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Generational Differences in the Reporting of Tinnitus

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Abstract

Objectives—Recent research suggests that hearing impairment is declining among older adults compared to earlier generations of the same age. Tinnitus is often associated with hearing impairment, so one might hypothesize that the prevalence of tinnitus is declining in a similar manner. The purpose of this study was to utilize multi-generational data with repeated measures to determine if the prevalence of tinnitus is declining among more recent generations.

Design—Using data from the Epidemiology of Hearing Loss Study (1993-95, 1998-00, 2003-05, 2009-10) and the Beaver Dam Offspring Study (2005-08), we examined birth cohort patterns in the report of tinnitus for adults aged 45 years and older (n=12,689 observations from 5,764 participants). Participants were classified as having tinnitus if they reported tinnitus in the past year of at least moderate severity or that caused difficulty falling asleep. A low-frequency (500, 1000, and 2000 Hz) and high-frequency (3000, 4000, 6000, 8000 Hz) pure tone average from the worse ear were used to summarize hearing status. Other potential risk factors for tinnitus were also explored to determine if changes in the prevalence of these factors over time could explain any observed birth cohort differences in the prevalence of tinnitus. These included: education, history of head injury, history of doctor-diagnosed ear infections, history of cardiovascular disease (myocardial infarction, stroke or angina), current noisy job, longest-held job, target shooting in the past year, number of concerts ever attended, alcohol use in the past year, doctor-diagnosis of arthritis, current aspirin use, regular exercise, and consulting with a physician in the past year about any hearing/ear problem. Birth cohort effects were modeled with alternating logistic regression (ALR) models which use generalized estimating equations to adjust for correlation among repeated measurements over time that are nested within families.

Results—The report of tinnitus tended to increase with more recent birth cohorts compared to earlier birth cohorts. For example, at ages 55-59 years, 7.6% of participants born in 1935-39 reported tinnitus, compared to 11.0% of those born in 1940-44, 13.6% of those born in 1945-49,

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and 17.5% of those born in 1950-54. Similarly, at ages 65-69 years, 7.9% of participants born in 1925-29 reported tinnitus, compared to 10.0% of those born in 1930-34, 11.9% of those born in 1935-39, and 13.7% of those born in 1940-44. Final ALR model results indicated that, on average, after adjusting for age and other factors, participants in a given generation were significantly more likely to report tinnitus than participants from a 20-year earlier generation (Odds Ratio = 1.78, 95%CI = 1.44, 2.21).

Conclusions—Increased reports of tinnitus may reflect increased prevalence of symptoms, increased awareness of symptoms, or higher health expectations among more recent generations of adults. Regardless of the reasons, the increasing prevalence of tinnitus suggests that health care providers may see an increased number of patients bothered by this common but little understood symptom.

Keywords

Tinnitus; hearing disorders; prevalence; birth cohort

Introduction

Recent research suggests that hearing impairment is declining among older adults compared to earlier generations of the same age (Hoffman et al. 2010; Zhan et al. 2010; Zhan et al. 2011). Improved medical care, along with differences in exposures due to changes in economic, technologic, and social environments over the past century, have served to reshape not only patterns of symptoms and disease, but also attitudes toward them. As a result, one might expect to see birth cohort differences in the prevalence of symptoms and disease that reflect these changing conditions.

While there is no single agreed-upon definition of tinnitus, several population-based studies have attempted to estimate the prevalence of this condition. Prevalence estimates generally range from 7 to 20% (Hoffman & Reed 2004), although a few estimates have been higher. In the Epidemiology of Hearing Loss Study (EHLS), the prevalence of tinnitus among the older adults of Beaver Dam, WI ages 48-92 years was 8.2% (Nondahl et al. 2002). Among their offspring, the prevalence was 10.6% (Nondahl et al. 2011).

