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Original Contribution

Tracking Population Health Based on Self-reported Impairments: Trends in the Prevalence of Hearing Loss in US Adults, 1976–2006

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Trends in the prevalence of hearing loss among US adults remain ambiguous because of variation across surveys in question wording and limited use of audiometric examinations. Pooling samples of participants aged 20–69 years in 4 nationally representative cross-sectional survey series conducted from 1976 to 2006 ($N = 990{,}609$), the authors performed logistic regression to quantify self-reporting biases compared with audiometric measurements. Statistically significant underreporting or overreporting of hearing loss was observed, with various patterns of bias across age groups and surveys. Substantial upward reporting biases appeared among young adults in the National Health and Nutrition Examination Survey since 1999 and in the National Health Interview Survey since 1997. Trends in age-standardized prevalence of bilateral hearing loss were estimated with corrections for self-reporting biases. Prevalence in men shifted from 9.6% (95% confidence interval (CI): 7.8, 11.8) in 1978 to 12.2% (95% CI: 10.1, 14.7) in 1993 and declined to 8.1% (95% CI: 7.0, 9.5) in 2000. In women, prevalence was relatively constant at approximately 6%–7% until the early 1990s and decreased from 7.0% (95% CI: 5.5, 9.1) in 1993 to 4.2% (95% CI: 3.4, 5.3) in 2000. Prevalence was stable in both sexes in the early 2000s. This approach to adjust for biases in self-reported impairments by using measured performance may be useful in various health domains.

adult; cross-sectional studies; health surveys; hearing loss; logistic models; prevalence; United States; validation studies

Abbreviations: CI, confidence interval; MEPS, Medical Expenditure Panel Survey; NHANES, National Health and Nutrition Examination Survey; NHIS, National Health Interview Survey; SIPP, Survey of Income and Program Participation.

Hearing loss is a major public health problem in the United States. One in every 6 American adults recently reported having hearing trouble, and prevalence rises with age to reach half of individuals aged 75 or more years (1). Hearing impairment imposes a substantial burden on individuals and society and is associated with poorer quality of life, increased comorbidity, greater difficulties with functional activities, and lower income (2–9).

Tracking the prevalence of hearing loss over time is essential for formulation and evaluation of policies to improve hearing status in the population. The "gold standard" for measurement of hearing status is audiometry; however, audiometric testing among nationally representative samples has been conducted relatively infrequently (10). A previous study based on audiometric measures estimated the prevalence of bilateral hearing loss at the speech frequencies among US adults aged 20–69 years to be 8% between 1999 and 2004, with no notable change during this period (11).

In contrast to the limited availability of audiometric data, self-reports on hearing status have been elicited regularly in multiple nationally representative interview surveys conducted in the United States (12–20). Previous studies based on the National Health Interview Survey indicated that the prevalence of self-reported hearing loss in adults rose sometime in the 1970s and 1980s and remained stable between 1986 and 1995 (17, 18). Although self-reported measures are attractive because of relatively low costs and ease of administration, they may not accurately quantify true levels of hearing (11, 21, 22). Moreover, question wording on hearing loss has varied across surveys and even within some

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Table 1. Sources of US Data Files and Recodes of Survey Years, 1976–2006

Survey (Year)	Data Files	Year Recodes
MEPS (1996–2005)	Household component full-year files	Annual, as is
NHANES II (1976–1980)	Medical history data tape, no. 5020	1978
NHANES III (1988–1994)	Adult data file	1990, 1993
NHANES IV (1999–2004)	Audiometry section of sample person questionnaire, audiometry examination component	1999, 2001, 2003
NHIS (1978–1996)	Person record; condition record	Annual, as is
NHIS (1997–2006)	Person-level file; sample adult file	Annual, as is
SIPP (1984–2004)	Topical modules data file	Panel 1984, wave 3: 1984; panel 1990, wave 3: 1990; panel 1991, wave 3: 1991; panel 1992, wave 6: 1993[a]; panel 1993, wave 3: 1993[a]; panel 1996, wave 5: 1997; panel 2001, wave 5: 2002; panel 2004, wave 5: 2005

Abbreviations: MEPS, Medical Expenditure Panel Survey; NHANES, National Health and Nutrition Examination Survey; NHIS, National Health Interview Survey; SIPP, Survey of Income and Program Participation.

