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Original Contribution

Generational Differences in the Prevalence of Hearing Impairment in Older Adults

Weihai Zhan*, Karen J. Cruickshanks, Barbara E. K. Klein, Ronald Klein, Guan-Hua Huang, James S. Pankow, Ronald E. Gangnon, and Theodore S. Tweed

* Correspondence to Dr. Weihai Zhan, Department of Population Health Sciences, School of Medicine and Public Health, University of Wisconsin-Madison, 610 Walnut Street, Madison, WI 53726 (e-mail: wzhan@wisc.edu).

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There were significant changes in health and lifestyle throughout the 20th century which may have changed temporal patterns of hearing impairment in adults. In this study, the authors aimed to assess the effect of birth cohort on the prevalence of hearing impairment in an adult population aged 45–94 years, using data collected between 1993 and 2008 from 3 cycles of the Epidemiology of Hearing Loss Study ($n = 3{,}753$; ages 48–92 years at baseline) and a sample of participants from the Beaver Dam Offspring Study ($n = 2{,}173$; ages $\geq$45 years). Hearing impairment was defined as a pure-tone average of thresholds at 0.5, 1, 2, and 4 kHz greater than 25-dB HL [hearing level]. Descriptive analysis, generalized additive models, and alternating logistic regression models were used to examine the birth cohort effect. Controlling for age, with every 5-year increase in birth year, the odds of having hearing impairment were 13% lower in men (odds ratio = 0.87, 95% confidence interval: 0.83, 0.92) and 6% lower in women (odds ratio = 0.94, 95% confidence interval: 0.89, 0.98). These results suggest that 1) older adults may be retaining good hearing longer than previous generations and 2) modifiable factors contribute to hearing impairment in adults.

age groups; aging; cohort effect; hearing; hearing loss; logistic models; prevalence

Abbreviations: ALR, alternating logistic regression; BOSS, Beaver Dam Offspring Study; CI, confidence interval; EHLS, Epidemiology of Hearing Loss Study; GEE, generalized estimating equations; OR, odds ratio.

The 20th century saw profound changes in the economic, technologic, and social environments. These changes greatly affected people's everyday lives and thus may have reshaped the pattern of disease from generation to generation. Changes across generations are referred to as the birth cohort effect. Understanding birth cohort effects has important implications for public health because of the key role they play in predicting health-care needs and developing corresponding prevention strategies, particularly in the field of chronic disability, with the aging of the population (1, 2). Hearing impairment is one such chronic disability.

As the third-most-prevalent chronic disability in the United States, hearing impairment is estimated to affect 29 million Americans aged 20–69 years (3). Hearing impairment usually causes difficulty in understanding speech, an extremely important tool for communication. People with hearing impairment may further suffer psychological, physical, and social consequences, which, together with its high prevalence, make hearing impairment a major public health concern (4). The number of people with hearing impairment is expected to increase as the population ages. However, the numbers may be lower if later generations have lower prevalences of hearing impairment. To our knowledge, there have been no population-based studies of generational differences or temporal trends in the prevalence of hearing impairment among adults using audiometric assessments.

In the present study, we used data from the population-based Epidemiology of Hearing Loss Study (EHLS) and the study of their adult children, the Beaver Dam Offspring Study (BOSS), to evaluate the effect of birth cohort on the prevalence of hearing impairment among 5,275 adults born between 1902 and 1962.

MATERIALS AND METHODS

Study population

Methods used to identify and recruit participants for the EHLS have been described in previous reports (5–8). Of 4,541 eligible residents of Beaver Dam, Wisconsin, 3,753 participated in the baseline EHLS (1993–1995), 2,800 participated in the 5-year follow-up study, and 2,395 participated in the 10-year follow-up study (2003–2005) (8). Characteristics of participants and nonparticipants have been reported elsewhere (6, 8, 9). In general, at baseline, nonparticipants were slightly older and more likely to be male. Nonparticipants in the 5- or 10-year follow-up examination were more likely to have had hearing impairment at baseline, even after adjustment for age and sex.

