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Current knowledge of US metal and nonmetal miner health: Current and potential data sources for analysis of miner health status

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ABSTRACT

Little is known about the current health status of US metal and nonmetal (MNM) miners, in part because no health surveillance systems exist for this population. The National Institute for Occupational Safety and Health (NIOSH) is developing a program to characterize burden of disease among MNM miners. This report discusses current knowledge and potential data sources of MNM miner health. Recent national surveys were analyzed, and literature specific to MNM miner health status was reviewed. No robust estimates of disease prevalence were identified, and national surveys did not provide information specific to MNM miners. Because substantial gaps exist in the understanding of MNM miners' current health status, NIOSH plans to develop a health surveillance program for this population to guide intervention efforts to reduce occupational and personal risks for chronic illness.

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Health promotion; mining; public health surveillance; respiratory tract diseases

The National Institute for Occupational Safety and Health (NIOSH), part of the Centers for Disease Control and Prevention (CDC), is responsible for the study and prevention of occupational illnesses and injuries. Surveillance of these illnesses and injuries is a critical aspect of NIOSH research and is important in determining research priorities focused on prevention and intervention to reduce risks. At present, little is known about the current health status of metal and nonmetal (MNM) miners in the United States, in part because no comprehensive or narrowly focused health surveillance systems exist for this population.

Metal and nonmetal mining is an important industry throughout the United States and provides minerals used to manufacture electronics, automobiles, pharmaceuticals, and many other products. During 2011, the US MNM mining industry directly or indirectly contributed approximately $135 billion to the national gross domestic product.[1] Metal mining primarily occurs in western states and consists of both precious and base metals, including gold, silver, platinum, copper, molybdenum, lead, and zinc. Nonmetal mines are located throughout the United States and consist of a wide array of commodities, including gypsum, sodium bicarbonate, silicates, aluminum oxides, and potash. Of approximately 261,784 total mining company employees in 2012, approximately 66,044 (25.2%), 92,472 (35.3%), and 103,268 (39.4%) were employed in the MNM, coal, and stone, sand, and gravel mining industry sectors, respectively, not including an additional 126,094 contractors.[2] Similar to the coal sector, MNM mining comprises both underground and surface mining.[3]

As in other mining sectors, recognized hazards in this industry include noise, heat, repetitive stress, silica and other dust, chemical fumes, radon, and diesel exhaust.[4] Efforts to remediate or reduce these hazards likely have improved health outcomes within this industrial sector. However, the current health status of this population of workers is unknown. NIOSH plans to implement a program to assess the health status of the MNM mining workforce. This knowledge will be used to develop targeted workplace health interventions ranging from engineering controls to personal health support using a Total Worker Health approach. Total Worker Health is a strategy that incorporates health promotion into occupational safety and health programs to more efficiently and effectively improve the overall health of the workforce.[5]

This report provides a brief review of the literature on MNM miner health and describes current and potential data sources for assessing the current

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knowledge of the health status of this population of US workers.

Methods

PubMed and Google Scholar searches were performed to identify literature specific to MNM miner health status, and a brief literature review was performed. Search terms included metal miners, nonmetal miners, disease, respiratory disease, and cardiovascular disease. We identified additional studies from the cited references in the articles found in our primary search. Non-English articles and articles focused on uranium miners, infectious diseases (human immunodeficiency virus [HIV], tuberculosis), or injuries were excluded. Previously completed analyses of specified national surveys were reviewed, and data from other national surveys were analyzed. State health departments were contacted to determine whether they collect data related to the health of this workforce.

The National Health Interview Survey (NHIS) is conducted annually by CDC's National Center for Health Statistics (NCHS) and is one of the principal means of understanding the overall health of the noninstitutionalized US population. The US Census Bureau collects data for NHIS by conducting in-person surveys of households selected by using a stratified multistage sample design, and survey responses are used to estimate the proportion of the population with various chronic diseases and risk factors for disease.[6] Occupational data collected on participants allows for categorization of each participant into industrial sectors and estimation of chronic disease prevalence by sector.[7] Analyses from the 1997–2007 National Health Interview Surveys[7] were reviewed and summarized. The National Survey of the Mining Population was conducted by NIOSH in 2008 to define the demographics and job descriptions of the mining population.[3,8] The results of this survey analysis were also reviewed and summarized.

