Prevalence of Hearing Loss and Work-Related Noise-Induced Hearing Loss in Michigan

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Objective: *This study assessed the prevalence of self-reported hearing loss (HL) and work-related noise-induced hearing loss (NIHL) in Michigan.* ***Methods:*** *Questions related to HL and NIHL were added to the 2003 Behavioral Risk Factor Surveillance System in Michigan, a national telephone survey-based surveillance system of health conditions among adults.* ***Results:*** *An estimated 19% reported HL; the proportion with HL increased steeply with age. Among those with HL, 29.9% reported that their HL was related to noise at work. Associations were found between HL/NIHL and current cigarette smoking and elevated cholesterol.* ***Conclusions:*** *Self-reported HL is common in Michigan. Almost 30% of this loss was attributed to noise exposure at work, a preventable condition. Prevalence estimates from this study were higher than previously published estimates. Better surveillance and prevention programs are recommended.* (J Occup Environ Med. *2008;50: 72–79*)

Workers in noisy industries are at increased risk of hearing loss (HL)[1,2] and approximately 30 million workers are exposed to dangerous noise levels each day.[2] The nation's public health goals for 2010 include objectives to reduce the proportion of adults with noise-induced hearing loss (NIHL),[3] but these objectives do not specifically address the major source of NIHL in adults—noise exposure at work. There is a lack of historic and current data on the magnitude of work-related NIHL.[4] This study provides estimates of the magnitude of work-related NIHL in Michigan. The approach used to generate these estimates can be used in other states.

Work-related NIHL has been a public health concern in Michigan, with its large manufacturing sector. Work-related HL is a reportable condition in the State's Public Health Code, but underreporting is likely.[5] To determine a better estimate of the prevalence of HL and work-related NIHL in the state, questions about HL and work-related NIHL were added to 1 year of an established, ongoing telephone survey-based surveillance system, the Behavioral Risk Factor Surveillance System (BRFSS). Questions were adapted from the National Health Interview Survey (NHIS), a national survey of health conditions and risk factors,[6] for inclusion in the 2003 survey of the Michigan BRFSS. Questions about HL related to noise exposure at work were also included. Data on health conditions and health risk behaviors routinely collected in BRFSS allowed for the inclusion of other

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health conditions such as hypertension and cigarette smoking in the analysis.

Materials and Methods

The BRFSS is a national surveillance system conducted by the Centers for Disease Control and Prevention in collaboration with participating states. It has been tracking health conditions and risk behaviors in the United States annually since 1984 and comprises state-level random-digit-dialed telephone surveys of the civilian, noninstitutionalized population aged 18 years and older. BRFSS provides state-specific information about the prevalence of health factors such as asthma, diabetes, health care access, alcohol use, hypertension, obesity, cancer screening, nutrition, physical activity, tobacco use, and more, along with basic demographic data. States have the option of adding questions or modules to the core questions from Centers for Disease Control and Prevention, which are included in all state surveys.[7]

The 2003 Michigan BRFSS survey included a state-added module on HL that consisted of the following questions: "Do you now have deafness or trouble hearing in one or both ears?" and "Do you now use a hearing aid?". Those who answered "yes" to either of these questions were asked: "How old were you when you first developed deafness or trouble hearing in one or both ears?". Those whose HL first developed at age 16 years or older were asked, "Did a doctor or other medical person ever tell you that your deafness or trouble hearing was related to noise exposure at work?" and "Did you ever tell a doctor or other medical person that your deafness or trouble hearing was related to noise exposure at work?". The questions on HL were adapted from questions used in the NHIS from 1971 to 1998. The questions on age of onset and work-relatedness were adapted from questions used to estimate the prevalence of work-related asthma in the 2002 BRFSS in three states.[8]

The 2003 Michigan BRFSS survey was conducted using a sample of telephone numbers selected using a random-digit-dialed methodology. The 2003 Michigan BRFSS included 3551 completed interviews. Estimates were weighted to adjust for the probabilities of selection and the distributions of Michigan adults by age, sex, and race.

HL was defined as a positive response to either the HL or hearing aid question. Work-related NIHL was defined as a positive response to at least one of the questions about whether either the respondent or a medical person thought that the deafness or trouble hearing was related to noise exposure at work; all other HL was considered non-work-related.