Participants who reported having living children at the EHLS 5-year follow-up examination were contacted for permission to contact their children about the BOSS. Of the 1,902 eligible participants, 87.9% ($n = 1{,}671$) of those contacted gave permission to contact their children, and 8.9% ($n = 170$) refused; 3.2% ($n = 61$) were deceased, and no contact information for their children could be obtained. Of the 4,965 adult children eligible for the BOSS, 3,285 (66.2%) participated, 731 (14.7%) refused, 23 (0.5%) had died, and 926 (18.7%) failed to complete an examination or questionnaire. Only children aged 45 years or more at the BOSS examination were included in the present study; age-specific prevalence rates in different birth cohorts could not be compared for age groups under 45 years, since EHLS participants were 48–92 years of age at the baseline EHLS. The participation rate in this subset was 71.2% ($n = 2{,}173$). Compared with BOSS participants, nonparticipants were slightly younger and more likely to be male (Table 1). After adjustment for age and sex, offspring with a parent with hearing impairment were slightly more likely to participate.

Data collection

The same standardized methods were used in all examinations (3 EHLS cycles and the BOSS), except as noted. Audiometric testing was conducted in a sound-treated booth with calibrated clinical audiometers according to the guidelines of the American Speech-Language-Hearing Association (10). At each examination, pure-tone air-conduction thresholds were measured for each ear at 0.5, 1, 2, 3, 4, 6, and 8 kHz. To aid in the identification of conductive hearing losses, bone-conduction thresholds were obtained at 0.5 kHz and 4 kHz at each examination, as well as at 2 kHz in the EHLS 5-year and 10-year follow-up examinations and in the BOSS. The same masking procedures were used as appropriate. Audiometric equipment was calibrated every 6 months according to the guidelines of the American National Standards Institute (11, 12). Informed consent was obtained for each participant.

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. In addition, a subgroup analysis was conducted after excluding participants with early onset of hearing impairment (self-reported onset of hearing impairment at <30 years of age), a history of ear surgery, a conductive hearing impairment which, if resolved, would leave the person with normal hearing, and asymmetric losses (difference in the pure-tone average between 2 ears larger than 20-dB HL). This subgroup excluded participants (751 observations) with patterns of hearing impairment that are not typically associated with aging.

Table 1. Characteristics of Participants and Nonparticipants Aged 45 Years or More, Beaver Dam Offspring Study, 2005–2008

Characteristic	Participants (n = 2,173)		Nonparticipants (n = 879)		P Value
	No.	%	No.	%	
Age group, years					
45–54	1,232	56.7	546	62.1	0.015
55–64	712	32.8	265	30.1	
65–74	194	8.9	61	6.9	
≥75	35	1.6	7	0.8	
Male sex	1,003	46.2	492	56.0	<0.001

Statistical methods

SAS software, version 9 (SAS Institute Inc., Cary, North Carolina), was used for the analyses. In a descriptive age-cohort analysis of the data, prevalence rates of hearing impairment were first assembled in a 2-way table for visualization and assessment of the effect of birth cohort on hearing impairment.

Treating age and birth cohort as continuous variables, we then applied the generalized additive model developed by Hastie and Tibshirani (13) to preliminarily explore whether there were nonlinear trends for age and birth cohort in hearing impairment. The generalized additive model extends the generalized linear models by replacing the usual linear function of a covariate with an unspecified smooth function (13). Smoothers are introduced to summarize the trend of a dependent variable as a function of 1 or more predictors. A significant term implies a nonlinear trend for this predictor.