[a] Panel 1992, wave 6, and panel 1993, wave 3, were combined.

surveys over time. The lack of consistency in eliciting self-reported hearing status makes it challenging to assess long-term trends in the prevalence of hearing loss among adults in the United States.

In this study, we use partial data on audiometric testing to examine and correct for biases in self-reports on hearing and develop valid estimates of levels and trends in the prevalence of bilateral hearing loss among US adults from 1976 to 2006.

MATERIALS AND METHODS

Data were obtained from interviews and examinations in 4 nationally representative survey series conducted between 1976 and 2006 in the United States: the Medical Expenditure Panel Survey (MEPS), 1996–2005 (23); the National Health and Nutrition Examination Survey (NHANES), 1976–1980 (II), 1988–1994 (III), 1999–2000, 2001–2002, and 2003–2004 (IV) (24); the National Health Interview Survey (NHIS), 1978–2006 (25); and the Survey of Income and Program Participation (SIPP), 1984–2004 (26). All of these surveys were conducted on stratified multistage probability samples of the civilian noninstitutionalized population in the United States. A summary of the data sources is provided in Table 1.

Measured data were obtained from the pure-tone air conduction audiometry performed in 3 cycles of NHANES IV, in 1999–2000, 2001–2002, and 2003–2004. In each survey, half of the sample of adults aged 20–69 years were randomly selected for testing. Participants were excluded from audiometric tests if they wore hearing aids and could not remove them for testing or if they had ear pain and could not tolerate headphones. The eligible sample size was 1,807 in 1999–2000, 2,046 in 2000–2001, and 1,889 in 2003–2004 (24). Procedures for collecting the audiometric data have been detailed elsewhere (10). In summary, an audiometry test was performed by trained personnel in a sound-isolated room in the mobile examination center. Hearing threshold testing was conducted on both ears of examinees at 7 frequencies (0.5, 1, 2, 3, 4, 6, and 8 kHz).

According to the classification by the World Health Organization, measured bilateral hearing loss was defined in this study as a value greater than 25 dB of the pure-tone average of audiometric hearing thresholds at the speech frequencies of 0.5, 1, 2, and 4 kHz in the better ear (27). To be consistent with the definitions for measured hearing, self-reported bilateral hearing loss was defined as use of hearing aids in both ears or decreased hearing in the better ear. The definitions of self-reported hearing loss in this study are detailed for each survey in Table 2.

The total sample size used in this analysis was 990,609. Sample sizes of individual surveys by age and sex are given in Table 3. Of the 5,742 respondents eligible for inclusion in the audiometry examination of NHANES IV, 324 (6%) were excluded from analysis because a test was not done at all, and 119 (2%) were excluded because of missing values. The final sample size with audiometric measurements was 5,299, accounting for 0.5% of the entire pooled sample.

As a preliminary descriptive analysis, the prevalence of measured or self-reported hearing loss among people aged 20–69 years was computed directly from individual surveys by sex and year to characterize variation in prevalence estimates across surveys.

Next, unit record data of all surveys were merged to investigate differences in self-reports due to variation in

Table 2. Definition of Self-reported Hearing Loss in US Surveys Used for Analysis, 1976–2006