Tinnitus is often associated with hearing impairment (Nondahl et al. 2002; Sindhusake et al. 2003), so one might hypothesize that the prevalence of tinnitus is declining among more recent generations in a manner similar to the prevalence of hearing impairment (Hoffman et al. 2010; Zhan et al. 2010; Zhan et al. 2011). The purpose of this study was to utilize multi generational data with repeated measures to determine if the prevalence of tinnitus at a given age is lower among more recent compared to earlier generations.

Methods

Subjects

The Epidemiology of Hearing Loss Study (EHLS) is a population-based study of hearing impairment in adults 48 to 92 years of age at baseline (Cruickshanks et al. 1998). During 1987 to 1988, residents of the city or township of Beaver Dam, Wisconsin who were 43 to 84 years of age (n = 5924) were identified through a private census and invited to participate in a study of age-related ocular disorders (The Beaver Dam Eye Study, 1988-1990, n = 4926) (Klein et al. 1991). All who participated in the baseline eye examination and were alive as of March 1, 1993 were eligible to participate in the baseline examination of the hearing study (EHLS, n = 4541). Of those eligible, 3753 (82.6%) participated (1993-1995). Some participants (n = 182) refused the hearing testing but completed an interview.

A five-year follow-up examination was conducted during 1998-2000 (n = 2800), followed by a ten-year (2003-2005; n = 2395) and 15-year follow-up examination (2009-2010; n = 1812). Comparisons between participants and non-participants have been reported elsewhere for the baseline examination (Cruickshanks et al. 1998), five-year examination (Cruickshanks et al. 2003), and the 10-year examination (Cruickshanks et al. 2010). The primary reason for non-participation in follow-up examinations was death.

In 2005, the offspring of the Epidemiology of Hearing Loss Study participants were enrolled in the Beaver Dam Offspring Study (BOSS), a study of multi-sensory impairments and aging. Data collection occurred during 2005-2008. Details regarding the BOSS study population are reported elsewhere (Zhan et al. 2010). Among the 3,285 participants in the BOSS (25% of whom lived outside the Beaver Dam, WI area), only those aged 45 years or more (n=2158 with a tinnitus assessment) are included in the present study. Age-specific prevalence rates could not be compared for age groups under 45 years since EHLS participants were 48-92 years of age at baseline.

In total, the current study included 5,764 participants aged 45 to 99 years with one to five examinations over a period of 18 years, from 2,734 families, for a total of 12,689 observations. Study approval for the EHLS and BOSS studies was granted by the Human Subjects Committee of the University of Wisconsin-Madison. Informed consent was obtained from each participant.

Procedure

The same standardized methods were used in all examinations (4 EHLS waves and BOSS), except as noted. The audiometric examination included otoscopic evaluation, screening tympanogram (GSI-37 Autotymp, Grason-Stadler, Inc., Madison, WI), and pure-tone air- and bone-conduction audiometry. Audiometric testing was conducted according to the guidelines of the American Speech-Language-Hearing Association in a sound-treated booth (Industrial Acoustics Company, New York, NY) (ASHA 1987; ASHA 2005). For the baseline EHLS study, Virtual 320 clinical audiometers (Virtual Corporation, Seattle, WA) equipped with TDH-50P earphones (Telephonics Corporation, Farmingdale, NY) and insert earphones (ER3A, Cabot Safety Corp., Indianapolis, IN) were used. In subsequent follow-ups, GSI-61 clinical audiometers (Grason-Stadler, Inc., Madison, WI) equipped with TDH-50P earphones and ER3A insert earphones were used. The audiometers were calibrated every six months during the study periods (ANSI 1989; ANSI 1996; ANSI 2004). Pure-tone air-conduction thresholds were obtained for each ear at 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz. Bone-conduction thresholds were measured at 500, 2000 and 4000 Hz. Masking was used as necessary. All testing was conducted by examiners trained and monitored by a licensed audiologist (TST). Ambient noise levels were routinely monitored at the field examination site to ensure that testing conditions complied with ANSI standards (ANSI 1992; ANSI 2003).