"Ever smoking" was defined as ever having smoked 100 cigarettes or more and "current smoking" as currently smoking every day or some days. Diabetes, high cholesterol, and high blood pressure were defined as a doctor or other health professional ever having told the respondent that he or she had that respective disease or condition.

Analyses were performed in SUDAAN (Research Triangle Institute, Research Triangle Park, NC), a statistical computing program designed for complex sample surveys. Prevalence estimates and 95% confidence intervals for any HL and work-related NIHL were estimated by age, sex, race, education, and household income. χ^2 tests and χ^2 linear tests for trend were performed by these same demographic variables. In addition, the population-based prevalence of all three HL indicators (ie, any HL, work-related NIHL, and non-work-related HL) were examined by four health-related conditions that may be associated with HL: smoking, diabetes, high cholesterol, and high blood pressure. Logistic regressions were generated and adjusted odds ratios (AOR) were examined using all respondents; this analysis was then repeated for younger adults (aged 18 to 54 years) and older adults (aged ≥55 years) separately. All demographic and health-related independent variables were kept in the models regardless of significance.

Results

Nearly 19% (18.9%) of Michigan adults aged 18 years and older were estimated to have deafness or trouble hearing in one or both ears in 2003 and 2.6% used a hearing aid (Table 1). Only 13.8% (95% CI, 11.3 to 16.4) of those with deafness or hearing trouble used the hearing aid. Combining responses from these two questions, 19.0% of Michigan adults were estimated to have HL, defined as either having deafness or trouble hearing, or using the hearing aid.

The proportion with HL increased steeply with age, from 10.2% of those aged 18 to 44 years to 44.2% of those 75 years or older. Men were more likely to have HL than were women (23.2% to 15.1%); and whites more likely than blacks (20.5% to 11.7%). The prevalence of HL was greater among those with less formal education versus those who had graduated from college, and greater among those with household incomes of <$50,000 compared with high-income groups.

The percent distribution of age when HL first developed is presented in Table 2. Only 12.0% reported that their HL began before the age of 16. The majority (54.0%) first developed HL between the ages of 16 and 54 years, 26.1% developed HL at age 55 or older, and 7.9% reported that they did not know when their HL first developed. Among the 88% whose HL began at age 16 or older (including those who did not know), a larger proportion of those with work-related HL developed trouble hearing between the ages of 16 and 54 compared with those whose HL was not work-related (76.9% vs 54.9%; $P < 0.0001$).

Among those whose HL developed at age 16 years or older, 20.4% had ever told a doctor or other medical person that their deafness was

TABLE 1
Prevalence of Self-Reported Hearing Loss, Hearing Aid Use, and Total Hearing Loss by Selected Demographic Characteristics, 2003 Michigan BRFSS, Percent (95% Confidence Interval)

Demographic Characteristics	Hearing Loss in One or Both Ears[a]	Currently Used Hearing Aid[b]	Total Hearing Loss[c]
Total	18.9 (17.5–20.3)	2.6 (2.2–3.1)	19.0 (17.6–20.5)
Age			
18–44	10.2 (8.5–12.2)	0.4 (0.1–1.0)	10.2 (8.6–12.2)*
45–64	22.9 (20.5–25.6)	1.7 (1.1–2.6)	23.0 (20.5–25.7)
65–74	33.1 (28.2–38.4)	7.7 (5.4–10.9)	33.1 (28.2–38.4)
≥75	43.1 (37.9–48.4)	14.9 (11.6–19.0)	44.2 (38.9–49.5)
Sex			
Male	23.2 (20.9–25.6)	3.0 (2.3–3.9)	23.2 (20.9–25.7)†
Female	14.9 (13.3–16.6)	2.2 (1.7–2.9)	15.1 (13.5–16.8)
Race			
White	20.3 (18.8–22.0)	3.0 (2.5–3.7)	20.5 (18.9–22.1)‡
Black	11.7 (8.2–16.4)	0.4 (0.1–1.8)	11.7 (8.2–16.4)
Other	13.3 (9.3–18.7)	1.1 (0.3–3.5)	13.3 (9.3–18.7)
Education			
Less than high school	23.4 (18.9–28.6)	4.4 (2.8–6.9)	23.5 (19.1–28.7)§
High school graduate	20.3 (17.8–23.0)	2.8 (2.0–3.8)	20.5 (17.9–23.2)
Some college	20.9 (18.2–23.9)	2.0 (1.3–3.0)	21.0 (18.3–24.0)
College graduate	13.6 (11.6–16.0)	2.4 (1.7–3.5)	13.7 (11.7–16.1)
Household income			
<$20,000	21.9 (18.4–25.9)	3.2 (2.1–4.8)	22.0 (18.4–26.0)¶
$20,000–$34,999	22.1 (18.9–25.6)	3.9 (2.8–5.4)	22.2 (19.1–25.7)
$35,000–$49,999	19.5 (16.1–23.6)	2.2 (1.3–3.8)	19.7 (16.2–23.7)
$50,000+	14.7 (12.7–17.0)	1.5 (0.9–2.3)	14.8 (12.8–17.1)