In the present study, the observations were not independent of each other. Participants from the same family were likely to be more similar to each other than those from different families because of shared genetic or environmental influences. Moreover, data from different follow-up visits within the same person were also correlated. A statistical method which can adjust for both correlations—alternating logistic regression (ALR), a relatively new method for correlated and longitudinal data with a binary outcome proposed by Carey et al. (14)—was used. In ALR, 2 regression models are specified: one to describe the odds ratio relating the response variable to risk factors (with parameter β) and the other to describe the correlations among participants (with parameter α). ALR is an implementation of the generalized estimating equations (GEE) method, combining a logistic regression model for the marginal mean with an unbiased nonlinear estimating equation for odds ratio parameters capturing the dependence of binary outcomes within clusters. Advantages of the ALR approach are fewer computational burdens than the second-order extension of GEE and reasonable efficiency of the estimation of mean and dependence parameters for binary data (14). In our ALR models, we included 2 terms to account for dependence, one for the repeated measures within a given individual over time (α_1) and one for the multiple persons within a single family (α_2).

Because age is the predominant factor in the development of hearing impairment among older adults, we started model-building from the model including only age. We included higher-order age terms in the ALR models to examine the existence of a nonlinear trend for age. Additional covariates were included, testing for interactions. Model fit was evaluated using score tests. Results from ALR (modeling correlations within families and among different follow-up visits separately) were compared with those from GEE (not distinguishing 2 correlations) and standard logistic regression (ignoring any correlation).

In order to demonstrate the potential future impact of the birth cohort effect, we compared numbers of projected hearing impairment cases with and without accounting for the birth cohort effect in the 2030 US population aged 45 years or older, using the projected age-specific 2030 population produced by the Census Bureau's Population Projections Program (15). By the year 2030, all baby boomers will be over the age of 65 years, placing a potential burden on the health-care system and public finances.

The following were the procedures used to project future cases of hearing impairment. The predicted age- and sex-specific prevalence rate ($P_{a,s}$) of hearing impairment was first calculated, by using the formula

$$P_{a,s} = \frac{\text{Exp}\,(\text{log odds})}{1 + \text{Exp}\,(\text{log odds})},$$

where 1) if accounting for the birth cohort effect, log odds = $\beta_0 + \beta_1 \times (\text{age} - 67) + \beta_2 \times (\text{age} - 67)^2 + \beta_3 \times (\text{age} - 67)^3 + \beta_4 \times (\text{birth year} - 1937)/5 + \beta_5 \times \text{sex} + \beta_6 \times \text{sex} \times (\text{birth year} - 1937)/5$ and birth year = 2030 − age (the regression coefficients were from the age-cohort-sex model based on our data from the EHLS (1993–2005) and the BOSS) and 2) if not accounting for the birth cohort effect, log odds = $\beta_0 + \beta_1 \times (\text{age} - 67) + \beta_2 \times (\text{age} - 67)^2 + \beta_3 \times (\text{age} - 67)^3 + \beta_4$ sex (the regression coefficients were from the age-sex model based on our data from the EHLS (1993–2005) and the BOSS).

The age-specific numbers of hearing impairment cases were then calculated by using

$$\text{Age-specific cases} = \sum_s \left(N_{a,s} \times P_{a,s}\right),$$

where $N_{a,s}$ is the projected number of persons for a specific age and sex obtained from the 2008 national population projections and $\sum_s$ indicates the summation over different sexes.

RESULTS

The present birth cohort study included 5,275 participants aged 45 years or more from 2,661 families. Overall, the prevalence of hearing impairment was 45.1%. Men had a higher prevalence rate than women (56.4% vs. 36.5%; $P < 0.0001$).

Table 2. Prevalence of Hearing Impairment by Age Group, Epidemiology of Hearing Loss Study (1993–1995) and Beaver Dam Offspring Study (2005–2008)

Age Group, years	EHLS		BOSS	
	No.	%	No.	%
45–49	99	15.2	529	9.1
50–54	615	17.1	476	13.0
55–59	532	25.6	370	23.5
60–64	513	37.8	171	24.6
65–69	543	49.4	70	30.0
70–74	510	60.4	28	50.0

Abbreviations: BOSS, Beaver Dam Offspring Study; EHLS, Epidemiology of Hearing Loss Study.

