

Hearing Impairment Among Noise-Exposed Workers — United States, 2003–2012

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Workers' Memorial Day — April 28, 2016

Workers' Memorial Day, observed annually on April 28, recognizes workers who suffered or died because of exposures to hazards at work. In 2014, 4,679 U.S. workers died from work-related injuries (1). Although deaths from work-related injuries are captured by surveillance systems, most deaths from work-related illness are not. In 2007, an estimated 53,445 deaths from work-related illness occurred (2). In 2014, employers reported approximately 3 million nonfatal injuries and illnesses to private industry workers and 722,000 to state and local government workers (3); an estimated 2.7 million work-related injuries were treated in emergency departments, resulting in 113,000 hospitalizations (National Institute for Occupational Safety and Health (CDC-NIOSH), unpublished data, 2016)*

Occupational injuries and illnesses also have economic costs. The societal cost of work-related fatalities, injuries, and illnesses was estimated at \$250 billion in 2007 on the basis of methods that focus on medical costs and productivity losses (2).

New estimates of worker hearing impairment from the CDC-NIOSH Occupational Hearing Loss Surveillance program are reported in this issue of *MMWR*. The audiometric data analyzed in this report represent one example of existing health data that CDC-NIOSH uses for occupational health surveillance.

* <http://www.cdc.gov/niosh/topics/surveillance/default.html>.

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Hearing Impairment Among Noise-Exposed Workers — United States, 2003–2012

Elizabeth A. Masterson, PhD¹; P. Timothy Bushnell, PhD²;
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Hearing loss is the third most common chronic physical condition in the United States, and is more prevalent than diabetes or cancer (1). Occupational hearing loss, primarily caused by high noise exposure, is the most common U.S. work-related illness (2). Approximately 22 million U.S. workers are exposed to hazardous occupational noise (3). CDC compared the prevalence of hearing impairment within nine U.S. industry sectors using 1,413,789 noise-exposed worker audiograms from CDC's National Institute for Occupational Safety and Health (NIOSH) Occupational Hearing Loss Surveillance Project (4). CDC estimated the prevalence at six hearing impairment levels, measured in the better ear, and the impact on quality of life expressed as annual disability-adjusted life years (DALYs), as defined by the 2013 Global Burden of Disease (GBD) Study (5). The mining sector had the highest prevalence of workers with any hearing impairment, and with moderate or worse

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impairment, followed by the construction and manufacturing sectors. Hearing loss prevention, and early detection and intervention to avoid additional hearing loss, are critical to preserve worker quality of life.

The NIOSH Occupational Hearing Loss Surveillance Project collects de-identified audiograms* for U.S. workers (4) who were tested to comply with regulatory requirements because of high occupational noise exposure, defined as ≥ 85 decibels on the A-scale (dBA).[†] Audiometric service providers and others that perform worker testing agreed to share these data with NIOSH. A cross-sectional retrospective cohort analysis was conducted using the last audiogram completed for each worker during 2003–2012. Audiograms missing necessary fields or with other quality issues, having hearing threshold values that suggested testing errors, or displaying attributes unlikely to be primarily caused by occupational exposures, were excluded (4). Industries were classified using the 2007 North American Industry Classification System.[§]

The prevalences of six severity levels of hearing impairment were calculated for workers in each industry sector using the audiometric definitions from the GBD Study (Table 1)

*Audiograms are the results of hearing tests.

[†] Decibel is a unit of measure of the intensity (or loudness). The A-scale is used because it corresponds better to the sound intensities perceived by the human ear at low frequencies.

[§] North American Industry Classification System (NAICS) codes range from two-digit to six-digit numbers and industry specificity increases with each digit (<https://www.census.gov/eos/www/naics/>).

