

# Prevalence of Hearing Loss and Differences by Demographic Characteristics Among US Adults

*Data From the National Health and Nutrition Examination Survey, 1999-2004*

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**Background:** Hearing loss affects health and quality of life. The prevalence of hearing loss may be growing because of an aging population and increasing noise exposure. However, accurate national estimates of hearing loss prevalence based on recent objective criteria are lacking.

**Methods:** We determined hearing loss prevalence among US adults and evaluated differences by demographic characteristics and known risk factors for hearing loss (smoking, noise exposure, and cardiovascular risks). A national cross-sectional survey with audiometric testing was performed. Participants were 5742 US adults aged 20 to 69 years who participated in the audiometric component of the National Health and Nutrition Examination Survey 1999-2004. The main outcome measure was 25-dB or higher hearing loss at speech frequencies (0.5, 1, 2, and 4 kHz) and at high frequencies (3, 4, and 6 kHz).

**Results:** In 2003-2004, 16.1% of US adults (29 million Americans) had speech-frequency hearing loss. In the youngest age group (20-29 years), 8.5% exhibited hearing loss, and the prevalence seems to be growing among this age group. Odds of hearing loss were 5.5-fold higher in men vs women and 70% lower in black subjects vs white subjects. Increases in hearing loss prevalence occurred earlier among participants with smoking, noise exposure, and cardiovascular risks.

**Conclusions:** Hearing loss is more prevalent among US adults than previously reported. The prevalence of US hearing loss differs across racial/ethnic groups, and our data demonstrate associations with risk factors identified in prior smaller-cohort studies. Our findings also suggest that hearing loss prevention (through modifiable risk factor reduction) and screening should begin in young adulthood.

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**H**EARING LOSS RESULTS from pathologic conditions along the sound transduction pathway.<sup>1-3</sup> The cochlea and, to a lesser extent, the middle and external ear are commonly involved; pathologic conditions of the auditory nerve or brainstem rarely manifest as hearing loss.

Hearing loss can be a disabling condition. Mild hearing loss can impair verbal language processing, thereby limiting meaningful communication and social connectivity. Such communication difficulties negatively affect work productivity, health-related quality of life, and cognitive and emotional status.<sup>4-9</sup> These disabilities impede health care access and use,<sup>10</sup> with possible adverse consequences to health<sup>11</sup> and survival.<sup>12</sup>

Hearing loss is a societal problem. It is known to be highly prevalent,<sup>13-16</sup> and the costs of increased needs and diminished autonomy associated with hearing loss are shared by society.<sup>17</sup> The prevalence of hearing loss in the United States is predicted to rise significantly because of an aging population and the growing use of per-

sonal listening devices.<sup>18-21</sup> Indeed, there is concern that we may be facing an epidemic of hearing impairment.<sup>22</sup>

Despite this concern, we lack a rigorous estimate of the current national prevalence of hearing loss. The best estimate (28 million Americans) is based on self-report, which tends to underestimate the phenomenon.<sup>22-24</sup> To our knowledge, there are no national-level assessments of the demographic patterns and risk factors for hearing loss that have used audiometric testing.

We herein report the prevalence of hearing loss among US adults aged 20 to 69 years based on data from the National Health and Nutrition Examination Survey (NHANES) 1999-2004. We evaluated the effects of demographic characteristics on hearing loss prevalence. The effect of noise exposure was also considered,<sup>25-27</sup> as were cardiovascular risks that have been shown to have a role in hearing loss.<sup>28-30</sup> Such epidemiological information can facilitate the delivery of general health care and preventive, screening, and rehabilitative services to individuals with hearing impairment.

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## STUDY POPULATION

The NHANES is an ongoing cross-sectional survey of the civilian noninstitutionalized population of the United States. Every 2 years, 12 000 to 13 000 individuals who are representative of the US population are selected at random based on demographic distributions. The participation rate in the past several cycles has ranged from 79% to 84%. Further details of the NHANES sampling process are available.<sup>31</sup>

The 1999-2000, 2001-2002, and 2003-2004 NHANES collected audiometric data on a nationally representative sample of adults aged 20 to 69 years. We combined these 2-year cycles of data to analyze 6 years of data per National Center for Health Statistics (NCHS) recommendations.<sup>31</sup> A total of 31 126 subjects of all ages took part in the NHANES from 1999 to 2004; 12 056 participants were aged 20 to 69 years. Half of those aged 20 to 69 years were selected to participate in an audiometry component (described herein). Participants using hearing aids who were unable to remove them for testing were excluded from audiometric testing. Participants were also excluded if they had sufficient otalgia to prevent the use of test headphones. The NHANES documentation did not report how many individuals were excluded for these reasons. Sign language interpreters were available if individuals with deafness were encountered during recruitment. The eligible sample size was 5742 participants. Sample weights for the combined 6-year sample were computed per NCHS guidelines.<sup>31</sup> These sample weights accounted for individual nonparticipation and preserved the national representativeness of the subsample.

## AUDIOMETRIC MEASURES

Audiometry was performed by mobile examination center health technicians trained by a certified audiologist from the National Institute for Occupational Safety and Health. Testing was conducted in a mobile examination center sound-isolated room. Instrumentation for the audiometric component included an audiometer (AD226; Interacoustics AS, Assens, Denmark) with standard headphones (TDH-39; Telephonics Corporation, Farmingdale, New York) and insert earphones (EarTone 3A; Ety-motic Research, Elk Grove Village, Illinois).

