Association of coffee consumption with the prevalence of hearing loss in US adults, NHANES 2003-2006

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Abbreviations

ARNS, autosomal recessive nonsyndromic; BMI, body mass index; CI, confidence interval; FFQ, food frequency questionnaire; MEC, mobile examination center; NCHS, the National Center for Health Statistics; NCI, National Cancer Institute; NHANES, the national health and nutrition examination survey; OR, odds ratio; PTA, Pure-tone average; RCS, restricted cubic spline; SD, standard deviation; SOD, superoxide dismutase; WHO, the world health organization.

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Abstract

Objective: This study aims to explore the association between coffee consumption and the prevalence of hearing loss in American adults based on a national population-based survey.

Design: Cross-sectional analysis of reported audiometric status and coffee intake from the 2003-2006 National Health and Nutrition Examination Survey (NHANES). Multivariate logistic regression, forest plots and restricted cubic spline (RCS) analyses were used to explore the associations and dose-response relationships between coffee consumption frequency and hearing loss.

Setting: The USA.

Participant: This study included 1894 individuals aged ≥ 20 from the 2003-2006 NHANES.

Results: In this study, the prevalence of speech-frequency hearing loss (SFHL) and high-frequency hearing loss (HFHL) among the participants was 35.90% and 51.54%, respectively. Compared with those who no consumed coffee, non-Hispanic White who consumed ≥ 4 cups/d had higher prevalence of SFHL (Odds Ratio[OR]: 1.87; 95% Confidence Interval[CI]: 1.003-3.47). And a positive trend of coffee consumption frequency with the prevalence of HFHL was found (P_{trend} = 0.001). This association of HFHL was similar for aged 20-64 participants (P_{trend} = 0.001), non-Hispanic White (P_{trend} = 0.002), non-noise exposure participants (P_{trend} = 0.03), and noise exposed participants (P_{trend} = 0.003). The forest plots analysis found that the association between 1 cup-increment of daily coffee consumption and the prevalence of HFHL was statistically significant in males. RCS model supported a positive linear association of coffee consumption with SFHL (*P* for overall association = 0.02, *P* for nonlinearity = 0.48), and a positive non-linear association of coffee consumption with HFHL (*P* for overall association = 0.001, *P* for nonlinearity = 0.001).

Conclusion: Our findings suggested that coffee consumption was associated with higher prevalence of hearing loss. Further cohort studies in larger population are needed to investigate these findings.

Keywords: hearing loss, coffee, NHANES, adult, risk assessment.

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INTRODUCTION

Hearing loss is a major global public health problem. Approximately, one-fifth of the global population currently suffer from hearing loss[1]. In America, nearly a quarter of people aged 12 years and over have hearing loss, including mild and unilateral hearing loss[2]. The World Health Organization (WHO) has estimated that hearing loss will be one of the main causes of disease burden globally by 2030[3]. Hearing loss may be associated with a variety of diseases. Evidence from epidemiological studies showed that hearing loss is related to the increased risks of depressive symptoms, falls, total mortality and heart disease mortality[4-6]. The traditional risk factors, including age, noise exposure, family history of hearing loss, exposure to ototoxic medications, smoking and diabetes, could only partially explain the causes of hearing loss[7]. Recently, accumulating studies have suggested that diet is related to hearing loss, and this effect can be attributed to specific dietary patterns or some special bioactive compounds, such as polyunsaturated fatty acids, vitamin A, isoflavone, riboflavin, niacin, and retinol[8-11].

Coffee is one of the most popular beverages in the world. Coffee and its compounds, such as caffeine, trigonelline, polyphenols and chlorogenic acid, have various impacts on human health[12]. Coffee trigonelline has anti-microbial, anti-carcinogenic and anti-hyperglycemic effects[13]. Coffee chlorogenic acid has some anti-cancer effects[14]. Caffeine has protective effect on neurodegenerative disease due to its strong antioxidant, anti-inflammatory and adenosine receptor antagonist properties[15]. It may also be related to increased risk of fractures and decreased sleep quality[16, 17]. Additionally, polyphenols, such as caffeic acid and caffeic acid phenethyl ester, have antioxidant effects and prevent hearing loss[18, 19]. However, caffeine are often considered a cause of tinnitus[20]. Large population-based studies on the association between coffee consumption and hearing loss are limited.

Currently, study about the effect of coffee consumption on hearing loss is scarce, and the results remain controversial. Two previous population-based studies have suggested a

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negative association between coffee consumption frequency and hearing loss[41, 42]. Contrary, previous animals studies have shown that caffeine in coffee can interfere with hearing recovery after acoustic overstimulation events[30-31]. Moreover, a previous study based on the NHANES has reported no significant association between urinary caffeine metabolites and hearing thresholds[40]. Therefore, in this study, we have investigated the association of coffee consumption with the hearing loss in adults from America according to the National Health and Nutrition Examination Survey (NHANES) database.

METHODS

Study design and participants

The data in this study was from the NHANES database, which is a national survey administered by the National Center for Health Statistics (NCHS). This survey investigated about 10 000 representative samples of the general American population per cycle using a complex, multistage, probability sampling design. The data from the 2003-2006 was used in our study, because the information on coffee consumption and audiometry data of adult participants were collected in the same period. In the 2003-2006 NHANES, a total of 4923 subjects participated in the audiometry component. Among 1735 subjecs were excluded because they lacked audiometry test data (n = 451) and coffee consumption data (n = 1284). Of the remaining 3188 participants, additional 1294 were eliminated because they aged < 20 (adolescents aged 12-19 in NHANES). Finally, 1894 subjects were recruited for analyses in this study (Figure 1).