(5), except that workers in this sample who had hearing aids did not wear them during testing. DALYs representing the number of healthy years lost per 1,000 workers each year were calculated by industry sector using the GBD Study disability weights (Table 1).[¶] Tinnitus information required to calculate the DALYs was not available in the NIOSH Occupational Hearing Loss Surveillance Project sample and was estimated using results from previous studies (6,7).^{**}

The final sample included 1,413,789 audiograms for workers employed by 25,908 U.S. companies during 2003–2012. Among 99% of audiograms for which information on the worker's sex was available, 78% were recorded for males and 22% for females. A greater percentage of males had any hearing impairment (14%) than did females (7%), and the prevalence and severity of impairment increased with age (Table 2) for

[¶] For morbid conditions, such as hearing impairment, the burden over a one-year period is represented by a "disability weight" between 0 and 1, representing life limitations as a lost fraction of a year of healthy life. Because the most recent audiograms for workers were used to characterize hearing impairment, the DALY results are an estimate of the annual number of DALYs per 1,000 workers in the year of the last audiogram, and a minimum estimate of DALYs in following years. Thus, the DALY results are estimates of the annual DALYs per 1,000 workers as of 2012, the last year included in the analysis.

^{**} Tinnitus prevalences were estimated using results for U.S. noise-exposed workers with daily or more frequent tinnitus comorbid with hearing loss (<http://onlinelibrary.wiley.com/doi/10.1002/ajim.22565/epdf>) and proportions of the general population experiencing daily tinnitus by GBD Study level of hearing impairment (http://www.who.int/healthinfo/statistics/GlobalDALYmethods_2000_2011.pdf). Tinnitus prevalence estimates for each level of hearing impairment severity for the DALYs calculations were as follows: mild (18.40%); moderate (26.58%); moderately severe (28.61%); severe (55.79%); profound (56.42%); and complete (47.97%).

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TABLE 1. Hearing impairment audiometric definitions, and Global Burden of Disease (GBD) Study disability weights and lay descriptions

Severity of hearing impairment	Audiometric definition*	GBD Study disability weight (no tinnitus)	GBD Study disability weight (with tinnitus)	GBD Study lay description (no tinnitus)	GBD Study lay description (with tinnitus)
Mild	20–34 dB [†] average hearing threshold level across 500, 1,000, 2,000, and 4,000 Hz in the better ear	0.01	0.021	Has great difficulty hearing and understanding another person talking in a noisy place (for example, on an urban street)	Has great difficulty hearing and understanding another person talking in a noisy place (for example, on an urban street), and sometimes has annoying ringing in the ears
Moderate	35–49 dB average hearing threshold level across 500, 1,000, 2,000, and 4,000 Hz in the better ear	0.027	0.074	Is unable to hear and understand another person talking in a noisy place (for example, on an urban street), and has difficulty hearing another person talking even in a quiet place or on the phone	Is unable to hear and understand another person talking in a noisy place (for example, on an urban street), has difficulty hearing another person talking even in a quiet place or on the phone, and has annoying ringing in the ears for 5 minutes at a time, almost every day
Moderately severe	50–64 dB average hearing threshold level across 500, 1,000, 2,000, and 4,000 Hz in the better ear	Not calculated by GBD Study	Not calculated by GBD Study	Not generated by the GBD Study	Not generated by the GBD Study
Severe	65–79 dB average hearing threshold level across 500, 1,000, 2,000, and 4,000 Hz in the better ear	0.158	0.261	Is unable to hear and understand another person talking, even in a quiet place, and unable to take part in a phone conversation. Difficulties with communicating and relating to others cause emotional impact at times (for example, worry or depression)	Is unable to hear and understand another person talking, even in a quiet place, is unable to take part in a phone conversation, and has annoying ringing in the ears for more than 5 minutes at a time, almost every day. Difficulties with communicating and relating to others cause emotional impact at times (for example, worry or depression)
Profound	80–94 dB average hearing threshold level across 500, 1,000, 2,000, and 4,000 Hz in the better ear	0.204	0.277	Is unable to hear and understand another person talking, even in a quiet place, is unable to take part in a phone conversation, and has great difficulty hearing anything in any situation. Difficulties with communicating and relating to others often cause worry, depression or loneliness	Is unable to hear and understand another person talking, even in a quiet place, is unable to take part in a phone conversation, has great difficulty hearing anything in any situation, and has annoying ringing in the ears for more than 5 minutes at a time, several times a day. Difficulties with communicating and relating to others often cause worry, depression or loneliness
Complete	95 dB or greater average hearing threshold level across 500, 1,000, 2,000, and 4,000 Hz in the better ear	0.215	0.316	Cannot hear at all in any situation, including even the loudest sounds, and cannot communicate verbally or use a phone. Difficulties with communicating and relating to others often cause worry, depression or loneliness	Cannot hear at all in any situation, including even the loudest sounds, and cannot communicate verbally or use a phone, and has very annoying ringing in the ears for more than half of the day. Difficulties with communicating and relating to others often cause worry, depression or loneliness

Abbreviations: dB = decibel; Hz = hertz.