We preliminarily compared the prevalence of hearing impairment between the parent generation and the child generation based on data from the baseline EHLS and the BOSS. We found that the prevalence of hearing impairment was lower in the offspring generation than in the parental generation across all age categories (Table 2). Using the GEE to adjust for familial aggregation among participants aged 45–74 years, we further found that the odds of having hearing impairment in the child generation were 31% lower (odds ratio (OR) = 0.69, 95% confidence interval (CI): 0.58, 0.82) than those in the parent generation after controlling for age and sex.

Table 3 illustrates the age-specific prevalence of hearing impairment by birth cohort for men and women. At most ages, earlier birth cohorts had relatively higher age-specific prevalences of hearing impairment. Among very old persons, the prevalence of hearing impairment differed slightly by birth cohort.

Results from the generalized additive model showed that there was a nonlinear trend for age ($P < 0.0001$) but not for birth cohort ($P = 0.220$). The nonlinear trend indicated that higher-order terms for age might be necessary in further analyses.

Model selection results from the ALR indicated a linear term for birth cohort and the need for higher-order terms for age, which was consistent with the exploratory results from the generalized additive model. Results from the ALR were compared with those from standard logistic regression and GEE under different covariance structures (Table 4). Hearing impairment at one visit was strongly associated with hearing impairment at future visits (OR = 121, $P < 0.0001$), and hearing impairment in one family member was associated with hearing impairment among other family members (OR = 1.23, $P = 0.044$), indicating that repeated measures were highly correlated and there was familial aggregation of hearing impairment. Controlling for age, the odds of having hearing impairment among participants from later birth cohorts were 13% lower in men (OR = 0.87, 95% CI: 0.83, 0.92) and 6% lower in women (OR = 0.94, 95% CI: 0.89, 0.98) than those from

Table 3. Prevalence of Hearing Impairment (%) by Birth Cohort, Age, and Sex, Epidemiology of Hearing Loss Study (1993–2005) and Beaver Dam Offspring Study (2005–2008)[a]

Birth Cohort	Age Group, years									
	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94
*Men (*n *= 4,049)*										
1960–1964	9.9									
1955–1959	15.4	16.7								
1950–1954		21.2	33.9							
1945–1949			32.7	36.4						
1940–1944		25.8	35.4	41.3	40.0					
1935–1939			41.5	50.4	58.9					
1930–1934				58.1	70.0	79.3				
1925–1929					64.8	73.1	82.5			
1920–1924						78.0	91.4	94.6		
1915–1919							87.2	93.5	97.8	
1910–1914								95.0	100.0	
1905–1909									100.0	
*Women (*n *= 5,302)*										
1960–1964	3.9									
1955–1959	6.0	4.4								
1950–1954		8.6	16.9							
1945–1949			15.0	12.2						
1940–1944		10.0	11.8	19.5						
1935–1939			10.5	14.3	23.8					
1930–1934				22.7	29.8	44.3				
1925–1929					34.9	46.4	59.9			
1920–1924						48.6	62.0	80.6		
1915–1919							65.7	82.7	89.5	
1910–1914								77.9	93.8	100.0
1905–1909									93.3	100.0

[a] For reliable estimates of prevalence, only results for subgroups with 30 or more participants are displayed.

5-year-earlier birth cohorts (for interaction between sex and birth cohort, $P = 0.015$). Regression coefficients from standard logistic regression were at least 10% larger in men and 25% larger in women than those from GEE models (including ALR). Despite these differences, all approaches demonstrated a significant effect of birth cohort on hearing impairment.

In a subgroup analysis excluding cases likely to be due to causes other than aging, later birth cohorts continued to be less likely to have a hearing impairment than earlier birth cohorts (OR = 0.85, 95% CI: 0.82, 0.89). The interaction between birth cohort and sex was not significant ($P = 0.171$) in the subpopulation analysis.