Assessment of coffee consumption

Coffee consumption frequency was calculated by the Food Frequency Questionnaire (FFQ), which was developed by the National Institutes of Health, National Cancer Institute (NCI) based on the NCI Diet History Questionnaire. Participants were asked to review and fill in their coffee consumption in the past 12 months. The question on coffee consumption

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frequency in the questionnaire was: “How many cups of caffeinated or decaffeinated coffee did you drink”. The possible responses were: none, ≤ 1 cup/m, 1-3 cups/m, 1 cup/w, 2-4 cups/w, 5-6 cups/w, 1 cup/d, 2-3 cups/d, 4-5 cups/d, ≥ 6 cups/d”. If select other option than “none”, participant need to answer the following question: “How often was you drank the decaffeinated coffee”. The possible responses were: “almost never or never, about 1/4 of the time, about 1/2 of the time, about 3/4 of the time, almost always or always”. In this survey, a cup of coffee was 8oz according to the Measuring Guides for the Dietary Recall Interview[21].

In present analysis, total coffee consumption frequency was categorized into five groups: none, ≤ 1 cup/d, 1 cup/d, 2-3 cups/d and ≥ 4 cups/d. Then coffee consumption frequency data was futher converted to quantitative data (e.g., 1-3 cups/m was converted to 0.07 cups/d). The prevalence of hearing loss related to caffeinated and decaffeinated coffee consumption was also investigated.

Audiometric measurement

All hearing measurements were conducted by a well-trained physicians in a dedicated, sound-isolating room at a mobile examination center (MEC). The test equipment included AD226 audiometer (Interacoustics AS, Assens, Denmark), TDH-39 standard headphones (Interacoustics AS, Assens, Denmark) and EARtone 3A insert earphones (Etymotic Research, Elk Grove Village, IL). The hearing threshold for each ear was measured at frequencies of 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz across an intensity range of -10 to 120 dB using the modified Hughson-Westlake procedure and invoking the automated testing mode of the audiometer. More details of Audiometric measures are displayed on NHANES website. In our study, speech-frequency hearing loss(SFHL) was defined as Pure-tone average (PTA) of hearing thresholds at 500, 1000, 2000 and 4000 Hz is > 25 dB in either ear, and high-frequency hearing loss (HFHL) was defined as Pure-tone average (PTA) of hearing thresholds at 3000, 4000 and 6000 Hz is > 25 dB in either ear[22].

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Other variables

Covariates were obtained from the questionnaire survey, including general characteristics (age, gender, ethnicity), lifestyles (smoking status, drinking status), noise exposure, history of diseases (hypertension and diabetes mellitus). Ethnicity was classified as non-Hispanic white, non-Hispanic black and other. Smoking status was categorized as never smoker, former smoker and current smoker. Drinking status was categorized as never drinker, low to moderate drinker (drinking < 1 drink/d in women and < 2 drinks/d in men) and heavy drinker (≥ 1 drink/d in female and ≥ 2 drinks/d in male)[23]. BMI status was classified as BMI < 25, BMI 25 - 30, and BMI ≥ 30[24]. The question on non-occupational noise exposure was: "Outside of a job, have you ever been exposed to steady loud noise or music for 5 or more hours a week? This is noise so loud that you have to raise your voice to be heard". The possible responses were: "yes" or "no". The question on occupational noise exposure was: "have you ever had a job where you were exposed to loud noise for 5 or more hours a week (you had to raise your voice to be heard)". The possible responses were: "yes" or "no". In addition, diagnoses of diabetes mellitus and hypertension and history of ear infection were self-reported by the subjects.

Statistical analyses

Given the design of complex, multistage, probability sampling in the NHANES, we implemented sampling weight, cluster, and strata in the analysis. Continuous variables were expressed as mean ± standard deviation (SD) for the normal distribution and as median (P_{25}, P_{75}) for skewed distribution and analyzed by Student's *t*-tests. Categorical variables were expressed as frequency (%) and analyzed by χ^2 test or Wilcoxon rank-sum test.

Multivariate logistic regression models were applied to assess the relationships between coffee consumption frequency and the prevalence of SFHL and HFHL. The "None" group were considered as the reference groups. Covariates including ethnicity, BMI, ear infection, occupational noise exposure, non-occupational noise exposure, smoking status, drinking

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status, hypertension and diabetes mellitus were adjusted. The trend test was conducted by taking the median of each coffee consumption frequency group as a continuous variable in these models. We also transformed coffee consumption frequency into continuous variable to explore the linear dose-response relationship. We also conducted subgroup analyses stratified by demographic characteristics (including age (20-64, ≥ 65), ethnicity (non-Hispanic white, non-Hispanic black, and other race), sex (male, female)), noise exposure source (including Yes (at work exposure Yes and/or outside work exposure Yes), No (at work exposure No and outside work exposure No), noise exposure unknown (outside work exposure No and at work exposure data missing)), and coffee type (caffeinated coffee, decaffeinated coffee, both). Moreover, we created forest plots to estimate the odds ratios (95% confidence interval (Cl)) of hearing loss related to a 1-cup/d increment for the different types of coffee separately in men and women. Furthermore, restricted cubic splines (RCS) regression model was conducted to further explore the dose-response relationship of coffee consumption with the prevalence of SFHL and HFHL in the multivariable-adjusted binary logistic regression analyses for sex, ethnicity, and noise exposure status separately, with four knots of at the 5th, 35th, 65th, and 95th percentiles. Adjusted factors were consistent with multivariate logistic regression model. *P* for non-linearity < 0.05 suggested a non-linear association, otherwise a linear association was indicated. RCS analyses was conducted using SAS macro program %RCS_Reg[25]. All statistical analyses were performed using SAS software (version 9.4; SAS Institute, Cary, NC, USA).