*$\chi^2 = 199.21$ ($P < 0.0001$); Wald χ^2 for trend = 181.77 ($P < 0.0001$).
†$\chi^2 = 30.70$ ($P < 0.0001$).
‡$\chi^2 = 20.13$ ($P < 0.0001$).
§$\chi^2 = 26.28$ ($P < 0.0001$); Wald χ^2 for trend = 14.26 ($P = 0.0002$).
¶$\chi^2 = 19.87$ ($P = 0.0002$); Wald χ^2 for trend = 12.57 ($P = 0.0004$).
[a]Responded "yes" to the question, "Do you now have deafness or trouble hearing in one or both ears?".
[b]Responded "yes" to the question, "Do you now use a hearing aid?".
[c]Responded "yes" to either of the above questions.

TABLE 2
Percent Distribution of Age When Hearing Loss First Developed, Among All Persons With Hearing Loss, and By Whether Hearing Loss Was Work-Related Among Those Whose Hearing Loss Developed at Age 16 or Older, 2003 Michigan BRFSS

Age (Yrs) When Hearing Loss First Developed	Any Hearing Loss % (95% CI)	Work-Related Noise-Induced Hearing Loss % (95% CI)	Non-Work-Related Hearing Loss % (95% CI)
0–15	12.0 (9.5–15.1)		
16–34	25.7 (22.0–29.8)	35.2 (27.6–43.7)	26.9 (22.1–32.3)
35–54	28.3 (24.7–32.1)	41.7 (34.0–49.9)	28.0 (23.7–32.9)
55–64	10.7 (8.7–13.3)	8.5 (5.3–13.2)	13.9 (10.9–17.5)
65–74	9.9 (8.0–12.1)	7.1 (4.4–11.4)	13.1 (10.4–16.4)
≥75	5.5 (4.2–7.3)	1.6 (0.6–4.0)	8.3 (6.2–11.1)
Don't know	7.9 (5.9–10.4)	5.9 (2.9–11.3)	9.8 (7.1–13.4)

related to noise exposure at work, and 25.9% had ever been told by a medical person that their deafness was related to noise exposure at work. Combining these two, 29.9% were classified as having work-related NIHL (Table 3). Those with HL who were aged 75 years or older were less likely to have work-related NIHL compared with other age groups, as were women compared with men, and those with a college degree compared with those without. Household income was not associated with work-related NIHL.

Population-based prevalence estimates and results from multiple logistic regressions are presented in Table 4 for work-related NIHL, non-work-related HL, and both types of HL combined. After adjusting for all other independent variables in the model, age, sex, race, and education

TABLE 3
Proportion Whose Hearing Loss is Related to Noise Exposure at Work, Among Those Whose Hearing Loss Developed at Age 16 yr or Older, 2003 Michigan BRFSS, Percent (95% Confidence Interval)