Application of these age-specific rates to the US population in 2010 (15) suggests that there are 42.9 million cases of hearing impairment among adults aged 45 years or older in the United States. If the rates observed in the present study are applied to the 2030 US population estimates without accounting for the birth cohort effect, 65.5 million adults aged 45 years or older will be estimated to have hearing impairment in 2030. If the birth cohort effect remains and is applied to the 2030 population estimates, this number will be 50.9 million, a reduction of 14.6 million (Table 5). If the birth cohort effect remains, the largest reductions in the total number of cases are expected in the age group 55–74 years.

DISCUSSION

In the present study, we found that the age-specific prevalence of hearing impairment was lower for more recent birth groups and that this birth cohort effect was stronger for men than for women. These data provide strong evidence that environmental, lifestyle, or other modifiable factors might contribute to the etiology of hearing impairment in older adults. On average, people born 5 years later were 13% (in men) and 6% (in women) less likely to have hearing impairment at the same age. This birth cohort effect was confirmed in subanalyses excluding persons with hearing histories and patterns less likely to be due to age-related hearing impairment.

Table 4. Estimated Effects of Birth Cohort on Hearing Impairment Derived From the Use of Different Regression Techniques ($n = 10{,}159$), Epidemiology of Hearing Loss Study (1993–2005) and Beaver Dam Offspring Study (2005–2008)[a]

Model	β[b]	Standard Error[c]	Odds Ratio	95% Confidence Interval	*P* Value
		Men			
Standard logistic regression	−0.158	0.029	0.85	0.81, 0.90	<0.0001
Autoregressive GEE[d]	−0.140	0.026	0.87	0.84, 0.92	<0.0001
Exchangeable GEE[e]	−0.138	0.026	0.87	0.83, 0.92	<0.0001
Unstructured GEE[f]	−0.142	0.026	0.87	0.83, 0.91	<0.0001
ALR[g]	−0.138	0.026	0.87	0.83, 0.92	<0.0001
		Women			
Standard logistic regression	−0.098	0.028	0.91	0.86, 0.96	0.0006
Autoregressive GEE	−0.069	0.025	0.93	0.89, 0.98	0.0061
Exchangeable GEE	−0.071	0.025	0.93	0.89, 0.98	0.0043
Unstructured GEE	−0.074	0.025	0.93	0.89, 0.98	0.0030
ALR	−0.066	0.024	0.94	0.89, 0.98	0.0068

Abbreviations: ALR, alternating logistic regression; GEE, generalized estimating equations.

[a] The main effects included in the model were age, age^2, age^3, cohort, and the interaction between sex and cohort.

[b] Regression coefficient for birth cohort. Birth cohort was centered at the year 1937 in the unit of 5-year increase.

[c] The standard error for GEE and ALR was the robust standard error.

[d] GEE with an autoregressive structure assumes that observations that are further apart in time have a lower correlation with each other.

[e] Exchangeable GEE assumes that the observations within a subject are equally correlated.

[f] Unstructured GEE assumes that correlations of repeated measurements are unconstrained.

[g] In the ALR analyses, regression coefficients for within-subcluster (α_1) and between-subcluster (α_2) associations were 4.794 ($P < 0.0001$) and 0.211 ($P = 0.0435$), respectively.

The patterns of hearing impairment observed in the present study (a decreasing birth cohort effect and the slight difference by birth cohort among very old persons) suggest a later onset of hearing impairment and accelerated incidence at very old ages among people from later birth cohorts, which are consistent with the ‘‘compression of morbidity’’ theory (16). According to this theory, the burden of age-related disorders can be reduced effectively through postponement of the onset of chronic illness by promoting a healthy lifestyle. Such patterns further indicate that modifiable risk factors play an important role in the development of hearing impairment at relatively younger ages (i.e., <85 years), while among the oldest old (i.e., ≥85 years), the effect of modifiable risk factors decreases. Therefore, identifying modifiable risk factors and changes in their frequencies over time may help to elucidate opportunities for slowing or preventing the decline in hearing in older adults (ages <85 years). It is possible that stopping risk behaviors (e.g., smoking and the use of recreational firearms without hearing protection) at earlier ages may produce more gain than at later ages. In a study by Doll and Peto (17), people who stopped smoking at age 30 years had a similar life expectancy as nonsmokers, while smoking cessation at age 60 years reduced the hazard by only one-third. Thus, targeting specific birth cohorts with different prevention strategies may be more efficient than using generalized population approaches. For example, if later birth cohorts have a higher rate of using personal music players at high volume, a campaign urging younger people to be aware of the risks may be more cost-effective than targeting the whole population.