Air conduction thresholds were determined for each ear from 0.5 to 8 kHz across an intensity range of -10 to 120 dB. The 1-kHz frequency was tested twice in each ear as a measure of the reliability of the subject's responses. Pure-tone audiograms were not accepted if there was more than a 10-dB difference between the 1-kHz test-retest thresholds. If an examinee did not respond to the signal tone at any level, a nonresponse code was entered. Ten patients did not respond at 1 or more frequency levels for undocumented reasons; the nonresponses were coded as missing values. Further details of the audiometric testing procedures are available online (<http://www.cdc.gov/nchs/data/nhanes/au.pdf>).

Hearing loss at the speech frequencies was defined as a pure-tone mean of 25 dB or higher at 0.5, 1, 2, and 4 kHz in either ear. We subdivided speech-frequency hearing loss into mutually exclusive unilateral and bilateral categories. High-frequency hearing loss was defined as a pure-tone mean of 25 dB or higher at 3, 4 and 6 kHz in 1 ear (unilateral) or both ears (bilateral). Using data from large population studies showing that frequencies of 3 kHz or higher are the earliest and most severely affected,<sup>32</sup> we assessed the prevalence of high-frequency hearing loss, which is sometimes concomitant with speech-frequency hearing loss. We evaluated for possible differences in pathogenesis or progression patterns of speech-frequency and high-frequency hearing loss.

Trained interviewers administered detailed questionnaires.<sup>33</sup> Age at interview was binned by decade. Race/ethnicity was grouped as non-Hispanic white (hereafter, white), non-Hispanic black (hereafter, black), Mexican American, or other. Education was grouped as less than high school, high school diploma (including general equivalency diploma), and beyond high school. Four participants had missing education data.

Exposure to recreational noise was determined by a question asking if the subject had ever been exposed outside of work to loud noise (eg, power tools or loud music) for a mean of at least once a month for 1 year (8 participants had missing data). Exposure to weapon noise was defined as exposure outside of work to the noise of a firearm a mean of at least once a month for 1 year (6 participants had missing data).

A complete smoking history included the number of years and the current number of cigarettes smoked per day. Pack-years of smoking were computed, and participants were divided into smoking categories (nonsmoker, <20 pack-years of smoking, or  $\geq$ 20 pack-years of smoking). There were substantial missing data ( $n=467$ ) on the quantity of tobacco smoked, so a separate category was made for persons who were ever smokers with unknown pack-years of smoking (14 participants had missing data). Hypertension was defined as self-reported physician diagnosis, the use of antihypertensive medication, or a mean systolic blood pressure exceeding 140 mm Hg or a mean diastolic blood pressure exceeding 90 mm Hg at the time of examination (7 participants had missing data). Diabetes mellitus was defined as self-reported physician diagnosis, the use of antihyperglycemic medication, an 8-hour fasting glucose level of 126 mg/dL or higher (to convert glucose to millimoles per liter, multiply by 0.0555), or a nonfasting glucose level of 200 mg/dL or higher.

Self-reported hearing status was determined by direct questioning. Those who reported "good hearing" were coded as not self-reporting hearing loss, whereas those who reported "a little trouble hearing," "a lot of trouble hearing," or "deafness" were coded as self-reporting hearing loss. Participants usually responded on their own behalf. Only in rare situations were proxy respondents used.<sup>34</sup>

Exposure to occupational noise was defined as noise exposure in the workplace (requiring speaking in a raised voice) for at least 3 months. Occupational noise exposure data were unavailable for the 2003-2004 NHANES, so all analyses involving occupational noise were based on 4 years of data from 1999 to 2002 and used 4-year sample weights. From 1999 to 2002, there were 21 004 participants, 8143 of whom were aged 20 to 69 years. The eligible sample size for the audiometric component from 1999 to 2002 was 3853 participants. No occupational noise exposure data were available for 6.3% of the audiometrically assessed subsample. No differences in the prevalences of speech-frequency or high-frequency hearing loss were noted between participants with and without occupational noise exposure data.

Of the initial sample of 5742 adults who underwent audiometry, participants were excluded if there were unreliable audiometric measurements (ie, there was a >10-dB difference between the 1-kHz test-retest thresholds [ $n=444$ ]) or if there was a nonresponse code to audiometric testing ( $n=10$ ), yielding a final sample size of 5288 participants. No significant differences were noted between included and excluded participants for sex, age, and race/ethnicity. In the 4-year sample of 3853 adults (for analyses involving the occupational noise exposure variable), 326 participants were excluded (6 for nonresponse and 320 for unreliable testing), yielding a final sample

**Table 1. Prevalence of Speech-Frequency and High-frequency Hearing Loss Among the Overall Population and by Demographic Characteristics, Noise Exposure, and Cardiovascular Risks, National Health and Nutrition Examination Survey (1999-2004)<sup>a</sup>**

