (37). However, the potential low specificity of a single question to assess hearing loss may mean that the magnitudes of the associations between greater adherence to healthier dietary patterns and lower risk of hearing loss may be even larger and may explain, in part, the greater magnitudes of the inverse associations found in our sensitivity analyses. Assessment of hearing loss was based on participant report in 2009 or 2013 regarding date of onset, yet information on exposures and covariates was collected before reported date of hearing loss onset; therefore, the relations were examined prospectively. This is an observational study, thus residual confounding could have influenced the results; nevertheless, we carefully adjusted for potentially confounding variables in our analyses, many of which have previously been demonstrated to be well-reported in this cohort (61–63). However, we cannot exclude the possibility of residual confounding by unknown risk factors. Our study was limited to predominantly non-Hispanic white women, and we cannot necessarily generalize these findings to women outside of this age range. The study population included female health care professionals, which was useful in enhancing the validity of the health information collected and in reducing the variability in educational achievement and socioeconomic status of the participants, thus these factors were unlikely to have influenced the results. Further research in additional populations is warranted.

In conclusion, in this large prospective study of dietary patterns and risk of hearing loss in >70,000 US women, we found that women whose diets were consistent with more healthful dietary patterns had a lower risk of developing moderate or worse hearing loss. The benefits of adherence to healthful dietary patterns have been demonstrated for numerous positive health outcomes. Consuming a healthy diet may also be helpful in reducing the risk of acquired hearing loss.

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