A decreasing trend in occupational noise exposure was recently observed (18, 19). Using noise records in the database of the Occupational Safety and Health Administration, Middendorf (18) found a trend of decreasing noise exposure from 1979 to 1999 in US manufacturing and service occupations. The author ascribed the reduction in occupational noise exposure to the decline of total employment in manufacturing and workplace changes designed to reduce noise exposure (e.g., changes in administrations and in policies and procedures at local levels). In another study, Joy and Middendorf (19) examined trends in occupational noise exposure in the mining industry from 1987 to 2004 and found a decline which accelerated after a new noise rule was promulgated in 2000. They also found a trend toward increasing use of hearing protection devices (19). In addition to the reduction in occupational noise exposure, people from recent generations had a higher socioeconomic status than their predecessors (20). It is possible that these trends may contribute to the observed birth cohort effect, although the role of occupational noise in hearing impairment with onset at older ages is not known.

Table 5. Projected Numbers of Cases (in Millions) of Hearing Impairment by the Year 2030 in Models Accounting and Not Accounting for the Birth Cohort Effect[a]

Age Group, years	Not Accounting for BCE	Accounting for BCE
45–54		
Projected population, millions	44.0	44.0
Projected no. of cases, millions	5.4	2.7
Projected prevalence, %	12.2	6.1
55–64		
Projected population, millions	40.3	40.3
Projected no. of cases, millions	11.9	7.1
Projected prevalence, %	29.6	17.7
65–74		
Projected population, millions	38.8	38.8
Projected no. of cases, millions	20.3	15.1
Projected prevalence, %	52.2	39.0
75–84		
Projected population, millions	24.6	24.6
Projected no. of cases, millions	19.7	17.8
Projected prevalence, %	80.0	72.3
≥85		
Projected population, millions	8.5	8.5
Projected no. of cases, millions	8.3	8.2
Projected prevalence, %	97.3	96.2
Total		
Projected population, millions	156.2	156.2
Projected no. of cases, millions	65.5	50.9
Projected prevalence, %	41.9	32.6

Abbreviation: BCE, birth cohort effect.

[a] Based on US Census data (15).

Besides the prevention implications, the birth cohort effect is also important in the projection of future prevalence of hearing impairment. Such projections may reflect future needs for treatment and prevention services and be of benefit in resource planning. Although the burden of hearing impairment is expected to increase with increases in longevity, our results suggest that a decline in age-specific prevalence may partly offset the potential increase. However, the number of people needing hearing health care will remain large.

In our study, we used ALR to adjust for familial correlation as well as the repeated measurements taken in some participants. Neglecting such correlations may yield biased or inefficient estimates (21). Our results show that standard logistic regression, a method which ignores correlations, gave a much smaller P value for the birth cohort effect. Odds ratios and 95% confidence intervals from ALR were qualitatively similar to those from GEE under different correlation structures. Familial aggregation of hearing impairment, although statistically significant, may not have been strong enough to result in important differences between the ALR and GEE methods. Because correlations are common in epidemiologic studies, more use of ALR is expected, particularly with the recent availability of standard software for ALR, such as PROC GENMOD with LOGOR in SAS.