* These are the same as GBD Study audiometric definitions, except that the workers in this sample with hearing aids did not wear them during testing.

[†] dB is a unit of measure of the intensity (or loudness) of a sound.

both sexes. Among all industries, 13% of noise-exposed workers had any impairment and 2% had moderate or worse impairment (Table 3). Workers with hearing impairment were represented in all industry sectors, with sharply decreasing numbers of workers with higher levels of impairment. The mining sector had the highest prevalence of workers with any impairment (17%) and with moderate or worse impairment (3%), followed by the construction sector (any impairment = 16%, moderate or worse impairment = 3%),

and the manufacturing sector (14% and 2%). The public safety sector, which includes police protection, fire protection (including wildland firefighters), corrections, and ambulance services, had the lowest prevalence of workers with any impairment (7%).

Across all industries, 2.53 healthy years were lost annually per 1,000 noise-exposed workers (Table 3). Mild impairment accounted for 52% of all healthy years lost and moderate impairment accounted for 27%. Workers

TABLE 2. Sample demographics for 1,413,789 workers in the United States,* with prevalence by hearing impairment severity,† 2003–2012

Characteristic	Total (%)	Any hearing impairment (mild–complete)							
		No. (prevalence %)	No. (prevalence %)	Mild No. (prevalence %)	Moderate No. (prevalence %)	Moderately severe No. (prevalence %)	Severe No. (prevalence %)	Profound No. (prevalence %)	Complete No. (prevalence %)
Sex									
Male	1,087,936 (78.11)	929,487 (85.44)	158,449 (14.45)	132,434 (12.17)	21,385 (1.97)	3,625 (0.33)	722 (0.07)	204 (0.02)	79 (0.01)
Female	304,830 (21.89)	282,700 (92.74)	22,130 (7.26)	18,941 (6.21)	2,375 (0.78)	560 (0.18)	182 (0.06)	57 (0.02)	15 (<0.01)
Missing	21,023	NA	NA	NA	NA	NA	NA	NA	NA
Age group (yrs)									
18–25	222,675 (15.75)	218,724 (98.23)	3,951 (1.77)	3,299 (1.48)	378 (0.17)	166 (0.07)	66 (0.03)	27 (0.01)	15 (0.01)
26–35	333,461 (23.59)	322,504 (96.71)	10,957 (3.29)	9,462 (2.84)	974 (0.29)	312 (0.09)	128 (0.04)	57 (0.02)	24 (0.01)
36–45	348,350 (24.64)	320,260 (91.94)	28,090 (8.06)	25,020 (7.18)	2,267 (0.65)	564 (0.16)	152 (0.04)	69 (0.02)	18 (0.01)
46–55	330,934 (23.41)	265,640 (80.27)	65,294 (19.73)	56,837 (17.17)	6,962 (2.10)	1,137 (0.34)	275 (0.08)	58 (0.02)	25 (0.01)
56–65	164,807 (11.66)	98,403 (59.71)	66,404 (40.29)	52,935 (32.12)	11,427 (6.93)	1,717 (1.04)	265 (0.16)	49 (0.03)	11 (0.01)
66–75	13,562 (0.96)	5,280 (38.93)	8,282 (61.07)	5,777 (42.60)	2,095 (15.45)	365 (2.69)	39 (0.29)	5 (0.04 [§])	1 ([¶])
Missing	—	—	—	—	—	—	—	—	—

Abbreviation: NA = not available.

* Worker representation in states of employment as condensed into six geographical regions based on the U.S. Embassy region groupings (<http://usa.usembassy.de/travel-regions.htm>) were the following: Mid-Atlantic with 244,930 workers (17.64%); Midwest with 641,487 workers (46.20%); New England with 11,255 workers (0.81%); South with 267,941 workers (19.30%); Southwest with 24,499 workers (1.76%); and West with 198,537 workers (14.30%). There were missing geographical region values for 25,140 workers.