Demographic Characteristics	Doctor Ever Told Respondent Hearing Loss Due to Noise Exposure at Work[a]	Respondent Ever Told Doctor Hearing Loss Due to Noise Exposure at Work[b]	Hearing Loss Related to Noise Exposure at Work[c]
Total	25.9 (22.2–29.9)	20.4 (17.1–24.2)	29.9 (26.0–34.1)
Age			
18–44	27.3 (18.6–38.2)	17.8 (10.9–27.6)	30.2 (21.0–41.3)*
45–64	30.2 (24.5–36.7)	26.6 (21.1–32.9)	34.9 (28.8–41.5)
65–74	30.6 (22.1–40.8)	21.6 (14.4–31.1)	34.3 (25.4–44.4)
≥75	10.9 (6.8–16.9)	9.6 (5.9–15.2)	15.4 (10.5–22.0)
Sex			
Male	36.4 (30.8–42.3)	27.9 (22.9–33.5)	41.6 (35.8–47.6)†
Female	9.8 (6.8–13.8)	9.1 (6.2–13.1)	11.9 (8.6–16.2)
Education			
<High school graduate	27.3 (18.0–39.1)	15.7 (9.4–25.0)	30.9 (21.2–42.7)‡
High school graduate	27.9 (21.7–35.2)	23.1 (17.2–30.3)	33.7 (26.9–41.3)
Some college	29.3 (22.5–37.2)	23.4 (17.3–30.8)	33.3 (26.1–41.4)
College graduate	16.8 (11.0–24.8)	15.3 (9.8–23.2)	18.3 (12.2–26.4)
Household income			
<$20,000	26.8 (19.1–36.3)	17.0 (11.1–25.0)	29.3 (21.3–38.9)§
$20,000–$34,999	22.8 (16.1–31.1)	22.5 (15.9–30.8)	30.9 (23.2–39.8)
$35,000–$49,999	26.9 (17.8–38.5)	18.6 (11.4–29.0)	31.0 (21.3–42.8)
≥$50,000	27.9 (21.0–36.2)	23.9 (17.4–31.9)	31.1 (23.8–39.4)

*$\chi^2 = 21.98$ ($P = 0.0001$); Wald χ^2 for trend = 6.40 ($P = 0.0114$).
†$\chi^2 = 61.20$ ($P < 0.0001$).
‡$\chi^2 = 11.13$ ($P = 0.0111$); Wald χ^2 for trend = 3.72 ($P = 0.0539$).
§$\chi^2 = 0.11$ ($P = 0.9912$).
[a]Responded "yes" to the question, "Did a doctor or other medical person ever tell you that your deafness or trouble hearing was related to noise exposure at work?".
[b]Responded "yes" to the question, "Did you ever tell a doctor or other medical person that your deafness or trouble hearing was related to noise exposure at work?".
[c]Responded "yes" to either of the above questions.

remained significantly associated with any HL (Wald F $P \leq 0.05$), whereas household income did not. When the logistic regressions were generated to examine work-related and non-work-related HL separately, work-related NIHL was significantly associated with age, sex, and education. Work-related NIHL was most strongly associated with the 65 to 74 year age group (AOR = 5.04) and to a lesser degree with the 45 to 64 year and ≥75-year groups (AOR ≈ 2.5). The prevalence of work-related NIHL was higher among men compared with women (8.7% vs 1.5%), higher among whites compared with blacks (5.5% vs 1.5%), and higher among non-college graduates compared with college graduates (6.8%/6.0% vs 2.2%). The AORs consistently supported these differences, although the overall Wald F *P*-value for race, for work-related NIHL, did not reach the 0.05 significance level ($P = 0.0739$). However, for non-work-related HL age was the only demographic variable that showed a significant association.

Four health-related factors were also included in the regression models (Table 4). The AOR was significant for current smokers compared with never smokers (but not significant for former smokers), for work-related NIHL but not for non-work-related HL. Diabetes was significantly associated with work-related NIHL (AOR = 1.72 [1.01–2.91]), but was not significantly associated with non-work-related HL (AOR = 1.14[0.79–1.65]). Neither work nor non-work-related HL was associated with high blood cholesterol. Although the prevalence estimates for HL were higher among those who had ever been told they had high blood pressure, within the multiple logistic regression framework none were significantly associated.

When these same regressions were repeated separately for younger adults (18 to 54 years) and older adults (≥55 years) results similar to those for all ages (as presented earlier) were observed for age and sex, ie, age was significantly associated with work- and non-work-related HL, with the exception of work-related NIHL among the 55+, whereas sex was associated with work-related NIHL, but not non-work related. Among younger adults, race was not associated with work or non-work-related HL, whereas among older adults, blacks had significantly lower odds of work-related HL (AOR = 0.10 [0.02–0.55]) compared with whites. Among younger adults, lower education was associated

TABLE 4
Prevalence and Adjusted Odds Ratios by Selected Demographic and Health-Related Characteristics for Any Hearing Loss, Work-Related Noise-Induced, and Non-Work-Related Hearing Loss, Among Those 18 yr or Older, 2003 Michigan BRFSS