This study had 3 important strengths. First and foremost, use of a combination of analysis techniques yielded a practical solution to the complex problems related to birth cohort analysis. For example, the descriptive age-cohort analysis, the most important complementary tool for birth cohort analysis, provided an intuitive picture of the birth cohort effect; the generalized additive model examined whether higher-order terms of age and birth cohort improved the model fit; and ALR provided robust and efficient estimates for the complex study design of repeated measures and familial aggregation with binary outcomes. Second, the standardized protocol for audiometry was applied to all 3 cycles of the EHLS and the BOSS, which ensured comparability of outcomes. Inconsistent measurements may yield a spurious birth cohort effect or period effect. Third, the sampling of multiple generations (parents and offspring) helped ensure that birth cohort effects were analyzed in subjects from the same underlying source population.

There were, however, several limitations of this study that warrant discussion. Since some shared familial lifestyle factors may not be disentangled from genetic contributions, concerns about overadjustment by means of ALR need to be considered. We compared regression coefficients and standard errors from the GEE method (adjusting only for repeated measures) and the ALR method (adjusting for both repeated measures and familial aggregation). The similar results obtained from the 2 techniques relieved this concern. This may also suggest that adjusting for familial aggregation was less important than adjusting for repeated measures in our study. Nonetheless, our results are consistent with those of other studies demonstrating that age-related hearing impairment is at least partially genetic (22, 23).

Another concern is that the observed birth cohort effect may reflect nonparticipation differences. This possibility was carefully examined. At the EHLS baseline examination, age-adjusted prevalence was unlikely to be biased because of the high participation rate. Nonparticipants at the 5- and 10-year follow-up examinations were more likely to have had hearing impairment at baseline (8). After adjustment for age and sex, the difference at the 10-year follow-up examination was no longer significant, while the difference at the 5-year follow-up examination remained; this suggests that the age-adjusted prevalence of hearing impairment at the 5-year follow-up examination may have been underestimated. In the BOSS, offspring with a parent with hearing impairment were slightly more likely to participate, suggesting that BOSS participants may have been slightly more likely to have a hearing impairment because of environmental and genetic factors they shared with their parents, and thus the age-adjusted prevalence of hearing impairment in the BOSS may have been slightly overestimated. As a consequence of such potential bias in age-adjusted prevalence estimates (no bias at baseline in the EHLS, slight underestimation at the EHLS 5-year follow-up examination, no bias at the 10-year EHLS follow-up examination, and slight overestimation in the BOSS), the observed effect of birth cohort on hearing impairment may have been slightly underestimated.

A third limitation is that these conclusions may not be generalizable to other racial/ethnic groups or geographic areas, because the parent population was drawn from a single Midwestern town and the population was predominantly non-Hispanic white. Populations in different geographic areas may have different risk exposures and thus may have different birth cohort patterns.

In summary, we found a significant birth cohort effect on the prevalence of hearing impairment. Controlling for age and sex, persons from later birth cohorts had lower prevalences of hearing impairment than those from earlier birth cohorts. Longitudinal studies are needed to confirm these patterns regarding the incidence of hearing impairment and to identify factors explaining the birth cohort effect. These data suggest that hearing impairment with aging is a preventable or delayable disorder, rather than a normal part of the aging process. Further investigations designed to identify environmental and behavioral factors (such as noise exposure, smoking, and socioeconomic status) which may contribute to the observed birth cohort effect may provide important information regarding the etiology and prevention of hearing impairment in older adults.

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Author affiliations: Department of Population Health Sciences, School of Medicine and Public Health, University of Wisconsin-Madison, Madison, Wisconsin (Weihai Zhan, Karen J. Cruickshanks, Ronald E. Gangnon); Department of Ophthalmology and Visual Sciences, School of Medicine and Public Health, University of Wisconsin-Madison, Madison, Wisconsin (Karen J. Cruickshanks, Barbara E. K. Klein, Ronald Klein, Theodore S. Tweed); Institute of Statistics, National Chiao Tung University, Hsinchu, Taiwan (Guan-Hua Huang); and Division of Epidemiology and Community Health, School of Public Health, University of Minnesota, Minneapolis, Minnesota (James S. Pankow).

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