A questionnaire about health history (including tinnitus) and noise exposure was administered as an interview. Participants were asked, “In the past year have you had buzzing, ringing, or noise in your ears?” (No/Yes/Unknown). Examiners were instructed to record “no” if a participant reported hearing an odd or unusual noise on a single occasion in the past year. Participants responding positively to this question were then asked, “How severe is this noise in its worst form?” (Mild/Moderate/Severe/Unknown), and “Does this noise cause you to have problems getting to sleep?” (No/Yes/Unknown). A person was classified as having tinnitus if he/she reported having “buzzing, ringing, or noise” in the ears in the past year that was at least moderate in severity or that caused problems getting to sleep (Nondahl et al. 2002; Nondahl et al. 2010; Nondahl et al. 2011).

Other Definitions

Potential risk factors were evaluated for their association with having tinnitus. Risk factors primarily included variables related to: 1) auditory function and possible injuries to the auditory system, including from noise exposure, and 2) cardiovascular disease (CVD) and its risk factors. These major categories and the risk factors within them were primarily selected based on previous cross-sectional findings in the EHLS and BOSS studies as well as other epidemiological studies (Brown 1990; Nondahl et al. 2002; Sindhusake et al. 2003; Nondahl et al. 2011). Data regarding symptoms of depression and use of NSAIDS, other risk factors of interest, were not available from all examination periods so are not included in the current analyses.

Specific variables related to auditory function and injuries included a low-frequency (500, 1000, and 2000 Hz) and high-frequency (3000, 4000, 6000, 8000 Hz) pure tone average from the worse ear, history of head injury (skull fracture; concussion; broken nose; or loss of consciousness due to a head injury), history of ear infection, regular aspirin use (at least twice a week for more than three months), current hearing aid use, and consultation with a physician within the past year about any hearing/ear problem. Noise exposure variables included exposure to firearms through target shooting (past year), having a current noisy job (within the past year, having to speak in a loud voice at work in order to be heard by another person two feet away), longest-held job classification (Managerial/Professional; Technical/Sales/Administration; Service; Farming/Forestry/Fishery; Production/Craftsman/Repairman;Operator/Fabricator/Laborer), and number of concerts ever attended (0, 1-9, 10-19, 20 or more). The relation between education and tinnitus was also assessed.

We previously reported that cardiovascular disease and some of its risk factors were associated with tinnitus (Nondahl et al. 2002; Nondahl et al. 2010; Nondahl et al. 2011). We therefore evaluated the effects of CVD (myocardial infarction, stroke, or angina), alcohol consumption (past year), and regular (at least weekly) exercise. History of arthritis was also examined due to its link to inflammatory processes.

Birth cohorts were defined as five-year birth groups beginning in 1905-09 and ending in 1960-64.

Statistical methods

Differences in baseline characteristics by participation status were tested with the chi-square test for general association. Comparisons of the prevalence of tinnitus between the EHLS cohort at baseline and the BOSS offspring cohort at baseline were done with the chi-square test for general association (unadjusted) or the Cochran-Mantel-Haenszel test for general association (adjusted for age and sex). Preliminary evidence for the linearity (or lack thereof) of the association between the prevalence of tinnitus and: 1) age and 2) cohort was assessed with a generalized additive model (Hastie & Tibshirani 1990). The generalized additive model extends the generalized linear model by replacing the usual linear function of a covariate with an unspecified smooth function. A significant term implies a nonlinear trend for that predictor.

In the present study, the observations were not independent. Two forms of correlation were present: correlation within family members (parents with children; siblings with each other), and correlation within person across examinations. We therefore utilized the alternating logistic regression (ALR) model, a method that can adjust for both types of correlation (Carey et al. 1993; Zhan et al. 2010). ALR is an implementation of the generalized estimating equations (GEE) method (Liang & Zeger, 1986), combining a logistic regression model with an unbiased nonlinear estimating equation for odds ratio parameters that takes into account the dependence of binary outcomes within clusters. The ALR model includes one parameter to account for the correlation within person across time (denoted $\alpha 1$), and one parameter to account for the correlation within family ($\alpha 2$). The ALR procedure models the association between pairs of responses with log odds ratios rather than with the correlations used by ordinary GEE models.