	Any Hearing Loss		Work-Related Noise-Induced Hearing Loss		Non-Work-Related Hearing Loss	
	% (95% CI)	AOR (95% CI)*	% (95% CI)	AOR (95% CI)†	% (95% CI)	AOR (95% CI)‡
Total	19.0 (17.6–20.5)		5.0 (4.2–5.8)		14.0 (12.8–15.3)	
Age						
18–44	10.2 (8.6–12.2)	1.00	2.3 (1.5–3.4)	1.00	8.0 (6.6–9.8)	1.00
45–64	23.0 (20.5–25.7)	2.23 (1.69–2.94)	7.4 (6.0–9.2)	2.68 (1.57–4.55)	15.6 (13.5–18.0)	1.86 (1.37–2.53)
65–74	33.1 (28.2–38.4)	4.05 (2.83–5.80)	10.6 (7.6–14.7)	5.04 (2.57–9.92)	22.5 (18.3–27.3)	3.02 (2.02–4.50)
≥75	44.2 (38.9–49.5)	5.86 (4.05–8.49)	6.4 (4.3–9.4)	2.46 (1.15–5.26)	37.2 (32.2–42.4)	5.70 (3.88–8.37)
Sex						
Male	23.2 (20.9–25.7)	1.87 (1.51–2.32)	8.7 (7.3–10.4)	7.69 (4.88–12.12)	14.4 (12.6–16.6)	1.09 (0.86–1.38)
Female	15.1 (13.5–16.8)	1.00	1.5 (1.1–2.1)	1.00	13.5 (12.0–15.2)	1.00
Race						
White	20.5 (18.9–22.1)	1.00	5.5 (4.7–6.5)	1.00	14.9 (13.5–16.3)	1.00
Black	11.7 (8.2–16.4)	0.51 (0.32–0.82)	1.5 (0.6–3.8)	0.28 (0.09–0.84)	10.2 (7.0–14.8)	0.65 (0.40–1.07)
Other	13.3 (9.3–18.7)	0.76 (0.47–1.23)	4.7 (2.6–8.2)	1.09 (0.53–2.27)	8.6 (5.4–13.4)	0.67 (0.37–1.19)
Education						
<High school	23.5 (19.1–28.7)	1.52 (0.98–2.35)	6.8 (4.4–10.1)	2.54 (1.17–5.54)	16.5 (12.8–21.1)	1.21 (0.75–1.95)
High school graduate	20.5 (17.9–23.2)	1.30 (0.95–1.78)	6.0 (4.7–7.8)	2.37 (1.26–4.45)	14.2 (12.1–16.6)	1.03 (0.73–1.45)
Some college	21.0 (18.3–24.0)	1.67 (1.25–2.24)	6.0 (4.5–7.8)	2.69 (1.46–4.94)	15.1 (12.8–17.8)	1.35 (0.98–1.84)
College graduate	13.7 (11.7–16.1)	1.00	2.2 (1.4–3.4)	1.00	11.5 (9.6–13.8)	1.00
Household income						
<$20,000	22.0 (18.4–26.0)	1.07 (0.75–1.52)	5.9 (4.1–8.4)	1.09 (0.61–1.94)	16.0 (12.9–19.5)	1.04 (0.70–1.54)
$20,000–$34,999	22.2 (19.1–25.7)	1.11 (0.82–1.51)	5.7 (4.1–7.8)	1.00 (0.59–1.71)	16.4 (13.7–19.5)	1.13 (0.81–1.59)
$35,000–$49,999	19.7 (16.2–23.7)	1.17 (0.86–1.61)	5.4 (3.5–8.2)	1.07 (0.59–1.94)	14.0 (11.1–17.5)	1.15 (0.82–1.63)
≥$50,000	14.8 (12.8–17.1)	1.00	4.0 (2.9–5.4)	1.00	10.9 (9.2–12.9)	1.00
Cigarette smoking						
Never smoked	15.3 (13.5–17.2)	1.00	2.9 (2.1–3.9)	1.00	12.4 (10.8–14.3)	1.00
Former smoker	25.1 (22.4–28.1)	1.20 (0.94–1.54)	7.3 (5.7–9.2)	1.31 (0.81–2.13)	17.5 (15.2–20.2)	1.10 (0.84–1.45)
Current smoker	19.8 (16.9–23.1)	1.52 (1.14–2.03)	6.6 (4.9–8.8)	1.88 (1.12–3.15)	13.3 (10.8–16.2)	1.30 (0.94–1.79)
Diabetes						
Never told diabetes	17.8 (16.4–19.4)	1.00	4.4 (3.7–5.3)	1.00	13.3 (12.1–14.7)	1.00
Told diabetes	32.6 (27.2–38.4)	1.37 (0.98–1.92)	11.1 (7.9–15.3)	1.72 (1.01–2.91)	21.5 (17.0–26.7)	1.14 (0.79–1.65)
High cholesterol						
Never told high	15.4 (13.8–17.1)	1.00	4.0 (3.2–5.0)	1.00	11.4 (10.0–12.9)	1.00
Told high	27.2 (24.5–30.1)	1.27 (1.01–1.59)	7.5 (6.0–9.4)	1.11 (0.74–1.67)	19.6 (17.3–22.2)	1.28 (0.99–1.64)
High blood pressure						
Never told high	15.6 (14.1–17.3)	1.00	4.2 (3.4–5.2)	1.00	11.5 (10.1–12.9)	1.00
Told high	27.8 (25.0–30.9)	1.20 (0.94–1.53)	7.1 (5.6–8.9)	1.14 (0.75–1.75)	20.6 (18.0–23.4)	1.19 (0.92–1.55)