RESUITS

Characteristics of study population

As shown in Table 1, a total of 1894 participants were included. Compared to non-coffee drinkers, those who with more consumption were older, were more likely to be non-Hispanic White and current smokers and heavy drinkers. Also, they had a lower proportion of BMI ≥ 30, and were more likely to have a diagnosis of hypertension and hearing loss; by contrast,

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they were more exposed to occupational noise exposure. No statistical differences between different coffee consumption frequency groups in sex, body mass index (BMI), ear infection, non-occupational noise exposure and diabetes mellitus were observed (all $P > 0.05$).

Association between coffee consumption and hearing loss risk

As shown in Table 2, there was no correlation between coffee consumption and the prevalence of SFHL and HFHL in all groups in the full-adjusted model. A positive trend and association of coffee consumption frequency with the prevalence of SFHL was found in crude model ($P_{trend} = 0.001$), but this trend has insignificant after full adjustments ($P_{trend} = 0.25$). Beside, a positive trend and association of coffee consumption frequency with the prevalence of HFHL in crude model was found ($P_{trend} < 0.05$), while only the trend remained after full adjustments ($P_{trend} < 0.05$).

Subgroup analyses

The results of subgroup analyses were shown in Table 3, Supplementary Table S1 and Supplementary Table S2. In non-Hispanic White subgroup, only participants who consumed ≥ 4 cups/d had a higher prevalence of SFHL compared to non-coffee drinker group (OR: 1.87; 95% CI: 1.003-3.47; $P = 0.049$, Table 3). Nevertheless, no trends and association of coffee consumption frequency with the prevalence of SFHL in subgroups of age (20-64, ≥ 65), ethnicity (non-Hispanic black, and other race), and sex (male, and female) were observed ($P_{trend} > 0.05$, Table 3). Besides, positive trends of coffee consumption frequency with the prevalence of HFHL in subgroups of age (20-64), ethnicity (non-Hispanic white), and sex (male and female) were observed ($P_{trend} < 0.05$, Table 3). Moreover, in noise exposure subgroup, a positive trend of coffee consumption frequency with the prevalence of SFHL in Model 1 was observed ($P_{trend} = 0.048$, Supplementary Table S1). Similarly, the positive trend of coffee consumption frequency with the prevalence of HFHL in Model 1 was also found in subgroups of loud noise exposure (yes and no). In addition, no significant correlations were also found between coffee consumption frequency and the prevalence of SFHL and HFHL in

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all coffee type subgroups (Supplementary Table S2).

The forest plot analysis of association of coffee consumption with hearing loss

The relationship between coffee consumption and the prevalence of SFHL and HFHL appeared to be more pronounced in male subgroup. However, only in caffeinated coffee subgroup, the association between per 1 cup-increment of daily coffee consumption and HFHL was statistically significant in male (Figure 2).

Dose-response relationships between coffee consumption and the prevalence of hearing loss

RCS model also showed a linear positive associations of coffee consumption with the prevalence of SFHL (*P* overall association = 0.02, *P* nonlinearity = 0.48; Figure 3 (a)), while a non-liner positive associations of coffee consumption with the prevalence of HFHL was found (*P* overall association = 0.001, *P* nonlinearity = 0.001; Figure 3 (b)). Beside, a positive linear associations of coffee consumption with the prevalence of SFHL were found in the noise exposure subgroup (*P* overall association = 0.03, *P* nonlinearity = 0.47; Supplementary Figure S1 (a)). Likewise, positive linear associations of coffee consumption with the prevalence of HFHL were found in male subgroup and non-noise exposure subgroup (all *P* overall association < 0.05, *P* nonlinearity > 0.05; Supplementary Figure S1 (f)-(g)), while positive non-linear associations of coffee consumption with the prevalence of HFHL were found in the age20-64, non-Hispanic white, female, and noise exposure subgroup (all *P* overall association < 0.05, *P* nonlinearity < 0.05; Supplementary Figure S1).

DISCUSSION

In present study, we assessed the relationship between coffee consumption and hearing loss in American adults with aged ≥ 20 from NHANES 2003-2006, and found that coffee consumption was related to the prevalence of hearing loss among US adults, especially male and participants with noise exposed. A significant trend of coffee consumption frequency

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with the prevalence of hearing loss was found. These results may be independent of the coffee type or the preparation method.