Survey (Year)/Item	Response Categories	Coded as Hearing Loss
MEPS (1996–2005)		
Does anyone in the family wear a hearing aid?	1 (yes)	✓
	2 (no)	
[If yes] Who is that?		
Does anyone in the family have any difficulty hearing (with a hearing aid, if they use one)?	1 (yes)	✓
	2 (no)	
[If yes] Who is that?		
NHANES II (1976–1980)		
How would you rate your hearing in your (right/left) ear?[a]	1 (good)	
	2 (fair)	✓
	3 (poor)	✓
	4 (deaf)	✓
Do you now use a hearing aid?[b]	1 (yes)	✓
	2 (no)	
NHANES III (1988–1994)		
Do you have total deafness in one or both ears?[c]	1 (yes, both)	✓
	2 (yes, one)	
	3 (no)	
Do you use a hearing aid?	1 (yes)	✓
	2 (no)	
Do you have trouble hearing (even when wearing your hearing aid)?	1 (yes)	✓
	2 (no)	
NHANES IV (1999–2004)		
Which statement best describes (your/sample person's) hearing (without a hearing aid)?	1 (good)	
	2 (a little trouble)	✓
	3 (a lot of trouble)	✓
	4 (deaf)	✓
NHIS (1978–1996)		
Does anyone in the family now have deafness in one or both ears?	1 (yes)	✓
	2 (no)	
[If yes] Who is this?		
Does anyone in the family now have any trouble hearing with one or both ears?	1 (yes)	✓
	2 (no)	
[If yes] Who is that?		
NHIS (1997–2006)		
Which statement best describes your hearing without a hearing aid?	1 (good)	
	2 (a little trouble)	✓
	3 (a lot of trouble)	✓
	4 (deaf)	✓
SIPP (1984–1993)		
Does [sample person] have any difficulty hearing what is said in a normal conversation with another person (using a hearing aid if [sample person] usually wears one)?	1 (yes)	✓
	2 (no)	
SIPP (1997–2004)		
(Do you/does sample person) use a hearing aid?	1 (yes)	✓
	2 (no)	
(Do you/does sample person) have difficulty hearing what is said in a normal conversation with another person even when wearing (your/his/her) hearing aid?	1 (yes)	✓
	2 (no)	
	3 (person is deaf)	✓

Abbreviations: MEPS, Medical Expenditure Panel Survey; NHANES, National Health and Nutrition Examination Survey; NHIS, National Health Interview Survey; SIPP, Survey of Income and Program Participation.

[a] Asked about both ears and coded as hearing loss based on the better of 2 ears.

[b] Coded as hearing loss if the answer to an earlier question (not shown) implies both ears.

[c] The response categories shown here reflect the composite of 2 questions: 1) one indicating total deafness; and 2) one indicating 1 or both ears.

question wording across surveys. A logistic regression model was applied, in which the dependent variable was a dichotomous measure of self-reported or measured hearing loss, and independent variables were age (continuous), year of survey (reference = 1997), and indicator variables for specific surveys (reference = NHANES audiometric tests). Odds ratios for survey indicator variables represent the bias in self-reported measures of hearing loss relative to the reference standard of audiometric measurement. For NHIS and SIPP, which underwent changes in survey design and item wording, separate survey indicator variables were included for the periods before and after the change. Table 1 presents how years were assigned to individual surveys. Years in NHANES were determined by the midpoint of each time period (1978 in NHANES II; 1990 and 1993 in the first and second phases, respectively, of NHANES III) or by the first year in each 2-year cycle in NHANES IV (1999, 2001, and 2003). Years in SIPP were defined by years of survey implementation rather than the starting years of the panels. Separate regressions were run by sex and for 3 different age groups, defined as 20–49, 50–59, and 60–69 years, to elaborate how patterns in self-reporting errors vary among these groups.

Regression coefficients were used to compute prevalence by sex and single year of age, for each calendar year between 1976 and 2006, with the survey variable held at the reference value (i.e., NHANES audiometric examination) to exclude systematic biases in self-reported values. Age-standardized prevalence estimates were based on the 2000 US population (28). Confidence intervals were calculated for prevalence estimates by statistical simulation to account for estimation uncertainty (29). For each regression model, 1,000 sets of sampled coefficients were drawn from a multivariate

Table 3. Sample Sizes Used for Analysis by Age, Sex, and US Survey, 1976–2006

Sex and Age, years	MEPS		NHANES Examination		NHANES Interview		NHIS		SIPP		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Men												
20–49	58,895	18.3	1,572	0.5	11,809	3.7	148,887	46.2	101,124	31.4	322,287	100
50–59	15,031	19.1	428	0.5	2,756	3.5	36,529	46.3	24,139	30.6	78,883	100
60–69	9,485	16.0	493	0.8	4,438	7.5	27,358	46.1	17,540	29.6	59,314	100
Women												
20–49	65,839	17.9	1,837	0.5	13,606	3.7	175,470	47.8	110,327	30.1	367,079	100
50–59	17,344	19.1	437	0.5	3,088	3.4	43,302	47.7	26,644	29.3	90,815	100
60–69	11,213	15.5	532	0.7	4,863	6.7	34,520	47.8	21,103	29.2	72,231	100

Abbreviations: MEPS, Medical Expenditure Panel Survey; NHANES, National Health and Nutrition Examination Survey; NHIS, National Health Interview Survey; SIPP, Survey of Income and Program Participation.

normal distribution based on the point estimates and variance-covariance matrix of the regression estimates. Each sampled set of coefficients was then used to compute prevalence by sex, single year of age, and calendar year, and these single-year estimates were combined into age-standardized estimates. The 95% confidence interval around prevalence in a given year was defined by the span across prevalence estimates at the 2.5th and 97.5th percentiles of the 1,000 simulations.

