Preventive Medicine 53 (2011) 338–342

Contents lists available at SciVerse ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Modifiable determinants of hearing impairment in adults

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ARTICLE INFO

Available online 17 August 2011

Keywords:
Hearing impairment
Hearing loss
Birth cohort effect
Education

ABSTRACT

Objective. To identify factors contributing to the declining prevalence of hearing impairment in more recent generations.

Methods. We used data on hearing thresholds and potential risk factors of hearing impairment collected from studies in Beaver Dam, Wisconsin, the Epidemiology of Hearing Loss Study (1993–1995, n = 3753; 1998–2000, n = 2800 and 2003–2005, n = 2395), the concurrent Beaver Dam Eye Study on the same cohort, and a subgroup (n = 2173) of the Beaver Dam Offspring Study (2005–2008).

Results. Educational attainment significantly reduced the odds ratio (OR) of the birth cohort effect on hearing impairment from 0.90 to 0.93, while a history of ear infection had a reverse effect on the decreasing trend (significantly changing the OR from 0.93 to 0.94). Occupational noise exposure, smoking, and a history of cardiovascular disease, while associated with hearing impairment, did not attenuate the cohort effect. The cohort effect remained significant after known risk factors were adjusted (OR = 0.93; 95% confidence interval, 0.89–0.97).

Conclusion. These data provide strong evidence that environmental, lifestyle, or other modifiable factors contribute to the etiology of hearing impairment and add support to the idea that hearing impairment in adults may be prevented or delayed.

Introduction

Rapid change in disease prevalence over time is a vital indicator that a disorder has environmental or other modifiable risk factors. Understanding these changes may provide important insights into ways to improve population health. Previously, Zhan et al. analyzed the trend of hearing impairment in older adults and found that people born in more recent years were less likely to have hearing impairment at a given age than those born in earlier years (Zhan et al., 2010). Over a typical generational span of 20 years, the prevalence of hearing impairment declined by 42% and 23% for men and women, respectively. This birth cohort effect suggested that environmental and modifiable factors may be associated with the development of hearing impairment because human genetic changes are extremely slow and unlikely to happen in less than 20 years.

During the 20th century there were many positive changes in the environment (e.g., cleaner air and water, institution of noise-reduction efforts in the work place) and behavioral factors (e.g., higher education, recent decreased rates of smoking), improvements in health care (e.g., immunizations and antibiotics), and declines in other disorders (e.g., cardiovascular disease (CVD), hypertension, and hypercholesterolemia), that may have beneficial effects on overall health and reduced morbidity, but obesity and sedentary lifestyles have become more common (Flegal et al., 2002; Garte, 2007; Hill and Needham, 2006; Middendorf, 2004).

Noise exposure, smoking, drinking, diabetes, CVD and its risk factors and socioeconomic factors (Agrawal et al., 2008; Cruickshanks et al., 2010; Gates et al., 2000; Helzner et al., 2005) have been associated with hearing impairment. However, which of these factors may be related to improvements in hearing health is unknown. Therefore, the purpose of this paper was to evaluate the associations of modifiable factors reported to be associated with hearing impairment to determine if these factors contributed to the observed decreasing temporal trend in a population-based cohort and a subgroup of their adult offspring.

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doi:10.1016/j.ypmed.2011.08.012

Methods

Subjects

Methods used in the Epidemiology of Hearing Loss Study (EHLS) and the Beaver Dam Offspring Study (BOSS) have been reported in detail elsewhere (Cruickshanks et al., 1998; Zhan et al., 2010). The EHLS cohort consisted of adults who participated in the population-based Beaver Dam Eye Study (BDES) and were alive as of March 1, 1993. This cohort was examined in 1993–1995 (n = 3753), 1998–2000 (n = 2800) and 2003–2005 (n = 2395). Adult offspring of participants in the EHLS participated in the BOSS (n = 3285). This analysis excluded 1112 BOSS participants younger than 45 years because all EHLS participants were older than 45 years. A signed informed consent was obtained from all study participants. Characteristics of participants and nonparticipants have been described in the previous reports (Nondahl et al., 2006; Zhan et al., 2010). In general, eligible people who did not participate in the EHLS were older, more likely to be male, and had a lower socioeconomic status as indicated by education level than participants; eligible people who did not participate in the BOSS were slightly younger and more likely to be male than participants.

Data collection

Data were collected through the use of examinations, questionnaire interviews and laboratory tests for blood samples. The same standardized hearing examination procedures (including an otoscopic evaluation, screening tympanogram, and pure-tone air- and bone-conduction audiometry) except minor modifications were applied to the three EHLS cycles and the BOSS. Pure-tone air-conduction thresholds were measured for each ear at 0.5, 1, 2, 3, 4, 6 and 8 kHz (American Speech-Language-Hearing Association (AHSA), 1987) in a sound-treated booth using clinical audiometers. Bone-conduction thresholds were measured at 0.5 and 4 kHz at the baseline EHLS, while at each follow-up and BOSS examination, bone-conduction thresholds were measured at 0.5, 2 and 4 kHz. Masking procedures were used when necessary. At each examination, hearing impairment was defined as a pure-tone average of air-conduction thresholds at 0.5, 1, 2 and 4 kHz greater than 25 dB HL (hearing level) in either ear.