As a common drink, coffee has attracted increasing attention on its health effects. However, studies about the impact of coffee consumption on hearing loss were limited, and the results were controversial. In this study, we found a positive association of coffee consumption frequency with the prevalence of SFHL and HFHL in US adults. Caffeine is one of the main components of coffee. Caffeine has non-selective adenosine receptor antagonist properties, which interfers hearing recovery after acoustic overstimulation events via antagonizing adenosine receptors in Corti organ, lateral wall, spiral ganglion cells and cochlear blood vessels, leading to interruption of cochlear blood reperfusion and the increased production of oxidative stress[26-28]. Also, caffeine increases the production and accumulation of calcium in the cochlear hair cells after noise exposure, which activate calcium dependent isomers and cleave calcium dependent neurons by phospholipase A2 that lead to the apoptosis of cochlear hair cells[29, 30]. Beside, caffeine exacerbates the noise-induced hypoperfusion and ischemia in the cochlea by promoting the reduction of cerebral blood flow and arteriole diameter[31, 32]. Caffeine also exacerbates the physiological increase of corticosterone by altering the hypothalamic-pituitary-adrenocortical axis, thus casuing an acute response to noise[33, 34]. In addition, caffeine caused autophagy and apoptosis in the cochlear hair cells through SGK1/HIF-1α pathway[35]. However, a previous study based on the NHANES showed that urinary caffeine metabolites were not associated with the changes of hearing thresholds in US adults[36]. Contrary to our findings, two previous population-based studies have shown a negative association between coffee consumption frequency and hearing loss[37, 38]. The inconsistent results can be mainly attributed to differences in the study population, the sample size, the definition of hearing loss, the measurement of hearing thresholds, the inclusion and exclusion criteria, the covariates included in statistical model[39].

Of note, our study showed a positive trend and association of coffee consumption frequency with the prevalence of SFHL and HFHL in non-Hispanic whites, and participants who

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consumed ≥ 4 cups/d coffee had a 1.87-fold higher prevalence of SFHL than non-coffee drinkers. Similar to our finding, another study based on the NHANES database also showed that the odds of hearing loss are substantially higher in non-Hispanic whites Americans than in other ethnic individuals (OR: 2.3; 95% CI : 1.3-3.9)[40]. Skin pigmentation, as a marker of melanocytic functioning, may mediate the close relationship of race/ethnicity and hearing loss[41]. Genes also play an important role in the occurrence and development of hearing loss. It has been reported that the prevalence of hearing loss caused by pathogenic autosomal recessive nonsyndromic (ARNS) HI genes varies from race to race, and African Americans/African Americans receive the least impact[42]. In addition, we also found that even after adjusting for covariates related to hearing loss, there was still a sex difference in the relationship between coffee and hearing loss, the association between per 1 cup-increment of daily coffee consumption and HFHL was statistically significant in men, but no significant association was found among women, which was similar to a previous study[2]. In this study, the proportion of male coffee consumers is higher than that of female (78.26% vs. 74.82%). Coffee drinking is widespread in the United States, and men consumed more coffee[43, 44]. Previous studies have shown that men may have a higher hearing threshold[2]. It may be due to the great differences between men and women in brain biochemistry, physiology, structure and function. In physiological structure, the length of the cochlea in men was longer than that in women, which could affect the auditory brainstem responses. Beside, estrogen also plays a protective role in the cochlear function[45]. Estrogen may play an important role in modulating the pathophysiological mechanisms in the hearing system, it could enhance the expression of antioxidant superoxide dismutase (SOD) and decrease apoptosis by upregulating Bcl-2/Bcl-xL and inhibiting the JNK pathway, and it also could inhibit glutamate excitotoxicity to regulate cochlear homeostasis[46]. Thus, in women, the effect of nutrition on auditory function may not be as relevant as in men. Besides, we found a positive trend and relationship between coffee consumption frequency with the prevalence of HFHL in non-noise exposure subgroup, suggesting that caffeine may have a potential effect on hearing. A previous study reported that caffeine significantly suppressed the compound action

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potential (CAP) of the auditory nerve after infusing caffeine into the perilymph compartment[47]. Noteworthy, we found a positive trend and relationship of coffee consumption frequency with the prevalence of SFHL and HFHL in the noise exposed participants. Noise-induced hearing loss mainly refers to the apoptosis of cochlear hair cells caused by noise through mechanical damage and metabolic damage (such as oxidative stress damage, Ca^{2+} overload, and immune and inflammatory damage)[48]. The interaction between coffee and noise may aggravate the apoptosis of cochlear hair cells. Given the biological plausibility, it will be very meaningful to conduct further studies to establish the potential role of coffee consumption combined with noise exposure on hearing loss.

This study has several advantages. First, the data is from NHANES, which has been implemented in the United States for a long time, and the survey implementation process is rigorous and mature, so the results of this study are relatively reliable. Second, given that the survey design was complex, multistage, probability sampling in the NHANES, we conducted sampling weight, cluster, and strata to solve the deviation of variance estimation caused by such clustering data in the statistical analyses. Beside, we explored the association between the prevalence of SFHL and HFHL with coffee consumption frequency. This study also has several limitations. First, since only two circles (2003-2006) in the NHANES have collected the information on coffee consumption frequency and audiometry test of American adults, the sample size was relatively small, thus, the extrapolation of this result to the general population should be more cautious. Secondly, coffee consumption is obtained through questionnaires, which may have participants' recall bias, and it is difficult to accurately obtain information about coffee consumption, such as individual coffee intake, type of coffee consumption and preparation process. Therefore, the error of coffee consumption between measured exposure and actual exposure cannot be completely eliminated[49]. Finally, this was an observation study, so causality between coffee consumption and hearing loss could not be shown.

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CONCLUSIONS

This finding suggested that the positive trend and association of coffee consumption frequency with the prevalence of hearing loss in US adults. And this association was found in non-Hispanic whites, men, aged 20-64 participants and noise exposed individuals. This association may be independent of the coffee type or the preparation method. Further cohort studies in larger population are needed to validate these findings, and the underlying mechanism also remains to be elucidated.