† Hearing impairment severity audiometric definitions and lay descriptions are provided in Table 1. Hearing impairment was measured in the better ear.

§ This estimate has a relative standard error $\geq 30\%$ and $< 50\%$ and should be used with caution as it does not meet standards of reliability/precision.

¶ Estimate not shown as it has a relative standard error $\geq 50\%$ and does not meet standards of reliability/precision.

TABLE 3. Annual number of disability-adjusted life years (DALYs) per 1,000 workers,* by industry sector, and estimated prevalence of workers with hearing impairment and percent of DALYs, by severity level† and industry sector — 1,413,789 workers in the United States, 2003–2012

Industry sector (NAICS 2007 Code)	Total (%)	DALYs/1,000 workers [§]	Total % DALYs per sector [¶]	Measure	Hearing impairment severity	
					No hearing impairment	Any hearing impairment (mild–complete)
All industries	1,413,789 (100)	2.53	100.00	No. (prevalence %) % DALYs within sector	1,230,811 (87.06)	182,978 (12.94) 100
Agriculture, forestry, fishing and hunting (11, except 115310)	15,945 (1.13)	2.17	0.97	No. (prevalence %) % DALYs within sector	14,171 (88.87)	1,774 (11.13) 100
Mining, quarrying, and oil and gas extraction (21)	7,274 (0.51)	3.45	0.70	No. (prevalence %) % DALYs within sector	6,058 (83.28)	1,216 (16.72) 100
Construction (23)	35,969 (2.55)	3.09	3.11	No. (prevalence %) % DALYs within sector	30,109 (83.71)	5,860 (16.29) 100
Manufacturing (31–33)	932,686 (66.01)	2.66	69.52	No. (prevalence %) % DALYs within sector	804,548 (86.26)	128,138 (13.74) 100
Wholesale and retail trade (42, 44–45)	110,299 (7.81)	2.57	7.95	No. (prevalence %) % DALYs within sector	95,904 (86.95)	14,395 (13.05) 100
Transportation, warehousing and utilities (48, 49, 22)	153,272 (10.85)	1.54	6.60	No. (prevalence %) % DALYs within sector	141,181 (92.11)	12,091 (7.89) 100
Healthcare and social assistance (62, except 62191)	8,056 (0.57)	2.69	0.61	No. (prevalence %) % DALYs within sector	7,020 (87.14)	1,036 (10.51) 100
Public safety (115310, 62191, 92212, 92214, 92216)	13,974 (0.99)	1.30	0.51	No. (prevalence %) % DALYs within sector	12,951 (92.68)	1,023 (7.32) 100
Services (51–56, 61, 71–72, 81, 92 [except 92212, 92214, 92216])	135,524 (9.59)	2.61	9.92	No. (prevalence %) % DALYs within sector	118,192 (87.21)	17,332 (12.79) 100

See table footnotes on next page.

in the mining and construction sectors lost 3.45 and 3.09 healthy years per 1,000 workers, respectively. Overall, 66% of the sample worked in the manufacturing sector and represented 70% of healthy years lost by all workers. Public safety workers lost 1.30 healthy years per 1,000 workers, the fewest among all workers.

Discussion

Findings of increasing prevalence with age and a higher prevalence among males were expected and consistent with other research (2,4,8). Industry results highlight the high prevalence of hearing loss within the noise-exposed working population

TABLE 3. (Continued) Annual number of disability-adjusted life years (DALYs) per 1,000 workers,* by industry sector, and estimated prevalence of workers with hearing impairment and percent of DALYs, by severity level† and industry sector — 1,413,789 workers in the United States, 2003–2012