*From logistic regression, with any hearing loss as the dependent variable and age group (Wald F $P < 0.0001$), sex ($P < 0.0001$), race ($P = 0.0138$), education ($P = 0.0059$), household income ($P = 0.7745$), smoking ($P = 0.0152$), diabetes ($P = 0.0653$), high cholesterol ($P = 0.0445$), and high blood pressure ($P = 0.1384$) as the independent variables.

†From logistic regression, with work-related hearing loss as the dependent variable and age group (Wald F $P < 0.0001$), sex ($P < 0.0001$), race ($P = 0.0739$), education ($P = 0.0134$), household income ($P = 0.9867$), smoking ($P = 0.0565$), diabetes ($P = 0.0443$), high cholesterol ($P = 0.6112$), and high blood pressure ($P = 0.5328$) as the independent variables.

‡From logistic regression, with non-work-related hearing loss as the dependent variable and age group (Wald F $P < 0.0001$), sex ($P = 0.4681$), race ($P = 0.1116$), education ($P = 0.2048$), household income ($P = 0.8039$), smoking ($P = 0.2832$), diabetes ($P = 0.4827$), high cholesterol ($P = 0.0575$), and high blood pressure ($P = 0.1843$) as the independent variables.

with non-work-related HL, whereas among older adults the opposite was observed, ie, lower education was associated with work-related NIHL but not non-work-related HL. Household income was consistently not associated with either work or non-work-related HL.

In terms of health-related conditions, current cigarette smoking was significantly associated with work-related HL among those aged 18 to 54 years (AOR = 2.87 [1.35–6.12]). A relationship between smoking and HL was not observed among older adults. Diabetes was not significantly associated with HL in either age group. Among older adults (but not younger adults), the odds of non-work-related HL were 1.56 (1.14–2.14) for those who had been told they had high cholesterol compared with those who had not. High blood

pressure was consistently not significantly associated with HL.

Discussion

This telephone survey of Michigan residents provided data to estimate that HL affected 19% of all adults and 44% of adults 75 or older; these results support findings from other studies and national survey data that HL is common, particularly in older adults.[6,9–12] Applying the age-specific percentages of HL from the BRFSS data to the Michigan adult population of approximately 7,500,000, one would estimate that 822,000 men and 574,000 women or approximately 1.4 million adults in Michigan have HL, of which 200,000 used hearing aids. The low percentage of use of hearing aids in people with HL is consistent with previously published studies.[13]

These data showed a greater prevalence of HL in Michigan than nationally. Using data from the NHIS, the prevalence of HL was estimated at 11% in the 1990s[6] and 15% in 2003.[14] These national estimates from the NHIS are also based on self-reports. The Michigan BRFSS questions were based on the NHIS HL questions used before 1998.[6] Respondents to the NHIS from 1998 onward were asked to select the statement that best describes their hearing without the hearing aid: "good," "a little trouble," "a lot of trouble," or "deaf." The 2003 NHIS national estimate for the prevalence of HL was calculated by classifying all respondents who reported a little trouble or worse as having HL. The higher prevalence in Michigan versus the United States in 2003 (19.0% vs 15%) is probably not secondary to the different questions used in the two surveys, because the 2003 NHIS prevalence estimate is likely to have resulted in a more inclusive estimate than the BRFSS questions because even a "little trouble" was considered a positive response.