ABBREVIATIONS

ARNS, autosomal recessive nonsyndromic; BMI, body mass index; CAP, compound action potential; CI, confidence interval; FFQ, food frequency questionnaire; MEC, mobile examination center; NCHS, the National Center for Health Statistics; NCI, National Cancer Institute; NHANES, the national health and nutrition examination survey; OR, odds ratio; PTA, Pure-tone average; RCS, restricted cubic spline; SD, standard deviation; SOD, superoxide dismutase; WHO, the world health organization.

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Table 1 Characteristics of study subjects by coffee consumption.

Symptoms by Group	Frequency of Coffee Consumption						*P* value
	Total	None	< 1cup/d	1cup/d	2-3cup/d	≥ 4cup/d	
Participants, n	1894	446	474	333	504	137	
Age (year), mean (95% CI)	49.66 (47.67, 51.64)	41.35 (39.12, 43.57)	44.62 (41.44, 47.81)	55.95 (53.08, 58.82)	56.55 (53.77, 59.32)	56.05 (52.50, 59.60)	0.001* **
Sex, n (%)							0.87
Male	897 (47.36)	195 (43.72)	201 (42.41)	158 (47.45)	268 (53.17)	75 (54.74)	
Female	997 (52.64)	251 (56.28)	273 (57.59)	175 (52.55)	236 (46.83)	62 (45.26)	
BMI, n (%)							0.36
< 25	639 (33.74)	165 (37.00)	148 (31.22)	109 (32.73)	166 (32.94)	51 (37.23)	
25-30	647 (34.16)	128 (28.70)	164 (34.60)	122 (36.64)	181 (35.91)	52 (37.96)	
≥ 30	608 (32.10)	153 (34.30)	162 (34.18)	102 (30.63)	157 (31.15)	34 (24.82)	
Ethnicity, n (%)							0.001* **
Non-Hispanic White	1139 (60.14)	251 (56.28)	217 (45.78)	189 (56.76)	372 (73.81)	110 (80.29)	
Non-Hispanic Black	326 (17.21)	110 (24.66)	122 (25.74)	40 (12.01)	43 (8.53)	11 (8.03)	
Other Race	429 (22.65)	85 (19.06)	135 (28.48)	104 (31.23)	89 (17.66)	16 (11.68)	

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Loud noise exposure							
At work, n(%)	518 (37.62)	108 (33.03)	103 (31.50)	101 (37.97)	163 (44.54)	43 (47.25)	0.04*
Missing	517	119	147	67	138	46	
Outside work, n (%)	427 (22.57)	111 (24.89)	103 (21.73)	61 (18.32)	116 (23.06)	36 (26.47)	0.18
SFHL, n (%)							0.001**
Yes	680 (35.90)	104 (23.32)	126 (26.58)	150 (45.05)	234 (46.43)	66 (48.18)	
No	1214 (64.10)	342 (76.68)	348 (73.42)	183 (54.95)	270 (53.57)	71 (51.82)	
HFHL, n (%)							0.001**
Yes	970 (51.54)	145 (32.73)	192 (40.51)	211 (63.94)	330 (66.27)	92 (67.15)	
No	912 (48.46)	298 (67.27)	282 (59.49)	119 (36.06)	168 (33.73)	45 (32.85)	
Ear infection, n (%)	83 (4.54)	19 (4.48)	22 (4.88)	11 (3.41)	20 (4.03)	11 (8.27)	0.55
Smoking status, n (%)							0.001**
Never smoker	927 (49.00)	277 (62.11)	282 (59.62)	171 (51.35)	176 (34.92)	21 (15.44)	
Former smoker	586 (30.97)	94 (21.08)	112 (23.68)	123 (36.94)	200 (39.68)	57 (41.91)	

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Current smoker	379 (20.03)	75 (16.82)	79 (16.70)	39 (11.71)	128 (25.40)	58 (42.65)	
Drinking status, n (%)							0.01**
Never drinker	591 (32.31)	186 (43.66)	147 (32.59)	105 (32.61)	115 (23.23)	38 (28.15)	
Low to moderate drinker	1081 (59.10)	216 (50.70)	272 (60.31)	190 (59.01)	318 (64.24)	85 (62.96)	
Heavy drinker	157 (8.58)	24 (5.63)	32 (7.10)	27 (8.39)	62 (12.53)	12 (8.89)	
History of diseases							
Hypertension, n (%)	728 (38.58)	136 (30.63)	165 (34.96)	154 (46.39)	223 (44.42)	50 (36.50)	0.001**
Diabetes mellitus, n (%)	212 (11.19)	35 (7.85)	44 (9.28)	44 (13.21)	69 (13.69)	20 (14.60)	0.10

P values from χ^2 test or *Wilcoxon rank-sum* test (categorical categories) and *Student's t*-tests (continuous covariates).

$^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

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Table 2 Odds ratios and 95% confidence intervals of coffee consumption for hearing loss.