Variable	No. (%) (n=5742) <sup>b</sup>	% (95% Confidence Interval)					
		Speech-Frequency Hearing Loss <sup>c</sup>			High-Frequency Hearing Loss		
		Overall	Unilateral <sup>d</sup>	Bilateral <sup>e</sup>	Overall	Unilateral <sup>f</sup>	Bilateral <sup>g</sup>
<b>Overall Population</b>							
1999-2000	1807 (31.5)	15 (12-19)	7.5 (6.0-9.0)	8.0 (5.9-10.0)	32 (28-35)	13 (11-16)	19 (16-22)
2001-2002	2046 (35.6)	15 (12-18)	7.3 (5.8-8.9)	8.0 (5.8-10.0)	32 (28-37)	14 (12-16)	19 (15-22)
2003-2004	1889 (32.9)	16 (13-19)	8.9 (6.8-11.0)	7.3 (5.5-9.1)	31 (28-34)	12 (10-13)	19 (17-22)
1999-2004	<b>5742 (100)</b>	16 (14-17)	7.9 (7.0-8.9)	7.8 (6.7-9.0)	32 (30-34)	13 (12-14)	19 (17-20)
<b>Demographic Characteristics</b>							
Sex							
Male	2674 (46.6)	21.0 (18.0-24.0)	10.0 (8.5-12.0)	11.0 (9.0-13.0)	45 (41-48)	17 (15-18)	28 (25-31)
Female	3068 (53.4)	11.0 (9.1-12.0)	5.9 (4.9-6.9)	4.9 (3.9-5.9)	19 (17-22)	9 (8-11)	10 (9-12)
Age, y							
20-29	1458 (25.4)	3.1 (1.7-4.6)	2.6 (1.3-3.9)	0.6 (0.1-1.0)	8.5 (6.3-11.0)	5.7 (4.1-7.4)	2.8 (1.4-4.2)
30-39	1220 (21.2)	5.4 (3.9-6.8)	3.4 (2.1-4.7)	2.0 (0.9-3.1)	17 (15-20)	11 (8-13)	6.6 (5.0-8.1)
40-49	1142 (19.9)	15.0 (12.0-17.0)	8.8 (6.8-11.0)	5.8 (4.1-7.5)	34 (30-38)	17 (14-19)	18 (15-20)
50-59	970 (16.9)	29 (25-33)	14 (11-18)	15 (12-18)	53 (49-57)	17 (15-19)	36 (31-41)
60-69	952 (16.9)	49 (44-54)	18 (14-21)	31 (26-37)	77 (74-80)	18 (15-21)	59 (54-63)
Race/ethnicity							
White, non-Hispanic	2653 (46.2)	18.0 (15.0-20.0)	8.7 (7.6-9.8)	8.8 (7.4-10.0)	36 (33-38)	14 (13-15)	22 (20-24)
Black, non-Hispanic	1183 (20.6)	8.2 (6.8-9.7)	4.6 (3.4-5.8)	3.6 (2.8-4.4)	19 (16-21)	9 (7-11)	9 (8-11)
Mexican American	1375 (23.9)	10.0 (8.7-12.0)	5.3 (3.9-6.7)	4.8 (3.9-5.8)	24 (21-26)	10 (8.5-12)	13 (12-15)
Other	531 (9.2)	16.0 (12.0-20.0)	8.1 (5.1-11.0)	8.2 (5.0-11.0)	27 (23-31)	12 (9.5-15)	15 (11-18)
Education <sup>h</sup>							
<High school	1741 (30.3)	24.0 (20.0-27.0)	9.4 (7.6-11.0)	14.0 (11.0-17.0)	40 (36-44)	14 (11-16)	26 (23-30)
High school diploma, including general equivalency diploma	1311 (22.8)	17.0 (15.0-19.0)	8.2 (6.3-10.0)	8.8 (6.8-11.0)	35 (32-38)	13 (11-15)	26 (23-30)
>High school	2686 (46.8)	13.0 (11.0-14.0)	7.3 (6.1-8.5)	5.3 (4.1-6.5)	28 (26-30)	13 (11-14)	15 (14-17)
<b>Noise Exposure</b>							
Loud noise							
Occupational <sup>i</sup>							
No	2482 (68.8)	13 (11-15)	7.0 (5.5-8.5)	6.0 (4.9-7.1)	27 (25-30)	12 (10-14)	15 (13-17)
Yes	1128 (31.2)	21 (16-25)	8.5 (6.0-11)	12 (8.8-15)	43 (38-48)	16 (14-18)	27 (22-31)
Leisure time <sup>j</sup>							
No	4413 (76.9)	15 (13-17)	7.7 (6.6-8.8)	7.6 (6.5-8.7)	30 (28-32)	12 (11-13)	19 (17-20)
Yes	1321 (23.0)	17 (14-20)	8.5 (6.5-10)	8.6 (6.4-11)	35 (32-39)	15 (13-18)	20 (17-23)
Leisure-time firearm <sup>k</sup>							
No	5352 (93.3)	15 (13-16)	7.6 (6.8-8.5)	7.1 (6.0-8.2)	30 (28-32)	12 (12-13)	17 (16-19)
Yes	384 (6.7)	28 (21-34)	11 (6.6-16)	17 (11-22)	53 (47-58)	17 (13-22)	35 (30-41)
<b>Cardiovascular Risks</b>							
Smoking, pack-years <sup>l</sup>							
Nonsmoker	3008 (52.4)	13.0 (11.0-15.0)	7.2 (5.9-8.4)	5.5 (4.2-6.8)	25 (23-27)	11 (9.4-13)	14 (12-15)
<20	1449 (25.2)	12.0 (9.3-14.0)	5.8 (4.4-7.2)	6.1 (4.5-7.8)	30 (26-34)	14 (12-16)	16 (13-19)
≥20	813 (14.2)	35 (30-39)	15 (11-19)	19 (16-22)	60 (56-65)	18 (15-21)	42 (38-47)
Unknown	458 (8.0)	11.0 (7.8-14.0)	5.4 (3.4-7.5)	5.4 (2.8-7.9)	25 (20-30)	12 (7-16)	13 (10-17)
Hypertension <sup>m</sup>							
No	3886 (67.7)	12 (10-13)	5.9 (4.9-6.9)	5.7 (4.7-6.6)	26 (24-28)	11 (10-13)	14 (13-16)
Yes	1849 (32.2)	26 (23-29)	13 (11-15)	13 (11-16)	47 (43-50)	17 (14-19)	30 (27-33)
Diabetes mellitus							
No	5198 (90.5)	14 (12-15)	7.2 (6.4-8.1)	6.7 (5.7-7.7)	29 (28-31)	13 (12-14)	17 (15-18)
Yes	544 (9.5)	39 (32-46)	17 (13-21)	22 (17-28)	61 (55-66)	15 (11-18)	46 (40-53)