The findings that HL in Michigan is reported by men more frequently than women (23.2% vs 15.1%), by whites more frequently than blacks (20.5% vs 11.7%), and by lower income groups more frequently than those in the highest income group (ie, ≥$50,000) (22.2% to 19.7% vs 14.8%) are similar to findings in other studies.[6,11,12]

Thirty percent of those in this study whose hearing trouble or deafness began at age 16 or older reported an association with noise exposure at work. The 1991 NHIS included a question about the cause of hearing trouble, and 23.4% with HL responded that noise was a cause; the question included noise from all causes, not just noise at work.[6] Another study of approximately 30,000 people who had been evaluated for HL from 1966 to 1971 in Hungary attributed 20.1% of the HL identified to noise, including but not limited to noise exposure at work.[15] A study by Nelson et al[16] estimated that 9% of all HL for North America was attributable to noise exposure at work. That study estimated NIHL of 12% for men and 5% for women, whereas our study estimated 41.6% for men and 11.9% for women. The percentages in the Nelson study were derived from a set of calculations based on estimates of the size of the noise-exposed workforce and the risk for developing NIHL in different workforces rather than actual population survey data. This study used a more stringent definition for HL of 41 dB or greater rather than the typical value used in studies of HL of greater than 25 dB. The burden attributable to noise at work may have been higher if a 25-dB cutoff had been used. The larger percent with work-related NIHL in Michigan compared with those other studies could reflect differences in time periods when data were collected, methodologies used to derive the percentages, or true differences that reflect the large number of individuals employed in noisy industries in Michigan, including the preponderance of automobile manufacturing.

Applying the percentages in Table 4 to the numbers estimated earlier for HL among Michigan adults, it can be estimated that approximately 375,000 adults have HL from exposure to noise at work in Michigan. Among those with HL, men were more likely to report their HL as related to noise exposure at work than women (41.6% to 11.9%) and non-college graduates more than graduates (30.9% to 33.3% to 18.3%); these findings are consistent with the demographics of those who are more likely to work in blue-collar jobs in manufacturing or construction with noise exposure.[17] No such gradient was found for income (29.3% vs 31.1%) suggesting that Michigan's highest income category ($50,000+) included sufficient number of individuals who had high paying but noisy union jobs in construction or manufacturing. The report of HL related to noise exposure at work decreased in the elderly (age 75 and greater) compared with all other age groups (15.4% vs 30.2% to 34.3%). We would hypothesize that much of this decrease is not secondary to a true difference in the cause of HL in the elderly but rather a tendency among the elderly and their health care providers to attribute HL in elderly retirees to presbycusis, rather than to work, which would have been 10 or more years ago.

These survey results support some, but not all, of the literature on the association between certain health conditions and an increased prevalence of HL, despite the fact that no attributions of causality can be made due to the cross-sectional nature of the data. The literature suggests that elevated cholesterol, diabetes, and cigarette smoking are risk factors for HL. Interference of cochlear blood supply by atherosclerosis is one of the hypothesized mechanisms for increased HL in the elderly and risk factors such as elevated cholesterol would increase atherosclerosis. In our study, cigarette smoking was only found to be significantly associated with work-related HL among current smokers younger than 55

years. These results suggest that cigarettes alone are not a risk factor for HL, but cigarettes plus noise exposure may be. Other studies have found smoking to be a risk factor for HL[18,19] although these studies did not control for noise exposure when assessing the association with cigarettes. One study determined that there was a dose response between smoking and hearing impairment among workers exposed to occupational noise.[20] A number of hypotheses have been proposed to explain the effects of cigarette smoking on hearing, including its effects on antioxidative mechanisms or on the vasculature supplying the auditory system, or through direct effects on hair cell function.[18]