All analyses were performed with STATA/MP 10.0 (StataCorp LP, College Station, Texas). The complex sampling designs in each survey were taken into account in estimation of variance throughout the analyses by incorporating information on sampling weights, stratification, and clustering.

RESULTS

Figure 1 presents age-standardized prevalence of bilateral hearing loss at speech frequencies by sex, estimated from individual surveys. The estimates of prevalence were substantially different across surveys in both sexes. Prior to 1997, the prevalence obtained from SIPP was considerably lower than those in NHIS and NHANES. For example, the prevalence estimate in men in 1993 was 5.8% (95% confidence interval (CI): 5.4, 6.3) in SIPP, while it was 15.1% (95% CI: 13.2, 17.2) in NHANES and 12.3% (95% CI: 11.4, 13.3) in NHIS. The discrepancies between surveys have become more marked since 1997, with the redesign of NHIS and the addition of MEPS and continuous NHANES examination surveys. For instance, the prevalence in men in 1999 was estimated to be 7.5% (95% CI: 6.8, 8.3) in MEPS, 25.9% (95% CI: 22.5, 29.6) in the NHANES interview, 7.8% (95% CI: 5.6, 10.7) in the NHANES examination, and 16.2% (95% CI: 15.4, 17.1) in NHIS. The redesign of NHIS produced a discernible discontinuity in the prevalence of self-reported hearing loss, while the impact of changes in SIPP was apparently more subtle.

Tables 4 and 5 show odds ratios of reporting hearing loss for specific interview surveys relative to the NHANES IV audiometric tests. The direction and magnitude of biases in self-reports in the different surveys were relatively consistent between men (Table 4) and women (Table 5). Overreporting of hearing loss compared with audiometry was statistically significant and substantial in NHANES IV interview surveys in all age-sex groups and in NHIS (1997–2006) ages 20–49 and 50–59 years, in both sexes. The likelihood of overreporting in these 2 surveys was highest in those aged 20–49 years and attenuated with rising age. Significant overreporting of hearing loss in ages 20–49 years also appeared in NHANES III in both sexes and in NHIS (1978–1996) in women only. On the other hand, SIPP showed significant underreporting of hearing loss relative to audiometry in both periods of 1984–1993 and 1997–2005, at ages 50–59 and 60–69 years in both sexes. Significant underreporting was also detected in MEPS, NHANES II, NHANES III, and NHIS (1978–1996) among respondents of both sexes aged 60–69 years.

Figure 2 shows the estimated trends in the age-standardized prevalence of bilateral hearing loss at the speech frequencies by sex among US adults aged 20–69 years after biases in self-reports were corrected on the basis of measured audiometric data. The prevalence of bilateral hearing loss in men shifted from 9.6% (95% CI: 7.7, 11.8) in 1978 to 12.2% (95% CI: 10.1, 14.7) in 1993, subsequently declined to 8.1% (95% CI: 7.0, 9.5) in 2000, and remained relatively constant at approximately 8%–9% until 2006. Among women, the age-standardized prevalence of bilateral hearing loss moved from 6.1% (95% CI: 4.7, 7.8) in 1978 to 7.0% (95% CI: 5.5, 9.1) in 1993, then decreased to 4.2% (95% CI: 3.4, 5.3) in 2000, and remained at approximately 4%–5% until 2006.

DISCUSSION

To our knowledge, this is the first study to provide comparable estimates of long-term trends in the prevalence of hearing loss among US adults from the late 1970s to the early 2000s. Our study indicates that the prevalence of bilateral hearing loss at the speech frequencies in US adults declined in the 1990s and stabilized in the early 2000s. We also demonstrate that biases in self-reported hearing measures vary substantially across different survey instruments and move in different directions according to the age of respondents.