<sup>a</sup> Among the audiometry subsample (n=5742), with sample weights applied.

<sup>b</sup> Unweighted number of participants.

<sup>c</sup> Unilateral and bilateral hearing loss are mutually exclusive categories.

<sup>d</sup> Pure-tone mean of 25 dB or higher at 0.5, 1, 2, and 4 kHz in 1 ear only.

<sup>e</sup> Pure-tone mean of 25 dB or higher at 0.5, 1, 2, and 4 kHz in both ears.

<sup>f</sup> Pure-tone mean of 25 dB or higher at 3, 4, and 6 kHz in 1 ear only.

<sup>g</sup> Pure-tone mean of 25 dB or higher at 3, 4, and 6 kHz in both ears.

<sup>h</sup> Four participants had missing data.

<sup>i</sup> Based on 1999-2000 and 2001-2002; 46 participants had missing data.

<sup>j</sup> Eight participants had missing data.

<sup>k</sup> Six participants had missing data.

<sup>l</sup> Fourteen participants had missing data.

<sup>m</sup> Seven participants had missing data.

**Table 2. Prevalence of Different Types of Hearing Loss by Age, Sex, and Race/Ethnicity, National Health and Nutrition Examination Survey (1999-2004)<sup>a</sup>**

Age, y	% (95% Confidence Interval)						P Value ( $\chi^2$ or F Statistic)
	Men			Women			
	White (n=1238)	Black (n=563)	Mexican American (n=618)	White (n=1415)	Black (n=620)	Mexican American (n=757)	
<b>Bilateral Hearing Loss<sup>b</sup></b>							
20-29	0.9 (0.0-2.3)	0.9 (0.0-2.6)	0.6 (0.0-1.8)	0.0 (0.0-0.1)	1.9 (0.3-3.6)	0.7 (0.0-1.8)	.14
30-39	3.3 (0.7-6.0)	2.5 (0.0-5.3)	4.4 (0.1-8.7)	1.5 (0.0-3.1)	...	0.9 (0.0-2.4)	.27 <sup>c</sup>
40-49	7.5 (3.7-11)	2.5 (0.0-5.7)	4.7 (1.1-8.4)	4.4 (1.2-7.6)	0.9 (0.0-2.8)	2.2 (0.0-4.6)	.10
50-59	24 (19-30)	14 (7-21)	21 (13-29)	7.5 (5-10)	3 (0-6)	13 (3-22)	<.001
60-69	43 (34-53)	21 (13-29)	52 (41-63)	20 (14-27)	13 (7-20)	13 (7-19)	<.001
<b>Unilateral Hearing Loss<sup>d</sup></b>							
20-29	2.6 (0.7-4.5)	4.2 (0.3-8.2)	4.2 (1.5-6.8)	1.7 (0.0-3.5)	1.5 (0.0-3.7)	0.1 (0.0-0.4)	.29
30-39	4.4 (1.9-7.0)	3.6 (0.0-7.3)	8.5 (4.0-13.0)	1.8 (0.2-3.4)	1.9 (0.0-4.4)	1.5 (0.0-3.6)	.01
40-49	14.0 (8.5-19.0)	4.7 (1.0-8.4)	14.0 (9.1-19.0)	5.8 (3.1-8.6)	1.6 (0.0-3.9)	2.1 (0.0-4.9)	<.001
50-59	19 (13-24)	9 (3-15)	5 (1-9)	12 (8-16)	7.5 (1-14)	5 (0-10)	.002
60-69	22 (16-28)	23 (13-34)	12 (8-16)	15 (11-20)	11 (5-17)	20 (13-26)	.01
<b>High-Frequency Hearing Loss<sup>e</sup></b>							
20-29	15 (9-20)	7 (2-12)	15 (10-20)	2.1 (0.2-3.9)	4.1 (1.4-6.8)	2.4 (0.0-4.8)	<.001
30-39	33 (26-39)	19 (11-27)	24 (15-33)	6.1 (3.3-8.9)	4.8 (1.5-8.1)	6.8 (0.8-13.0)	<.001
40-49	57 (50-65)	23 (16-29)	49 (43-55)	20 (15-25)	13 (7.5-18)	16 (11-22)	<.001
50-59	79 (72-85)	50 (42-59)	72 (63-84)	34 (29-40)	27 (16-7)	42 (30-54)	<.001
60-69	93 (90-96)	74 (66-83)	92 (86-98)	65 (58-73)	46 (38-54)	57 (50-65)	<.001

<sup>a</sup>Among the audiometry subsample (n = 5742), with sample weights applied. Ellipsis indicates no participants in this category.

<sup>b</sup>Pure-tone mean of 25 dB or higher at 0.5, 1, 2, and 4 kHz in both ears.