Industry sector (NAICS 2007 Code)	Measure	Hearing impairment severity					
		Mild	Moderate	Moderately severe	Severe	Profound	Complete
All industries	No. (prevalence %)	153,330 (10.85)	24,103 (1.70)	4,261 (0.30)	925 (0.07)	265 (0.02)	94 (0.01)
	% DALYs within sector	51.64	26.66	4.83–22.38**	5.58	1.82	0.69
Agriculture, forestry, fishing and hunting (11, except 115310)	No. (prevalence %)	1,492 (9.36)	233 (1.46)	31 (0.19)	10 (0.06††)	5 (0.03††)	3 (§§)
	% DALYs within sector	51.88	26.49	3.51–16.55**	6.06	3.37	2.16
Mining, quarrying, and oil and gas extraction (21)	No. (prevalence %)	994 (13.67)	178 (2.45)	33 (0.45)	9 (0.12††)	2 (§§)	—
	% DALYs within sector	47.57	27.95	5.24–24.46**	7.72	1.92	—
Construction (23)	No. (prevalence %)	4,902 (13.63)	805 (2.24)	123 (0.34)	27 (0.08)	3 (§§)	—
	% DALYs within sector	53.01	28.56	4.47–20.72**	5.23	0.62	—
Manufacturing (31–33)	No. (prevalence %)	107,514 (11.53)	16,845 (1.81)	2,933 (0.31)	620 (0.07)	180 (0.02)	46 (<0.01)
	% DALYs within sector	52.09	26.80	4.78–22.15**	5.38	1.78	0.49
Wholesale and retail trade (42, 44–45)	No. (prevalence %)	12,099 (10.97)	1,832 (1.66)	345 (0.31)	85 (0.08)	26 (0.02)	8 (0.01††)
	% DALYs within sector	51.28	25.49	4.91–22.78**	6.44	2.23	0.71
Transportation, warehousing and utilities (48, 49, 22)	No. (prevalence %)	10,186 (6.65)	1,528 (1.00)	290 (0.19)	51 (0.03)	20 (0.01)	16 (0.01)
	% DALYs within sector	51.95	25.59	4.96–23.02**	4.64	2.07	1.76
Healthcare and social assistance (62, except 62191)	No. (prevalence %)	847 (10.51)	146 (1.81)	34 (0.42)	6 (0.07††)	2 (§§)	1 (§§)
	% DALYs within sector	46.94	26.43	6.19–29.06**	5.80	2.22	0.99
Public safety (115310, 62191, 92212, 92214, 92216)	No. (prevalence %)	885 (6.33)	111 (0.79)	26 (0.19)	—	1 (0.01)	—
	% DALYs within sector	58.66	24.05	5.69–26.64**	—	1.13	—
Services (51–56, 61, 71–72, 81, 92 [except 92212, 92214, 92216])	No. (prevalence %)	14,319 (10.57)	2,409 (1.78)	442 (0.33)	116 (0.09)	26 (0.02)	20 (0.01)
	% DALYs within sector	48.62	26.87	5.04–23.39**	7.04	1.79	1.47

Abbreviations: GBD = Global Burden of Disease; NAICS = North American Industry Classification System.

* Annual number of DALYs per 1,000 workers represent how many years of healthy life were lost by 1,000 workers each year and can be compared across different health conditions.

† Hearing impairment severity audiometric definitions and lay descriptions are provided in Table 1. Hearing impairment was measured in the better ear.

§ DALYs were calculated by 1) applying the GBD Study disability weight with tinnitus to the number of workers estimated to have tinnitus; 2) applying the GBD Study disability weight without tinnitus to the number of workers estimated not to have tinnitus; and 3) adding these two values together for each industry sector and overall.

¶ Percent of total DALYs lost by all noise-exposed workers within each industry sector.

** The GBD Study did not calculate a disability weight for moderately severe hearing impairment. DALYs are presented as a range, applying the disability weight for moderate impairment to obtain the lower limit, and applying the disability weight for severe impairment to obtain the upper limit. The average of the lower and upper limits was used to calculate the total DALYs in each industry sector and overall.

†† This estimate has a relative standard error $\geq 30\%$ and $< 50\%$ and should be used with caution as it does not meet standards of reliability/precision.