The estimated trends in the prevalence of bilateral hearing loss in this analysis agree with previous findings that studied

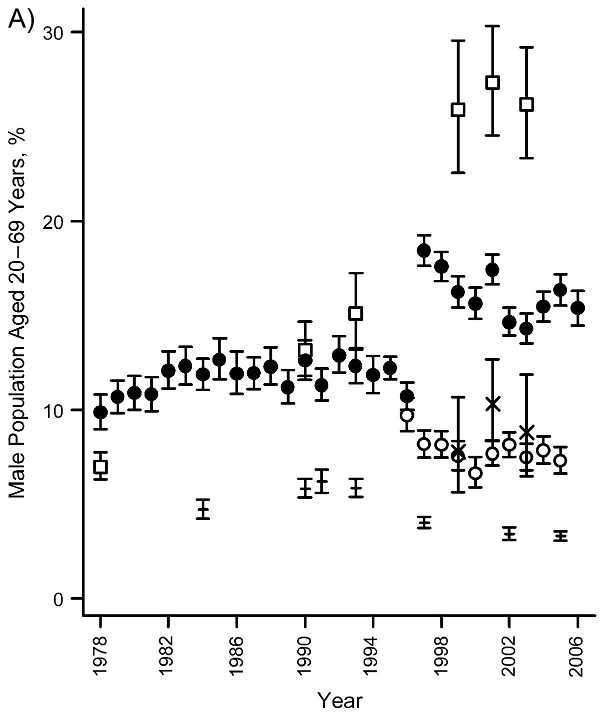

Figure 1. Age-standardized prevalence of bilateral hearing loss before corrections for biases in self-reports in US men (A) and women (B), aged 20–69 years, by survey, 1976–2006. Open circle, Medical Expenditure Panel Survey; filled circle, National Health Interview Survey; open square, interview surveys in the National Health and Nutrition Examination Survey (NHANES); cross, examination surveys in NHANES; plus sign, Survey of Income and Program Participation. Error bars indicate 95% confidence intervals.

earlier periods (17, 18, 30). A unique contribution of the present study is to overcome differences in measurement methods across time periods and surveys in order to link these past trends to more recent measurements. Such explicit connections are complicated by the redesign of NHIS in 1997 and the lack of audiometric testing results in past periods, but our study uses regression methods to make full use of available data and to enable adjustment and comparison of self-reports by leveraging audiometric testing data from more recent years.

Table 4. Odds Ratios and 95% Confidence Intervals for Reporting Hearing Loss in Various National Surveys, Relative to NHANES IV Examination Surveys (1999–2004), in US Men by Age Group[a]

Survey	Age, years					
	20–49		50–59		60–69	
	Odds Ratio	95% Confidence Interval	Odds Ratio	95% Confidence Interval	Odds Ratio	95% Confidence Interval
MEPS	1.45	0.99, 2.11	0.82	0.59, 1.13	0.52	0.40, 0.68
NHANES II	0.92	0.56, 1.51	0.83	0.50, 1.39	0.37	0.24, 0.57
NHANES III	1.93	1.22, 3.08	1.31	0.81, 2.13	0.51	0.33, 0.78
NHANES IV	9.38	6.34, 13.90	3.28	2.28, 4.72	1.66	1.24, 2.24
NHIS (1978–1996)	1.51	0.98, 2.34	1.09	0.72, 1.64	0.54	0.38, 0.79
NHIS (1997–2006)	4.32	2.97, 6.27	1.82	1.31, 2.52	0.99	0.76, 1.30
SIPP (1984–1993)	0.64	0.41, 1.00	0.46	0.30, 0.71	0.24	0.16, 0.35
SIPP (1997–2005)	0.62	0.42, 0.91	0.31	0.22, 0.44	0.23	0.17, 0.30

Abbreviations: MEPS, Medical Expenditure Panel Survey; NHANES, National Health and Nutrition Examination Survey; NHIS, National Health Interview Survey; SIPP, Survey of Income and Program Participation.

[a] The model controls for age and survey year.