<sup>c</sup> $\chi^2$  Test excluded black women because of few participants in this category.

<sup>d</sup>Pure-tone mean of 25 dB or higher at 0.5, 1, 2, and 4 kHz in 1 ear only.

<sup>e</sup>Pure-tone mean of 25 dB or higher at 3, 4, and 6 kHz in either ear.

size of 3527 participants. Again, there were no significant differences between included and excluded participants for sex, age, and race/ethnicity.

## STATISTICAL ANALYSIS

We estimated the prevalence of speech-frequency and high-frequency hearing loss among the overall population and as stratified by noise exposure, cardiovascular risks, and demographic characteristics. Analyses were performed for unilateral and bilateral hearing loss. For ease of interpretation, we herein present analyses of unilateral and bilateral loss at speech frequencies and at high frequencies only in the first reported result. Thereafter, we distinguish between unilateral and bilateral hearing loss only in the speech-frequency response.

We explored the progression in hearing loss prevalence with age by sex and race/ethnicity categories. Within each age category, we used the  $\chi^2$  F statistic to evaluate whether prevalence levels differed across demographic groups.

Multiple logistic regression analysis was used to estimate the odds of having hearing loss associated with demographic characteristics, adjusting for noise exposure and cardiovascular risks. We evaluated the validity of self-reported hearing loss against a criterion standard of audiometric measurement. The sensitivity, specificity, and positive and negative predictive values of self-reported hearing loss were considered as measures of validity. We also assessed whether the validity of self-reported hearing loss differed across demographic groups.

All analyses were adjusted for the survey design using statistical software (SURVEY procedures in SAS; SAS Institute, Inc, Cary, North Carolina). Sample weights were incorporated into all analyses by using NCHS instructions (WEIGHT statement in SAS). All prevalences, odds ratios, and variance estimates

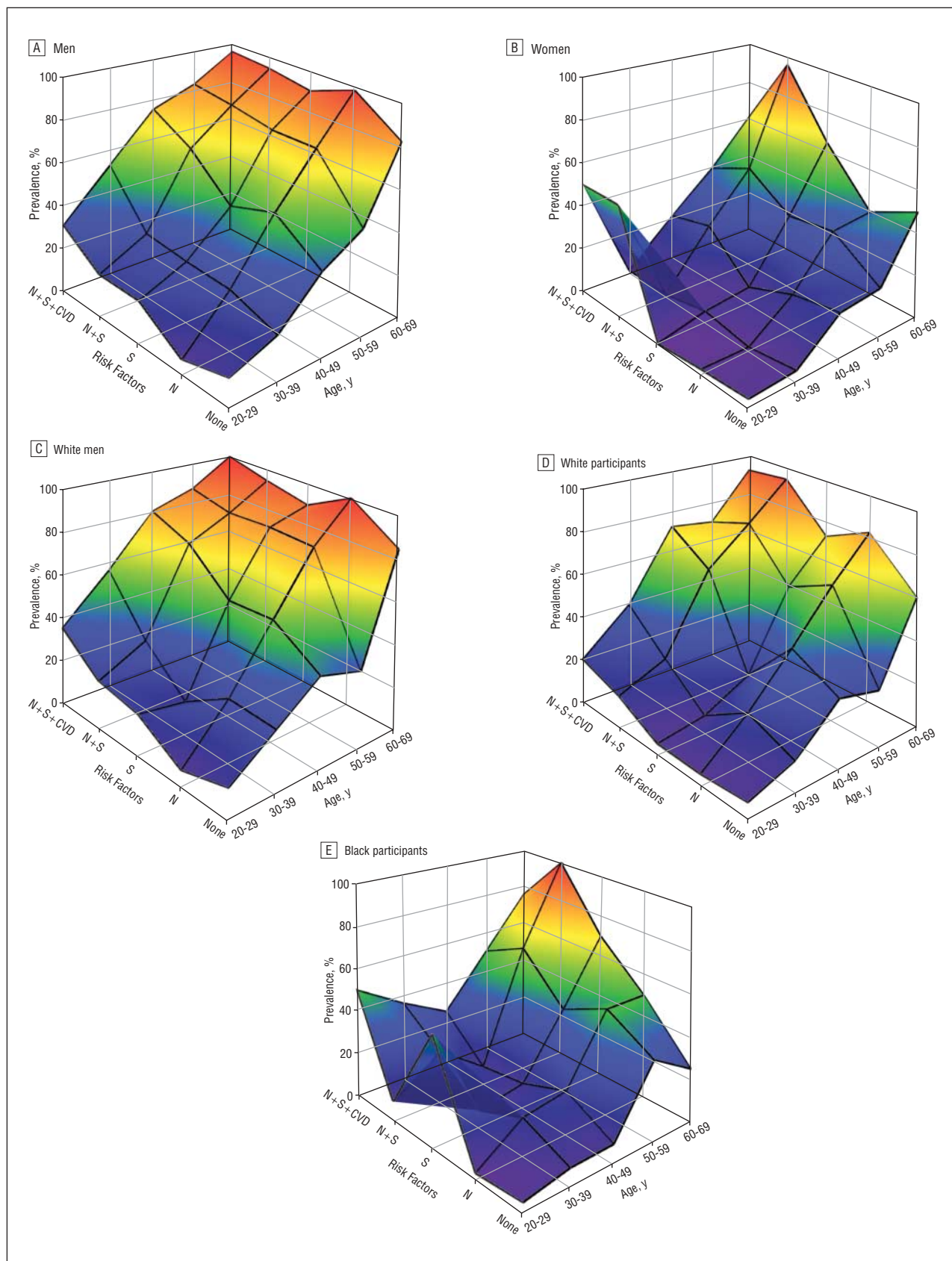
are from weighted analyses unless otherwise specified.  $P < .05$  was considered statistically significant.