	Frequency of Coffee Consumption					
	None	< 1cup/d	1cup/d	2-3cup/d	≥ 4cup/d	*P* trend
SFHL						
Total (n = 1894)						
Cases/N	104/446	126/474	150/333	234/504	66/137	
Crude model	Ref	1.28 (0.80, 2.04)	2.57 (1.52, 4.36)[b]	2.55 (1.57, 4.15)[b]	2.82 (1.65, 4.81)[b]	0.001[*]
Model 1[a]	Ref	1.12 (0.61, 2.04)	1.46 (0.83, 2.57)	1.27 (0.68, 2.37)	1.54 (0.81, 2.91)	0.25
HFHL						
Total (n = 1882)						
Cases/N	145/443	192/474	211/330	330/498	92/137	
Crude model	Ref	1.32 (0.87, 2.02)	3.26 (2.03, 5.26)[b]	3.94 (2.66, 5.86)[b]	3.72 (2.34, 5.93)[b]	0.001[*]
Model 1[a]	Ref	1.18 (0.63, 2.21)	2.41 (1.28, 4.55)[b]	2.61 (1.51, 4.50)[b]	1.89 (0.90, 3.99)	0.001[*]

[a] Adjusted for age, sex, ethnicity, ear infection, occupational noise exposure, non-occupational noise exposure, smoking status, drinking status, hypertension, diabetes mellitus, BMI.

[b] $P < 0.05$.

[*] P trend < 0.05.

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Table 3 Odds ratios and 95% confidence intervals of coffee consumption for hearing loss stratified by demographic characteristics.

	Frequency of Coffee Consumption					
	None	< 1cup/d	1cup/d	2-3cup/d	≥ 4cup/d	*P* trend
SFHL						
Age						
Age20-64 (n = 1194)						
Cases/N	35/348	37/337	27/174	57/259	20/76	
Crude model	Ref	1.28 (0.65, 2.54)	1.62 (0.82, 3.20)	2.07 (0.98, 4.38)	2.50 (1.01, 6.21)[b]	0.03[*]
Model 1[a]	Ref	1.17 (0.48, 2.83)	1.29 (0.63, 2.64)	1.32 (0.62, 2.84)	1.31 (0.63, 2.75)	0.46
Age ≥ 65 (n = 700)						
Cases/N	69/98	89/137	123/159	177/245	46/61	
Crude model	Ref	0.85 (0.42, 1.70)	1.43 (0.75, 2.73)	0.99 (0.50, 1.97)	1.38 (0.50, 3.78)	0.58
Model 1[a]	Ref	0.88 (0.44, 1.75)	1.25 (0.67, 2.33)	0.94 (0.48, 1.84)	1.16 (0.39, 3.48)	0.82
Ethnicity						
Non-Hispanic White (n = 1139)						
Cases/N	68/251	77/217	101/189	195/372	54/110	
Crude model	Ref	1.48 (0.82, 2.67)	2.60 (1.35, 5.03)[b]	2.77 (1.63, 4.73)[b]	2.62 (1.58, 4.32)[b]	0.001[*]
Model 1[a]	Ref	1.22 (0.58,	1.52 (0.70,	1.62 (0.82,	1.87 (1.003,	0.07

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		2.58)	3.29)	3.17)	3.47)[b]	
Non-Hispanic						
Black (n = 326)						
Cases/N	17/110	24/122	15/40	6/43	4/11	
Crude model	Ref	1.60 (0.50, 5.11)	3.05 (1.02, 9.07)[b]	0.62 (0.14, 2.76)	3.51 (0.95, 12.95)	0.55
Model 1[a]	Ref	1.51 (0.33, 6.89)	0.48 (0.09, 2.50)	0.13 (0.01, 1.80)	0.29 (0.03, 2.46)	0.10
Other Race (n = 429)						
Cases/N	19/85	25/135	34/104	33/89	8/16	
Crude model	Ref	0.64 (0.28, 1.43)	2.08 (0.72, 6.04)	0.86 (0.37, 2.00)	3.01 (0.53, 17.12)	0.20
Model 1[a]	Ref	0.51 (0.18, 1.47)	0.80 (0.27, 2.40)	0.37 (0.10, 1.35)	0.49 (0.07, 3.36)	0.24
Sex						
Male (n = 897)						
Cases/N	64/195	60/201	80/158	149/268	44/75	
Crude model	Ref	1.21 (0.60, 2.44)	2.23 (1.02, 4.87)[b]	2.84 (1.46, 5.52)[b]	3.30 (1.41, 7.69)[b]	0.001[*]
Model 1[a]	Ref	1.10 (0.48, 2.51)	1.16 (0.55, 2.46)	1.39 (0.64, 3.02)	1.50 (0.58, 3.89)	0.37
Female (n = 997)						
Cases/N	40/251	66/273	70/175	85/236	22/62	
Crude model	Ref	1.31 (0.70, 2.45)	2.94 (1.56, 5.53)[b]	2.29 (1.13, 4.64)[b]	2.22 (1.02, 4.85)[b]	0.002[*]
Model 1[a]	Ref	0.87 (0.37, 2.06)	1.53 (0.62, 3.77)	0.95 (0.34, 2.67)	1.23 (0.50, 3.02)	0.72