The linearity of age and birth cohort was also explored using a series of indicator variables within the ALR models. Higher order terms within the ALR models were explored for age and cohort. Covariates were assessed one at a time within age- and sex-adjusted ALR models, as well as age-adjusted models stratified by sex. Interactions between covariates and age, sex and cohort were evaluated, as were interactions between age, sex and cohort. The resulting model was reduced to its most parsimonious form using a manual backwards elimination selection approach. To check robustness of results, we re-ran the final model with an alternate definition of tinnitus that excluded the sleep criterion. All analyses were completed with the SAS System (SAS Institute, Inc., Gary, NC).

Results

Baseline characteristics of EHLS and BOSS participants included in the present study are shown in Table 1. The offspring from BOSS were younger, had less hearing impairment, and had more education than the EHLS cohort.

In unadjusted analyses, we compared the prevalence of tinnitus between the EHLS cohort at baseline and the BOSS offspring at baseline. The offspring had a significantly higher prevalence of tinnitus than the original cohort (11.0% vs 8.2%, $p < .001$). A statistically significant difference remained after adjusting for age and sex ($p < .001$).

The age-specific prevalence of tinnitus by birth cohort is shown in Table 2. With most age groups, more recent birth cohorts had a higher prevalence of tinnitus than earlier birth cohorts. For example, at ages 55-59 years, 7.6% of participants born in 1935-39 reported tinnitus, compared to 11.0% of those born in 1940-44, 13.6% of those born in 1945-49, and 17.5% of those born in 1950-54. Similarly, at ages 65-69 years, 7.9% of participants born in 1925-29 reported tinnitus, compared to 10.0% of those born in 1930-34, 11.9% of those born in 1935-39, and 13.7% of those born in 1940-44.

The generalized additive model did not show strong evidence for a nonlinear trend for age ($p = .20$) or birth year ($p = .09$). Defining a typical generational span as 20 years, an ALR model adjusted only for age and gender showed that participants in a given generation were significantly more likely to report tinnitus than participants from a 20-year earlier generation (Odds Ratio (OR) = 1.69, 95% Confidence Interval (CI) = 1.41, 2.04). The result was similar (OR = 1.78, 95%CI = 1.44, 2.21) after further adjusting for high-frequency PTA, history of head injury, history of ear infections, arthritis, consulting a doctor about a hearing/ ear problem within the past year, and interactions between age/PTA and age/gender. The interaction between age and cohort was also examined to test whether the slope of the age-related differences in prevalence of tinnitus varied significantly by birth cohort. This interaction was not significant ($p = .37$). Other covariates examined (education, low-frequency PTA, aspirin use, exercise, hearing aid use, alcohol consumption, history of CVD, current loud job, target shooting, longest-held job, and number of concerts ever attended) were not significantly associated with tinnitus and were not retained in the final model. Associations within person across time (denoted $\alpha 1$) and within family ($\alpha 2$) were both statistically significant (regression coefficient for $\alpha 1 = 2.46$, $p < .0001$; $\alpha 2 = 0.49$, $p = .0001$). Figure 1 shows predicted prevalence from the final adjusted ALR model by age and birth cohort for a hypothetical participant with average levels of each covariate.

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To check the robustness of the model results, we re-ran the final adjusted ALR model with an alternate definition of tinnitus that excluded the sleep criterion. The cohort effect remained essentially unchanged (OR = 1.83, 95%CI 1.47, 2.28) for a given generation compared to a generation 20-years earlier.

Discussion

This study demonstrated that, for a given age group, recent birth cohorts were more likely to report tinnitus than earlier birth cohorts, even after adjusting for gender, hearing ability, history of head injury, history of ear infections, arthritis, recent hearing-related medical consultation and correlation associated with individuals and family clusters. Put another way, over a typical generational span of 20 years, a given generation was significantly more likely to report tinnitus than the previous generation.