## RESULTS

The overall prevalence of unilateral and bilateral hearing loss among the US population aged 20 to 69 years in 2003-2004 (the most recent dataset) was 16.1% (7.3% bilateral and 8.9% unilateral), corresponding to 29 million Americans (**Table 1**). Thirty-one percent of participants (equivalent to 55 million Americans) had high-frequency hearing loss. The prevalences of unilateral and bilateral high-frequency hearing loss were 12% and 19%, respectively.

We observed pronounced differences in hearing loss prevalence by demographic characteristics. Prevalences of speech-frequency and high-frequency hearing loss (unilateral and bilateral) were higher among men and among white, older, and less educated participants (Table 1). Hearing loss, particularly at high frequencies, was present in the third (8.5% prevalence) and fourth (17% prevalence) decades of life. Participants with exposure to occupational, leisure-time, and firearm noise had more unilateral, bilateral, and high-frequency hearing loss compared with participants without those noise exposures. Hearing loss prevalences were higher among participants with hypertension, diabetes mellitus, and heavy tobacco use ( $\geq 20$  pack-years).

We evaluated whether the pattern of increasing prevalence with age differed by sex or race/ethnicity (**Table 2**).



**Figure.** Graphical representation of high-frequency hearing loss (the most prevalent form of hearing loss detected in the present study) by age and by risk factors. Risk factors are as follows: no risk factors (None); noise exposure only (firearm, leisure time, or occupational) (N); smoking only (S); noise exposure and smoking (N + S); and noise exposure, smoking, and cardiovascular risks (ie, hypertension and diabetes mellitus) (N + S + CVD) among men (A), women (B), white men (C), white participants (D), and black participants (E). Graphs could not be created for Mexican Americans and for groups of other races/ethnicities because of too many missing data points.

**Table 3. Adjusted Odds Ratios (ORs) of Hearing Loss by Demographic Characteristics, National Health and Nutrition Examination Survey (1999-2002)<sup>a</sup>**

Demographic Characteristic	OR (95% Confidence Interval) of Type of Hearing Loss		
	Bilateral <sup>b</sup>	Unilateral <sup>c</sup>	High Frequency <sup>d</sup>
Sex			
Female	1 [Reference]	1 [Reference]	1 [Reference]
Male	2.4 (1.7-3.5)	2.0 (1.4-2.9)	5.5 (4.0-7.5)
Age, y			
20-29	1 [Reference]	1 [Reference]	1 [Reference]
30-39	3.3 (0.9-12.0)	1.1 (0.4-2.8)	2.1 (1.4-3.2)
40-49	9.5 (3.3-28.0)	4.0 (1.7-9.4)	6.7 (4.3-10.0)
50-59	33 (10-112)	4 (2-9)	14 (9-23)
60-69	101 (29-344)	5 (2-12)	50 (31-81)
Race/ethnicity			
White, non-Hispanic	1 [Reference]	1 [Reference]	1 [Reference]
Black, non-Hispanic	0.4 (0.2-0.5)	0.5 (0.3-0.7)	0.3 (0.3-0.4)
Mexican American	0.7 (0.4-1.1)	0.8 (0.5-1.1)	0.6 (0.5-0.9)
Other	1.3 (0.7-2.1)	0.8 (0.5-1.5)	0.7 (0.5-1.0) <sup>e</sup>
Education			
<High school	1 [Reference]	1 [Reference]	1 [Reference]
High school diploma, including general equivalency diploma	0.4 (0.3-0.6)	0.9 (0.6-1.4)	0.6 (0.4-0.9)
>High school	0.3 (0.2-0.5)	0.6 (0.4-0.9)	0.5 (0.3-0.7)

<sup>a</sup> Adjusted for age, sex, race/ethnicity, education, smoking, noise exposure, diabetes mellitus, and hypertension among the audiometry subsample (n=3853), with sample weights applied.

<sup>b</sup> Pure-tone mean of 25 dB or higher at 0.5, 1, 2, and 4 kHz in both ears.

<sup>c</sup> Pure-tone mean of 25 dB or higher at 0.5, 1, 2, and 4 kHz in 1 ear only.

<sup>d</sup> Pure-tone mean of 25 dB or higher at 3, 4, and 6 kHz in either ear.

<sup>e</sup> P < .05.

White and Mexican American men had the highest prevalences of bilateral and high-frequency hearing loss, and this difference was first noted in the third decade of life, particularly among white men. The prevalence of high-frequency hearing loss was 15% among white and Mexican American men aged 20 to 29 years compared with 6.8% among black men and 2.1% to 4.1% among women of the same age. Differences by sex and race/ethnicity in hearing loss prevalence (particularly high-frequency hearing loss) became pronounced among subjects aged 40 to 49 years: 57% of white men had high-frequency hearing loss compared with 23% of black men and 13% to 20% of women. White men aged 60 to 69 years had a 93% prevalence of high-frequency hearing loss; men generally had higher prevalences of bilateral, unilateral, and high-frequency hearing loss across the age range compared with women, and white women generally had greater hearing loss than black and Mexican American women. Overall tests for differences among demographic groups showed statistically significant differences in high-frequency hearing loss prevalence at all age levels.