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HFHL						
Age						
Age20-64 (n = 1194)						
Cases/N	60/348	71/337	61/174	111/258	37/77	
Crude model	Ref	1.26 (0.76, 2.10)	2.33 (1.35, 4.02)[b]	3.57 (2.12, 6.00)[b]	3.49 (1.74, 6.99)[b]	0.001*
Model 1[a]	Ref	1.19 (0.60, 2.36)	2.30 (1.12, 4.69)[b]	2.91 (1.69, 5.03)[b]	1.75 (0.75, 4.11)	0.001*
Age ≥ 65 (n = 688)						
Cases/N	85/95	121/137	150/156	219/240	55/60	
Crude model	Ref	0.81 (0.22, 2.95)	3.37 (0.75, 15.13)	1.09 (0.34, 3.49)	1.74 (0.35, 8.81)	0.50
Model 1[a]	Ref	1.23 (0.29, 5.22)	3.98 (0.83, 19.08)	1.39 (0.40, 4.85)	2.10 (0.50, 8.81)	0.32
Ethnicity						
Non-Hispanic White (n = 1127)						
Cases/N	93/248	105/217	134/186	267/367	77/109	
Crude model	Ref	1.53 (0.97, 2.42)	3.03 (1.83, 5.05)[b]	3.94 (2.51, 6.17)[b]	3.39 (2.10, 5.47)[b]	0.001*
Model 1[a]	Ref	1.24 (0.66, 2.36)	2.01 (1.02, 3.94)[b]	2.83 (1.49, 5.37)[b]	2.29 (1.06, 4.93)[b]	0.002*
Non-Hispanic Black (n = 327)						
Cases/N	22/110	44/122	22/40	15/43	7/12	
Crude model	Ref	2.22 (1.08,	6.02 (1.99,	2.24 (0.83,	4.52 (1.10,	0.01*

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		4.55)[b]	18.18)[b]	6.06)	18.51)[b]	
Model 1[a]	Ref	4.50 (1.24, 16.39)[b]	5.86 (0.57, 60.54)	1.79 (0.47, 6.77)	0.26 (0.04, 1.69)	0.66
Other Race (n = 428)						
Cases/N	30/85	43/135	55/104	48/88	8/16	
Crude model	Ref	0.64 (0.28, 1.49)	3.22 (1.56, 6.65)[b]	2.31 (0.64, 8.35)	1.51 (0.34, 6.60)	0.03*
Model 1[a]	Ref	0.31 (0.10, 0.90)[b]	2.22 (0.98, 5.03)	1.27 (0.36, 4.49)	0.07 (0.01, 0.33)[b]	0.56
Sex						
Male (n = 887)						
Cases/N	88/192	96/201	110/155	203/264	62/75	
Crude model	Ref	1.09 (0.58, 2.04)	2.16 (0.98, 4.76)	4.08 (2.57, 6.47)[b]	4.98 (2.39, 10.37)[b]	0.001*
Model 1[a]	Ref	0.84 (0.38, 1.87)	1.42 (0.63, 3.19)	2.33 (1.44, 3.78)[b]	1.70 (0.81, 3.57)	0.001*
Female (n = 995)						
Cases/N	57/251	96/273	101/175	127/234	30/62	
Crude model	Ref	1.59 (0.89, 2.85)	4.93 (3.06, 7.94)[b]	4.31 (2.30, 8.05)[b]	3.05 (1.54, 6.03)[b]	0.001*
Model 1[a]	Ref	1.34 (0.50, 3.60)	3.85 (1.71, 8.68)[b]	2.62 (0.90, 7.66)	1.72 (0.54, 5.49)	0.04*

[a] Adjusted for age, sex, ethnicity, ear infection, occupational noise exposure, non-occupational noise exposure, smoking status, drinking status, hypertension, diabetes mellitus, BMI.

[b] $P < 0.05$.

*P trend < 0.05.

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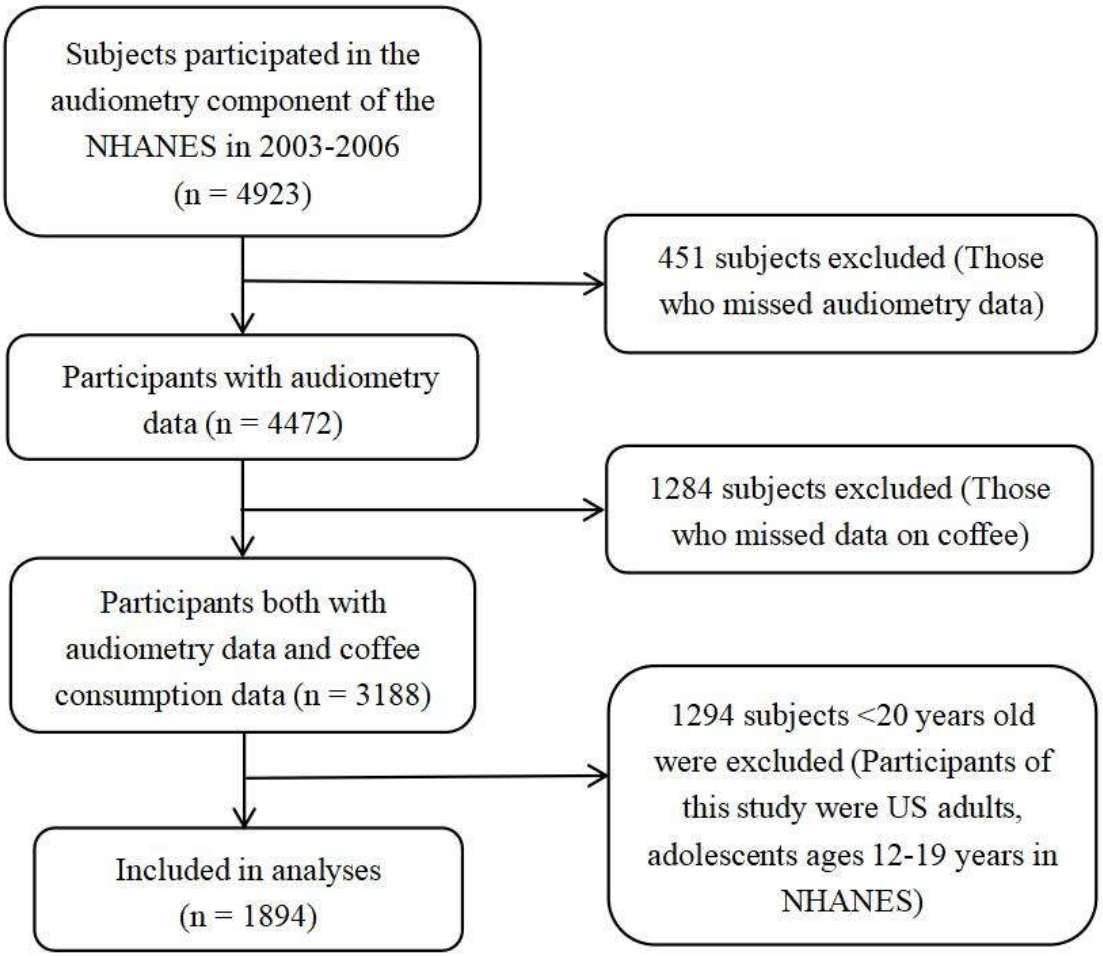