The questionnaire was administrated as an interview, focusing on ear and hearing-related medical history, noise exposure (occupational noise exposure, military service and leisure-time noise exposure), hearing perception, socioeconomic status including educational attainment, lifestyle factors, general medical history and medication use. Some variables for the EHLS participants were provided by the concurrent BDES on the same cohort (Klein et al., 2006). Birth cohort was defined as the year of birth. Educational attainment was divided into four categories: less than high school, high school, some college, college graduate and above. History of ear infection was based on the question, "Has a doctor ever told you (or your parents) that you had an ear infection?" Smoking status was classified as non-smoker, past smoker and current smoker, and history of CVD was defined as reporting a history of angina, heart attack, or stroke.

Analysis techniques

All statistical analyses were conducted by using SAS software, version 9 (SAS Institute Inc., Cary, North Carolina). The alternating logistic regression (ALR) proposed by Carey et al. (1993) was first applied to determine factors associated with hearing impairment, accounting for correlations from the repeated measurements and familial aggregations. ALR was then used to examine how each significant modifiable factor changed the birth cohort effect on hearing impairment by comparing the odds ratios (ORs) and regression coefficients for the birth cohort effect in the fully-adjusted model to those in the model with one factor removed.

Statistical significance ($p<0.05$) of the change of the birth cohort effect was tested using the bootstrap approach (Miller, 2004). To account for the correlation within families and within subjects, we resampled families as a whole. A total of 1000 bootstrap data sets were generated and 95% confidence interval (CI) for the change of the regression coefficient was calculated. A 95% CI excluding zero indicated a statistically significant change of the birth cohort effect.

As a sensitivity analysis to reduce heterogeneity in hearing impairment, 751 hearing impairment cases were excluded if they had self-reported onset of hearing impairment at <30 years old, a history of ear surgery, a conductive hearing impairment without any evidence of decreased hearing sensitivity if the conductive hearing impairment was resolved, or the difference in the PTA between two ears was >20 dB.

Results

Participants included in these analyses were ages 45–100 years, with birth years between 1902–1946 (EHLS) and 1922–1962 (BOSS). Shown in Table 1 are the characteristics of baseline EHLS participants and a subgroup of the BOSS participants. The overall prevalence of hearing impairment at each baseline was 45.9% (EHLS) and 18.9% (BOSS), respectively. Only 30.2% EHLS participants had received education higher than high school, while 63.6% of the BOSS subjects attended college. Occupational noise exposure was common (51% and 43.5% of EHLS and BOSS participants, respectively).

Table 2 shows age-adjusted associations between potential risk factors and hearing impairment. Results from sex-specific (stratifying on sex) models were similar to those from sex-adjusted models for most factors. Higher education was significantly associated with lower odds of hearing impairment. History of heavy drinking was significantly associated with higher odds of hearing impairment. Occupational noise exposure was significant only in men while ear infection and CVD were significant only in women. Leisure time noise exposure, serum HDL cholesterol, serum total cholesterol, diabetes, hypertension and body mass index were not associated with hearing impairment.

In a stepwise analysis (model 1, Table 3), age, sex, occupational noise exposure (men only), smoking, CVD (women only) and a history of ear infection (women only) remained significantly associated with the higher prevalence of hearing impairment, and higher education was associated with lower odds of hearing impairment.

The previous study (Zhan et al., 2010) conducted in the same population observed a significant birth cohort effect (adjusting for age

Table 1
Distributions of factors and hearing impairment in the Epidemiology of Hearing Loss Study (EHLS, 1993–1995) and a subgroup of the Beaver Dam Offspring Study (BOSS, 2005–2008), Beaver Dam, Wisconsin.

	EHLS (1993–1995)		BOSS (2005–2008)	
	n	%	n	%
Hearing impairment	1631	45.9	332	18.9
Education				
Less than high school	847	23.8	54	3.1
High school	1632	45.9	583	33.4
Some college	549	15.4	584	33.4
College or greater	527	14.8	527	30.2
Smoking				
Never	1600	45.9	902	51.3
Past	1374	39.4	572	32.6
Current	513	14.7	283	16.1
History of heavy drinking	584	16.8	334	19.0
Diabetes	343	10.0	162	9.2
Cardiovascular disease	504	14.5	74	4.2
Hypertension	1760	50.8	804	45.8
History of ear infection	1104	32.1	923	54.2
Occupational noise exposure	1769	50.8	764	43.5
Leisure time noise exposure	2356	66.3	1419	80.8
	n	Mean (SD[a])	n	Mean (SD[a])
Age (years)	3556	65.1 (10.5)	1758	54.4 (7.2)
Birth year[b]	3556	1928 (10)	1758	1951 (7)
Serum total cholesterol (mg/dl)	3430	238.7 (45.3)	1734	206.7 (39.5)
Serum high density lipoprotein cholesterol (mg/dl)	3423	52.4 (16.7)	1733	50.2 (15.2)
Body mass index (kg/m^2)	3396	29.6 (5.5)	1744	30.9 (6.5)

[a] Standard deviation.
[b] The birth year for EHLS and the subgroup of BOSS participants ranged from 1902–1946 and 1922–1962, respectively.