We explored the effects of age, sex, race/ethnicity, smoking, noise exposure, and cardiovascular risks on the most prevalent form of hearing loss assessed (high-frequency hearing loss) (Figure). We show separate graphs for male, female, white, and black participants; graphs could not be created for Mexican Americans and for groups of other races/ethnicities because of a scarcity of observations within data subsets. Prevalence trends were similar for bilateral and high-frequency hearing loss; graphs of high-frequency hearing loss are shown be-

cause prevalences were higher and the trends easier to discern. Among white participants (male and female; Figure, D) and male participants (all races/ethnicities; Figure, A), the prevalence of hearing loss increased as a function of age and with increasing risk factors. This relationship was most apparent in white male participants (Figure, C), among whom high-frequency hearing loss was almost 100% prevalent among those aged 60 to 69 years at all risk factor levels. However, steep increases in hearing loss prevalence occur earlier among participants with smoking, noise exposure, and cardiovascular risks (at age 40-49 years) compared with participants without these risk factors (at age 60-69 years).

We evaluated whether the observed differences in hearing loss prevalence by demographic characteristics could be explained by differences in noise exposure and cardiovascular risks (Table 3). In multiple regression analysis, male subjects and white, older, and less educated participants had significantly higher odds of bilateral and high-frequency hearing loss, even after adjustment for noise exposure and cardiovascular risks. We subsequently restricted analyses to participants without noise exposure (n=2293), without cardiovascular risks (n=1395), and without noise exposure or cardiovascular risks (n=926). Significant associations among age, sex, and race/ethnicity with bilateral and high-frequency hearing loss persisted (data not shown). The associations between demographic characteristics and unilateral hearing loss were generally weaker.

Given that the most widely cited national estimate of hearing loss prevalence is based on self-report,<sup>22</sup> we evalu-

**Table 4. Sensitivity, Specificity, Positive Predictive Value (PPV), and Negative Predictive Value (NPV) of Self-reported Hearing Loss With Audiometry as the Gold Standard, National Health and Nutrition Examination Survey (1999-2004)<sup>a</sup>**

Type of Hearing Loss	% (95% Confidence Interval)			
	Sensitivity	Specificity	PPV	NPV
Bilateral <sup>b</sup>	65 (60-69)	83 (82-84)	28 (25-30)	96 (95-97)
Unilateral <sup>c</sup>	46 (42-51)	81 (80-82)	17 (15-20)	95 (94-95)
High frequency <sup>d</sup>	41 (39-44)	88 (87-89)	63 (61-66)	76 (74-77)

<sup>a</sup>Among the audiometry subsample (n=5742), with sample weights applied.

<sup>b</sup>Pure-tone mean of 25 dB or higher at 0.5, 1, 2, and 4 kHz in both ears.

<sup>c</sup>Pure-tone mean of 25 dB or higher at 0.5, 1, 2, and 4 kHz in 1 ear only.

<sup>d</sup>Pure-tone mean of 25 dB or higher at 3, 4, and 6 kHz in either ear.

ated the accuracy of self-report as a measure of hearing loss compared with a criterion standard of audiometric measurement (**Table 4**). Overall, the sensitivity of self-reported hearing loss was low (range, 41%-65%). The sensitivity of self-report was significantly higher for bilateral hearing loss (65%) than for unilateral hearing loss (46%) or high-frequency hearing loss (41%).

Finally, in light of concern that hearing loss is growing, particularly among young people, we explored whether hearing loss prevalences changed between 1999-2000 and the 2001-2002 and 2003-2004 datasets (**Table 5**). As already reported, the overall prevalences of speech-frequency and high-frequency hearing loss among the population changed little. However, in analyses stratified by age, we observed an increase in high-frequency (3, 4, and 6 kHz) pure-tone (8.9-10 dB) means among subjects aged 20 to 29 years from 1999 to 2004. This difference was statistically significant between the 1999-2000 and 2001-2002 datasets; no other differences achieved statistical significance. We observed similar trends for speech-frequency hearing loss (data not shown).

#### COMMENT

Findings from this study suggest that hearing loss is more common among US adults than previously reported. Our estimate of 29 million Americans was among subjects aged 20 to 69 years and exceeds the often-cited estimate of 28 million Americans among all ages who were found (in 1989) to have hearing loss based on self-report.<sup>22</sup> This increased prevalence may in part reflect a true increase in prevalence driven by the aging population (represented as a skew toward the older age groups in our data)<sup>18</sup> and a heightened risk posed by exposure to damaging noise.<sup>20,21</sup>

The difference in prevalence estimates may also result from differences in the method used to assess hearing loss. Estimates based on self-report may be inaccurate given the observed tendency of some individuals to deny or minimize their hearing loss. Indeed, our findings corroborate that the sensitivity of self-reported hearing loss for identifying audiometrically confirmed hear-

**Table 5. Comparison of High-Frequency Pure-tone Means Among 1999-2000, 2001-2002, and 2003-2004 National Health and Nutrition Examination Survey Data<sup>a</sup>**

Age, y	Pure-Tone Mean (95% Confidence Interval), dB <sup>b</sup>		
	1999-2000	2001-2002	2003-2004
Overall	20 (18-21)	20 (18-22)	20 (18-21)
20-29	8.9 (7.8-10.0)	10.0 (9.4-11.0)	10.0 (8.1-12.0)
30-39	14 (13-16)	14 (13-16)	15 (14-16)
40-49	21 (19-23)	21 (19-23)	20 (18-22)
50-59	30 (26-34)	29 (26-33)	28 (25-31)
60-69	39 (34-44)	39 (37-41)	38 (35-40)

<sup>a</sup>Among the audiometry subsample in all 3 datasets (1682 participants in 1999-2000, 1864 participants in 2001-2002, and 1768 participants in 2003-2004), with sample weights applied.