In this study, the prevalence of non-work-related HL among those aged 55 years or older was found to be higher among those ever diagnosed with high cholesterol compared with those who had not. An association between HL and elevated cholesterol has previously been reported although not just in older individuals as we found.[21] Studies of the relationship between diabetes, HL, and noise have had conflicting results.[22–24] The prevalence of work-related HL was significantly higher in our study among those who had been diagnosed with diabetes compared with those who had not. Diabetes approached significance in the work-related HL model among those aged 18 to 54 (AOR = 2.30 [0.90–5.85]) but was not significant among those aged 55 or older. These results suggest that diabetes alone, like cigarettes alone, is not a risk factor for HL, but diabetes plus noise exposure may be. Data from this study did not support an association between high blood pressure and HL, whether noise/work-related or not, in contrast to other literature supporting this association.[25]

There are some limitations to this study. First, our estimates are based on self-reports. However, most other prevalence estimates for HL are also based on self-report data, including the widely cited data from the NHIS.[26] Studies have found that self-reports of HL have reasonably good sensitivity when compared with the objective evidence of audiograms,[6,27–29] but may underestimate prevalence.[30] Second, those not covered by the BRFSS sampling protocol, including those living in institutions and those unable to respond to a telephone survey for reasons including HL, are likely to have a higher prevalence of HL. Taken together these two potential sources of bias would indicate that the true prevalence of HL may be even greater than our estimate. A third limitation is noncoverage of those who live in households without landlines, estimated by the 2004 NHIS to be 7.2% of adults,[31] who may have somewhat different demographics than those with landlines. Fourth, it should be noted that the response rate to the Michigan BRFSS survey was 49.8%; there may have been differences between the responders and non-responders that would have affected survey results. These latter two sources of potential bias would, at least in part, be adjusted for by the post-stratification weighting factors. Finally, there have been no studies to assess the validity of self-reporting of the work-related origin of HL.

Assessing the contribution of noise at work to HL is complicated by the fact that people can be exposed to excessive noise in non-work settings from music listening to hobbies and that HL can be caused by other factors such as medications, industrial chemicals, and a number of medical conditions, in addition simply to aging. In a study of three worker groups in Finland with excessive noise exposure, cholesterol, blood pressure, and analgesic use were significant risk factors for HL, and as the number of these factors increased, the importance of noise exposure was reduced.[32]

The cross-sectional design of our study limits its usefulness for attributing causation. For example, the association found with smoking could be secondary to a physiological effect of cigarette smoke or it could be secondary to incomplete control in the statistical analysis for increased cigarette smoking in blue-collar workers who are more likely to be exposed to noise.

In conclusion, this survey of self-reported HL supports findings of other studies that HL is a very common problem, particularly in older age groups. Currently, hearing conservation programs provided by employers in selected types of industries (eg, manufacturing but not construction) constitute preponderance of adult HL prevention activity. More preventive activity is needed to address the HL that begins in adulthood. Increasing the screening for HL in adults in the general population and the use of ear protection devices are both "Healthy People 2010" objectives.[3]

This study suggests that noise exposure at work is a significant factor in the development of HL in adults. NIHL is entirely preventable. The National Institute for Occupational Safety and Health has estimated that approximately 30 million workers are exposed to hazardous noise on the job, and work-related HL imposes a heavy economic burden on the United States.[2] Better surveillance data on work-related HL nationally has been recommended by the National Academy of Sciences, which noted many limitations in the national work-related HL surveillance system implemented in 2004 by the Bureau of Labor Statistics.[4]

Identification of noisy workplaces and implementation of hearing conservation programs in these workplaces is one important approach to prevention.[2] Michigan is the only state in the United States that has had a work-related HL surveillance system based on mandatory public health reporting of work-related HL.[4] The surveillance system receives 1000 to 2000 reports a year of individuals with work-related HL, and the data are used by the Michigan Occupational Safety and Health Administration to enforce regulations that require employers to implement hearing conservation programs.[5]

Surveillance data are essential for documenting trends and targeting high-risk groups for prevention activities. Using surveillance data to understand the interactions of noise and other risk factors in the development of HL and to target noise prevention programs are recommended. Despite the widespread occurrence of HL in adults, most public health activity on HL is directed at screening in children.[33] Eighty-eight percent of HL identified in this survey began at age 16 or older. Further efforts are need to reduce the burden of HL in adults and to address the "Healthy People 2010" objectives on primary and secondary prevention.

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