Figure 1 Flow chart of the selection process.

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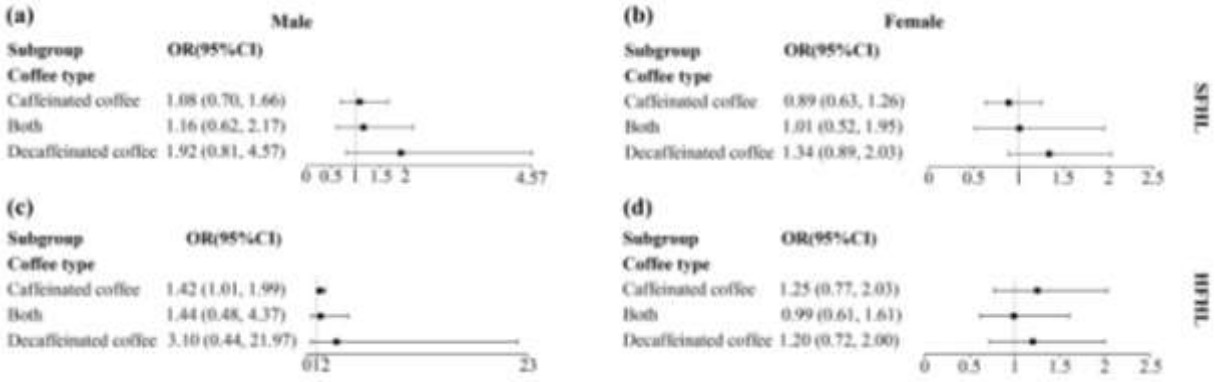

Figure 2 Odds ratios (95% confidence interval) per 1 cup-increment for the association between the different types of coffee and the prevalence of hearing loss stratified by sex. (a)-(b)speech-frequency hearing loss (SFHL). (c)-(d)high-frequency hearing loss(HFHL). Analyses are adjusted for age, ethnicity, ear infection, occupational noise exposure, non-occupational noise exposure, smoking status, drinking status, hypertension, diabetes mellitus, BMI.

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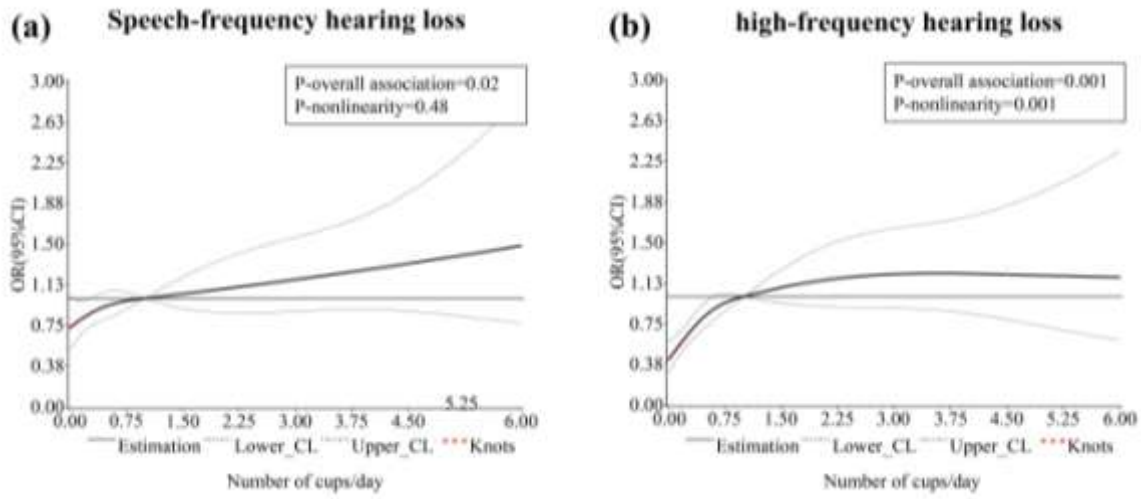

Figure 3 Multivariable adjusted spline curves of relation between total coffee and the prevalence of hearing loss. (a)SFHL. (b)HFHL. Covariates were age, sex, ethnicity, ear infection, occupational noise exposure, non-occupational noise exposure, smoking status, drinking status, hypertension, diabetes mellitus, BMI.

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