§§ Estimate not shown as it has a relative standard error $\geq 50\%$ and does not meet standards of reliability/precision.

and the need for continued prevention efforts, especially in the mining, construction, and manufacturing sectors. The proportion of mining sector employees exposed to hazardous noise (76%) was the highest in any sector (3), and studies have consistently indicated elevated risks for occupational hearing loss within this sector (2,4). Occupational hearing loss risks have also been established within the construction sector (2,4); however, current noise regulations do not require audiometric testing for construction workers (2). Without testing to identify workers losing their hearing, intervention might be delayed or might not occur. Although a comparatively smaller percentage of manufacturing workers are noise-exposed (37%), this sector accounts for the most noise-exposed workers in the United States (3), and, as expected, the largest number of workers with hearing impairment. Some manufacturing sub-sectors, such as wood product, apparel, and machinery manufacturing, have been found to have occupational hearing loss risks as high as those in the mining and construction sectors (4). Another study using earlier GBD Study hearing impairment definitions also found the heaviest burdens of hearing impairment were in the

mining, construction, and manufacturing sectors, indicating the most healthy years were lost in these sectors (8).

Approximately 78% of the healthy years lost were attributable to mild or moderate hearing impairment. Preventing any occupational hearing loss is the best way to reduce worker hearing impairment over a lifetime, because even mild-to-moderate impairment during working years can culminate in more healthy years lost during retirement. Prevention also has short-term benefits; persons with even mild hearing loss experience reduced audibility (loudness), reduced dynamic range of hearing (the difference between the softest and loudest perceptible sounds), and increased listening fatigue (2). They also often experience difficulties understanding speech, especially in the presence of background noise (2). Other effects include degraded communication (2), cognitive decline (9), and depression (2).

In the general population, the prevalence of impairment also sharply decreases at higher levels of impairment, and severe impairment is not typically caused exclusively by noise. Some workers with a substantial hearing impairment might transfer

Summary**What is already known about this topic?**

Hearing loss is prevalent in the United States, especially among noise-exposed workers.

What is added by this report?

This is the first known study to quantify the disability-adjusted life years attributable to hearing impairment for noise-exposed U.S. workers, and to estimate the prevalence at each level of hearing impairment by industry sector.

What are the implications for public health practice?

Prevention, early detection, and intervention to preclude additional hearing loss are essential to reducing worker disability caused by hearing impairment.

away from noisy jobs because of difficulties communicating in noisy environments, or from jobs where hearing is critical for productivity and safety. For example, although the public safety sector had fewer older workers (lowering the prevalence), hearing impairment might have resulted in attrition because of the hearing-critical nature of many occupations in this sector (2).

The findings in this report are subject to at least seven limitations. First, this was a convenience sample and might not be representative of all noise-exposed workers tested in the United States. Second, not all noise-exposed workers are tested in the United States, especially in industries with high proportions of mobile or temporary workers, such as the construction and agriculture sectors. Third, in the absence of additional information, such as medical records, hearing impairment caused by occupational exposures can only be inferred. However, this inference was strengthened by studying exposed workers and excluding audiograms indicating nonoccupational exposures. Fourth, GBD Study disability weights were developed using international surveys asking respondents to compare life limitations posed by different health conditions, and to compare the value of preventing certain health conditions to the value of preventing death (5); respondents might not be able to appreciate the impact a disability can have on quality of life if they do not have that disability. Fifth, GBD Study audiometric definitions for impairment levels are conservative, with stringent requirements to reach even mild impairment. In addition, no impairment is identified when there is a total loss of hearing in one ear, and the impairment in the other ear can be lessened by hearing aid use. These limitations might have lowered impairment estimates, and worker impairment might be higher than reported here. Sixth, workers in the Occupational Hearing Loss Surveillance Project who wear hearing aids did not wear them during testing. However, few persons wear hearing aids during working years (9), so no adjustments were made for hearing aid use. Finally, no information was available on other conditions, so healthy years lost because of hearing impairment were not adjusted for comorbidities (5).

Occupational hearing loss is a permanent but entirely preventable condition with today's hearing loss prevention strategies and technology (2). Concurrent with prevention efforts, early detection of hearing loss by consistent annual audiometric testing, and intervention to preclude further loss (e.g., refitting hearing protection, training), are critical. Although lost hearing cannot be recovered, workers can benefit from clinical rehabilitation, which includes fitting hearing aids, learning lip-reading, and adopting other compensation strategies to optimize hearing. Study results support beginning rehabilitation at a mild level of hearing impairment. Prevention, and early detection, intervention, and rehabilitation, might greatly improve workers' quality of life (2,9).

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