<sup>b</sup>At 3, 4, and 6 kHz in both ears.

ing loss is poor. Therefore, estimates based on self-reported hearing loss may underestimate the true extent of the prevalence of a disorder. Comparisons of our prevalence findings with other national estimates are difficult because of differences in the age distributions of the populations surveyed. As would be expected, the present prevalence estimate of 16.1% (based on US adults aged 20-69 years) is lower than national estimates derived from adults of all ages (eg, 27% in Norway,<sup>35</sup> 35% in the United Kingdom,<sup>36</sup> and 22% in Australia<sup>37</sup>). In addition, our prevalence may be an underestimate given that the audiometric instrumentation used in the survey had a hard upper limit of hearing level, possibly causing a downward bias in pure-tone means.

Hearing loss is highly prevalent among persons older than 70 years.<sup>13,16</sup> However, few studies<sup>35,38</sup> have evaluated when hearing loss first develops among large populations of adults and whether prevalences increase gradually or nonlinearly with age. The degree to which trends in the prevalence of hearing loss differ by sex and race/ethnicity has not been shown, to our knowledge. We found that hearing loss, specifically high-frequency hearing loss, was present in 8.5% of the youngest age group (20-29 years) and in 17% of the group aged 30 to 39 years. Our data suggest that the prevalence of hearing loss is increasing among these younger age groups. In addition, a disproportionate burden of hearing loss is experienced by male and white (and to a lesser extent Mexican American) participants and is manifest in the third decade of life. Discrepancies in hearing loss prevalence by sex and race/ethnicity have been noted among children as well,<sup>39</sup> suggesting that divergences in hearing level are set in motion at earlier life stages.

The results of our study also suggest that hearing loss develops first at high frequencies. Because high-frequency hearing loss alters the reception of consonant sounds (or phonemes), it reduces speech recognition.<sup>40</sup> In addition, high-frequency hearing loss may be a precursor of further significant hearing loss affecting mid- and lower-spectrum speech frequencies. We found that individuals are substantially less likely to report or be aware of high-frequency hearing loss compared with bilateral hearing loss. Therefore, audiometric screening is

critical to capture the true prevalence of hearing loss, particularly at an early pathogenetic stage among young adults.

These data show that the prevalence of hearing loss increased with age among all demographic groups and at all levels of smoking, noise exposure, and cardiovascular risks. Hearing loss prevalence progressed at an earlier age among participants with smoking, noise exposure, and cardiovascular risks. Smoking cessation, reduction of noise exposure, and effective treatment of diabetes mellitus and hypertension may delay the onset of hearing loss. Addressing some of the modifiable health risks associated with aging could result in further hearing loss prevalence reductions.

In this study, approximately 50% of speech-frequency hearing loss was unilateral, and 50% was bilateral. Age had a markedly smaller association with unilateral hearing loss prevalence, and male, white, and less educated participants had a modestly increased risk of unilateral hearing loss. These findings suggest that unilateral and bilateral hearing losses may be mediated by distinct pathophysiologic processes among susceptible populations with different risk factors. Unilateral hearing loss may be associated with more focal processes, including thromboembolic phenomena, infections (eg, otitis media and mumps), local tumors (eg, vestibular schwannoma), and certain types of noise exposure (eg, firearm noise).<sup>41</sup> Bilateral hearing loss may be associated with more diffuse or systemic exposures such as occupational noise exposure or microvascular disease. Risk factors for unilateral hearing loss seem not to segregate as closely with age, sex, or racial/ethnic factors.

The NHANES data are comprehensive and nationally representative; nevertheless, there are several potential sources of bias in the data that must be considered. Participants were selected at random based on demographic criteria; it is possible that medically unwell individuals were more (or perhaps less) likely to participate. Approximately 8% of individuals had missing audiometric data, which was not accounted for by the sample weights; this may also have introduced bias.

It is important for health care providers (ie, primary care physicians, specialists, and other medical personnel and allied health professionals) to fully appreciate the manifold and nuanced effects of hearing loss. Mild hearing loss can impair speech processing, particularly if speech is rapid or delivered with an unfamiliar accent or voice<sup>42</sup> or if multiple talkers in large rooms generate reverberant noise.<sup>43</sup> Therefore, verbal communication difficulties are most prominent in settings where people gather. Reduced social connectivity likely mediates the observed associations between hearing loss and depression, cognitive decline, reduced quality of life, and increased morbidity and mortality.<sup>5-8,10-12</sup>

The public health implications of our findings are underscored by the dramatic projected increases in the prevalence of hearing loss. Although these data are cross-sectional, they offer some insight into the progression of hearing loss and identify particularly vulnerable groups. The results of our study suggest that prevention (through risk factor reduction) and screening must begin at least in young adulthood and that efforts should be intensi-

fied among white and Mexican American men. Hearing loss reduces health-related quality of life<sup>9</sup> and access to health care.<sup>11</sup> Minimizing this morbidity through hearing loss prevention and management programs may produce substantial public health benefits.

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