The observed higher prevalence of tinnitus with more recent birth cohorts is the opposite of what one might expect based upon recent research that suggests a lower prevalence of hearing impairment with more recent birth cohorts based on audiometric testing (Hoffman et al. 2010; Zhan et al. 2010; Zhan et al. 2011). However, self-reported hearing impairment may be on the rise (Wallhagen et al. 1997). In addition, self-rated health status has declined with more recent birth cohorts (Spiers et al. 1996; Chen et al. 2007), despite evidence that actual physical functioning may not have declined (Spiers et al. 1996).

A significant positive birth cohort effect was observed before and after adjusting for several additional covariates. One possible explanation is that participants from more recent birth cohorts are in fact experiencing more tinnitus symptoms, and that there are additional environmental, lifestyle, or other modifiable factors for which we did not adjust that contribute to the birth cohort differences in tinnitus prevalence observed in this study. The identity of these factors is open to speculation. For example, these could include changes in toxic exposures (chemical or noise) or availability and usage of medications.

Another possibility is that participants have more awareness of symptoms. If it were possible to objectively measure these symptoms, they might not be any worse in severity than symptoms experienced by those in earlier birth cohorts. This increase in awareness could, for example, be due in part to media reports that raise the general level of awareness of tinnitus in the minds of the general public, or perhaps due to friends or family members being more open about their symptoms. On a broader level, it could be due in part to higher health-related expectations among those from more recent birth cohorts. Conrad (1994) argued that the pursuit of health and wellness has become a moral issue for many. That is, it has become “the right thing to do.” This attitude may result in higher awareness of one’s symptoms and a more diligent pursuit of their alleviation, especially with the greater availability and utilization of health care in more recent decades.

Tinnitus symptoms, or one’s awareness of the symptoms, can vary over time (Nondahl et al. 2002). In this study we utilized individuals’ report of tinnitus at up to five examination periods, without regard to consistency of report. The ALR model takes into account covariates from the same examination as the tinnitus assessment. Like tinnitus symptoms, these covariates may vary over time (eg., current noisy job).

This study is the first to examine birth cohort effects on the prevalence of tinnitus. It utilizes more than 12,000 observations from population-based data gathered from five examinations over an 18-year period, taking into account correlation within person over time and within family cluster. However, results may not be generalizable to other racial/ethnic groups or geographic areas, since the original population was drawn from a single mid-sized Midwestern community with predominantly non-Hispanic white citizens. Populations in other geographic areas may have different attitudes, risk factors, and prevalence levels and thus may exhibit different birth cohort patterns.

In summary, we found that participants in a given generation were significantly more likely to report tinnitus than participants from a 20-year earlier generation. These results are consistent with recent research demonstrating lower-rated self-reported health status among more recent birth cohorts. Increased reports of tinnitus may reflect increased prevalence of symptoms, increased awareness of symptoms, or higher health expectations among more recent generations of adults. Regardless of the reasons, the increasing prevalence of tinnitus suggests that health-care providers may see an increased number of patients bothered by this common but little understood symptom.

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Abbreviations

ALR	Alternating logistic regression
BOSS	Beaver Dam Offspring Study
EHLS	Epidemiology of Hearing Loss Study
CI	Confidence interval
OR	Odds ratio

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Short Summary

The authors examine birth cohort patterns in tinnitus prevalence utilizing multi-generational data with repeated measures among adults aged 45 years and older (n=12,689 observations over an 18-year period from 5,764 participants born from 1905 to 1964). They demonstrate that, after adjusting for age and other factors, participants in a given generation were significantly more likely to report tinnitus than participants from a 20-year earlier generation (Odds Ratio = 1.78, 95%CI = 1.44, 2.21). Increased reports of tinnitus may reflect increased prevalence of symptoms, increased awareness of symptoms, or higher health expectations among more recent generations of adults.