Table 5. Odds Ratios and 95% Confidence Intervals for Reporting Hearing Loss in Various National Surveys, Relative to NHANES IV Examination Surveys (1999–2004), in US Women by Age Group[a]

Survey	Age, years					
	20–49		50–59		60–69	
	Odds Ratio	95% Confidence Interval	Odds Ratio	95% Confidence Interval	Odds Ratio	95% Confidence Interval
MEPS	1.30	0.77, 2.20	0.86	0.60, 1.24	0.49	0.35, 0.68
NHANES II	1.27	0.67, 2.41	0.52	0.28, 0.98	0.22	0.14, 0.37
NHANES III	2.65	1.44, 4.89	1.35	0.78, 2.35	0.48	0.27, 0.83
NHANES IV	7.70	4.48, 13.22	4.53	3.08, 6.64	1.96	1.35, 2.85
NHIS (1978–1996)	1.99	1.11, 3.55	1.13	0.69, 1.83	0.58	0.37, 0.91
NHIS (1997–2006)	4.06	2.41, 6.86	2.23	1.56, 3.19	1.07	0.77, 1.49
SIPP (1984–1993)	0.62	0.34, 1.12	0.36	0.22, 0.60	0.18	0.11, 0.30
SIPP (1997–2005)	0.67	0.39, 1.14	0.43	0.29, 0.63	0.24	0.17, 0.34

Abbreviations: MEPS, Medical Expenditure Panel Survey; NHANES, National Health and Nutrition Examination Survey; NHIS, National Health Interview Survey; SIPP, Survey of Income and Program Participation.

[a] The model controls for age and survey year.

Previous studies indicated that self-reports may underestimate the prevalence of hearing loss (11, 21, 22). We found that directions and patterns of bias varied by the wording and response scales of survey instruments. Overreporting of hearing loss is particularly pronounced in NHANES IV self-reports—as observed previously (11)—and in NHIS after 1997. These findings might be partly attributable to the use of a scaled response question, presumably resulting in worse accuracy against audiometry than self-reports based on ‘‘yes’’/‘‘no’’ questions. Another possible factor is the lack of specification of which ear in the question. In these surveys, a substantial fraction of people reported mildly