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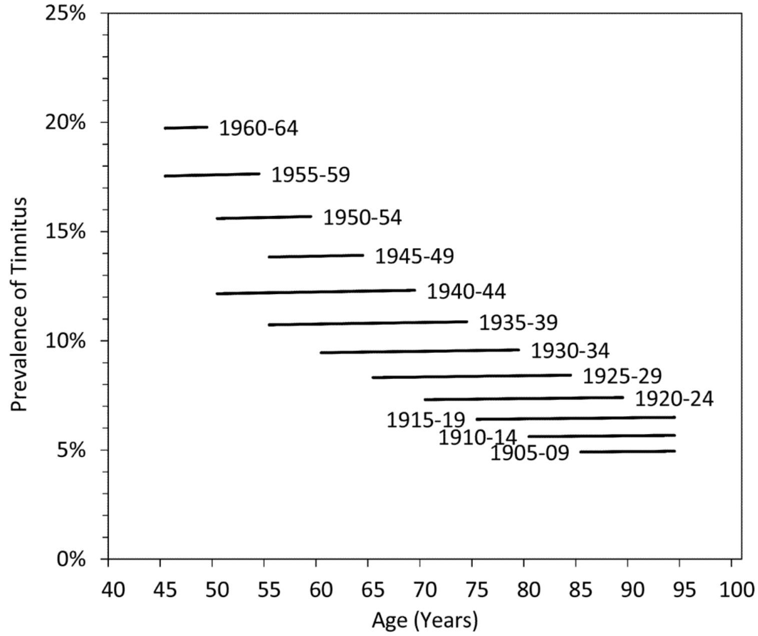

Besides age and cohort, covariates included in the model included gender, history of arthritis, history of head injury, high-frequency PTA (3000, 4000, 6000, and 8000 Hz) from the worse ear, history of ear infections, consulting a doctor about a hearing/ear problem within the past year, and interactions between age/PTA and age/gender.

Figure 1.
Predicted prevalence of tinnitus by age and birth cohort. Results are shown for a hypothetical individual with average levels of each covariate.

Table 1

Baseline characteristics of EHLS (1993-95) and BOSS (2005-08) participants included in the present study.*

Baseline Characteristic	EHLS Participants N=3704		BOSS Participants N=2158	
	n	%	n	%
Gender				
Female	2127	57.4	1162	53.9
Male	1577	42.6	996	46.2
Age group (yrs)				
< 60	1296	35.0	1672	77.5
60-69	1102	29.8	395	18.3
70-79	936	25.3	84	3.9
80+	370	10.0	7	0.3
Education (yrs)				
< 12	888	24.0	61	2.9
12	1703	46.0	665	31.1
13-15	567	15.3	710	33.2
16+	544	14.7	700	32.8
Hearing impairment				
No	1925	54.7	1492	81.3
Yes	1597	45.3	343	18.7

*98 people participated in both the EHLS and BOSS baseline examinations.

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Table 2

Prevalence (%) of tinnitus by age and birth cohort. The number of observations represented is shown in parentheses. A total of 11,930 observations are shown.*

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**
1905-09									5.4 (130)	9.6 (52)
1910-14								8.1 (236)	9.2 (119)	9.4 (53)
1915-19							8.5 (386)	8.9 (269)	11.0 (145)	15.5 (58)
1920-24						9.9 (504)	12.2 (376)	13.0 (270)	11.9 (151)	
1925-29					7.9 (495)	8.3 (421)	10.9 (320)	11.2 (241)		
1930-34				11.5 (511)	10.0 (458)	11.6 (372)	14.2 (337)			
1935-39			7.6 (537)	8.9 (496)	11.9 (463)	14.0 (450)				
1940-44		6.5 (583)	11.0 (544)	12.9 (606)	13.7 (539)					
1945-49			13.6 (272)	7.8 (128)						
1950-54		9.1 (339)	17.5 (183)							
1955-59	8.9 (393)	7.7 (234)								
1960-64	10.8 (259)									

* This table excludes 759 observations where: 1) the cell count was less than 40, or 2) the ages represented in a cell only included one or two years (eg., ages 78-79 in cohort 1910-14, n = 59) and so could result in a biased estimate of the prevalence for that cell.