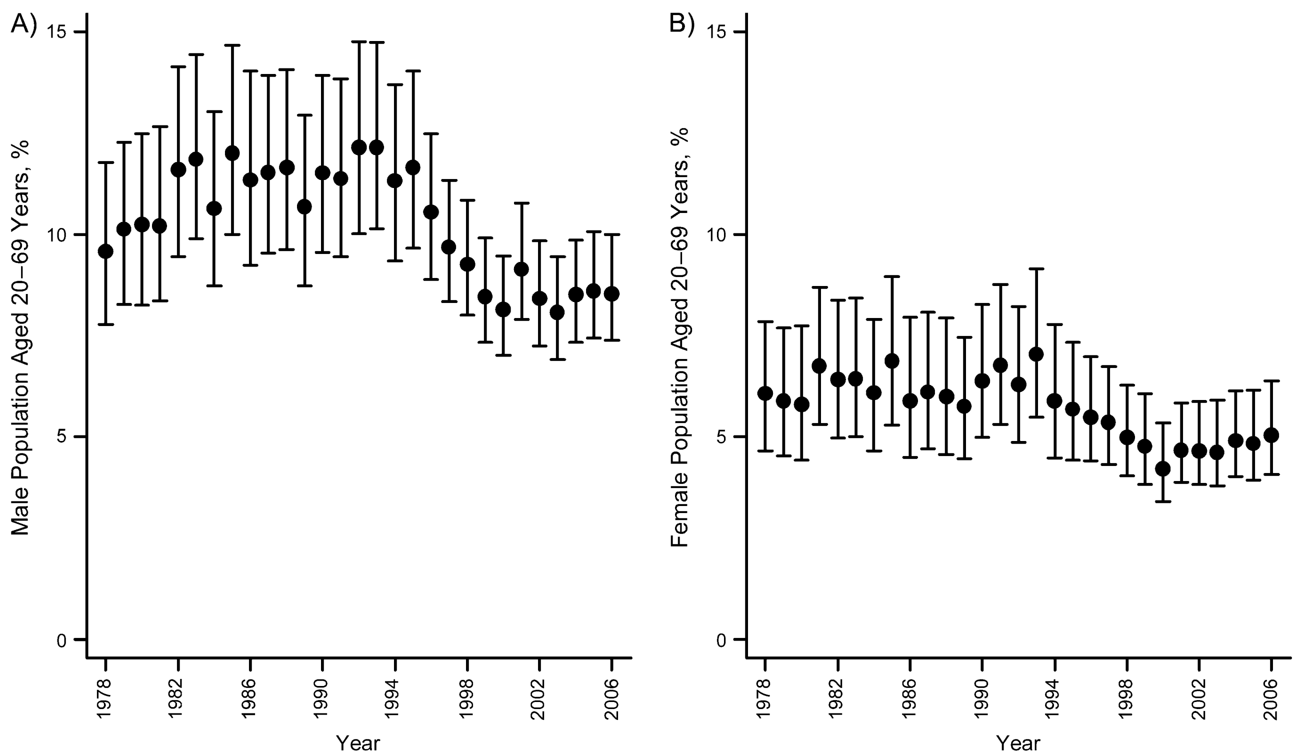

Figure 2. Age-standardized prevalence of bilateral hearing loss at speech frequencies after corrections for biases in self-reports in US men (A) and women (B), aged 20–69 years, 1976–2006. Error bars indicate 95% confidence intervals.

decreased hearing (either "a little decreased" or "a little trouble"), which might have included individuals with unilateral hearing loss. One explanation for the underreporting of hearing loss in SIPP is that the question relating to hearing a normal conversation did not easily accommodate the "slight impairment," i.e., inability to hear whispers, referenced in the World Health Organization classification (27). People who have problems in hearing whispers might not report the impairment if they could hear a normal conversation with another person.

Another key finding of our study is that biases in self-reports may vary systematically with age. The likelihood of reporting hearing loss relative to audiometric tests attenuates with increasing age. A possible interpretation is that expectations for hearing decline with advancing age, which makes older individuals less likely than younger ones to report hearing loss. The large sample sizes in this study allowed us to estimate separate regressions by age group in order to characterize these varying patterns. If our approach were applied to smaller data sets, pooling across age groups might be necessary for statistical power, which would add some constraints to the types of inference that could be made.

A previous study has proposed tracking population health over time by using data on self-reported symptoms and impairments from nationally representative surveys in the United States (31). Our results on survey-specific biases in self-reported hearing status reinforce the need for caution in interpreting and comparing self-reports in different surveys. Nevertheless, our findings indicate that partial data on measured performance may be exploited successfully to correct for these differences. This approach may have general utility for enhancing the comparability of various health impairments and symptoms measured with self-reports and, thus, for improving the validity of monitoring long-term trends in population health.

Our analysis has various limitations that should be noted. First, the survey samples exclude military personnel, residents in institutions, and individuals aged 70 or more years, which may result in an underestimate of hearing loss prevalence. Second, our model assumes that biases in self-reported hearing loss are constant over time within any given survey (barring changes in survey methods or items). This assumption will be overly restrictive if expectations have shifted over the duration of a particular survey's implementation. Further accumulation of data including audiometric measurements would enable empirical testing of this assumption based on more flexible models. Meanwhile, the fact that identical question wording was preserved within each survey provides some reassurance that this simplifying assumption may be reasonable.

From a public health perspective, several plausible hypotheses on the causes of declines in the prevalence of hearing loss in the 1990s might warrant further empirical investigation. One explanation might be decreased incidence of noise-induced hearing loss. Noise was reported to be the most frequent cause of hearing impairment in US adults aged less than 65 years in the early 1990s (17). Under occupational noise regulations, exposures to hazardous levels of noise decreased, and the use of hearing protection devices increased in the manufacturing and coal mining sectors (32, 33). Given that hearing loss is still highly prevalent in the industrial sectors involving hazardous noise (34), however, further corporate and governmental efforts at hearing conservation might be beneficial. Another possible explanation for decreased prevalence of hearing loss during the 1990s is improvement in screening and use of hearing aids, although to our knowledge there is no evidence that detection and treatment of hearing impairment increased dramatically during the period.

Estimates of the prevalence of hearing loss from self-report must be evaluated with caution because of differential biases across age groups and surveys. However, correction of these biases is possible if audiometric measurements are available from at least 1 survey, and if survey periods partially overlap with each other. Hearing loss remains an important public health problem in the United States. Following the decline in the prevalence of bilateral hearing loss at the speech frequencies during the 1990s, more recent trends have been stable in both adult men and women. Further strategies to promote prevention of hearing loss at work and in communities may be needed to resume progress in reducing the burden of hearing loss.

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