The National Occupational Mortality Surveillance system (NOMS) compiles death data gathered from states during years in which industry- and occupation-coded death certificates met quality criteria established by NIOSH and NCHS.[9] Data from 1999, 2003–2004, and 2007, years in which data met these quality criteria, were aggregated to estimate the most common causes of death among MNM miners. International Classification of Diseases (10th edition) codes for underlying causes of death were aggregated by disease categories according to NCHS guidelines.[10] The Mine Safety and Health Administration (MSHA) Accident, Injury, and Illness database collects information regarding any adverse health event or accident that occurs within a mine.[11] All events must be reported to MSHA, which maintains a database of these events, categorized by mine sector. All incidents occurring during 2007–2011 were aggregated to estimate selected causes of morbidity among miners.

Results

Literature review

Respiratory diseases

A substantial portion of the literature regarding MNM miner health is focused on lung cancer. The majority of studies comparing lung cancer mortality among MNM miners with that of the general population have demonstrated significant increases in standardized mortality ratios (SMRs), with ranges of 1.3–6.7.[12–16] Investigators have compared lung cancer mortality among ever-underground MNM miners with that of surface MNM miners and have demonstrated similar or higher SMRs in ever-underground miners.[14,17] Excess lung cancer deaths have been demonstrated in MNM miners with longer durations of underground mining or with increasing lifetime exposures to radon and diesel exhaust.[12,14,18–20]

Some investigators have demonstrated an association between the elevated risk of lung cancer and radon exposure in MNM mines,[21] whereas others have found that exposure to silica[22,23] or diesel[14,20] were associated with elevated rates. Interpretation of study results is complicated by variability in exposures, confounders, and duration and classification of work history. Misclassification bias could have occurred in studies estimating silica, radon, or diesel exposures by using work histories and job titles.[22,23] Because studies relied on retrospective cohorts, accurate assessment of true exposures was difficult; additionally, individual exposures could exert synergistic effects between radon or silica and mined commodities on the development of lung cancer or respiratory disease. Many studies had little if any confounding exposure information.[17,19,22] Despite these limitations, lung cancer appears to be a risk for at least some segments of the MNM workforce.

Some research addresses nonmalignant respiratory diseases and symptoms among MNM miners. Many investigations of mortality among MNM miners reported associations between MNM mining and nonmalignant respiratory disease, demonstrating significant increases in SMR ranging from 2.4 to 12.2.[13,14,21,23] Studies evaluating respiratory symptoms have demonstrated increased chronic cough, sputum production, wheezing, physician-diagnosed chronic bronchitis, and increased inflammatory cells in sputum among miners.[24–27] No differences in pulmonary function test (PFT) results

have been demonstrated when comparing MNM miners with nonminer workers[24] or when comparing MNM miners with high and low diesel exhaust exposures;[25] however, miners with respiratory disorders or current smoking histories were excluded from analysis, and preserved lung function would thus be expected in this population.[24] Miners exposed to dust have exhibited excess loss of lung capacity with a clear exposure-response relationship to respirable dust and respirable quartz.[28]

Other investigations of nonmalignant respiratory diseases have demonstrated elevated risk of pneumoconiosis among MNM miners in job descriptions with higher dust exposures than other job categories[16] and increased silicosis risk with increases in cumulative total dust exposures.[29,30] In comparing respiratory disease mortality between underground and surface MNM miners, underground miners had higher SMR for nonmalignant respiratory disease than surface miners.[18] Among US national death records with idiopathic pulmonary fibrosis as the underlying or contributing cause of death, decedents had increased odds of having worked in metal mining.[31]

A community-based study of former molybdenum, zinc, and gold miners performed in Leadville, Colorado, demonstrated a silicosis prevalence of approximately 32% among former miners exposed to an estimated average silica level below the permissible exposure limit.[32] Increasing silicosis rates were associated with increasing cumulative dust exposures.[32] Prevalence of silicosis among persons exposed to dust increased with years of exposure, from 15.4% of miners with <20 years of dust exposure to 47.1% of miners with ≥30 years of exposure.[32] This study demonstrates the importance of assessing workers after they leave the mining workforce to determine the true burden of silicosis. Approximately 97% of study subjects were evaluated at least 20 years after first dust exposure, and approximately half of those with silicosis were unaware of the diagnosis.[32]

Although the risks of silicosis and loss of lung function have been demonstrated in specific mining populations, the extent of these risks in the industry and in various subsectors of the industry are unknown. Modern mining practices may mitigate these hazards and reduce the risk. The literature raises concerns about lung cancer and nonmalignant respiratory diseases, but questions remain about the exposures of interest, effects of underground versus surface mining, timing and dose-response of exposures, and the effects of specific mined commodities. As a result, more work needs to be done to define disease risks among this population.

Other health outcomes

A limited number of studies have reported health outcomes other than respiratory disease. Excess mortality from esophageal and stomach cancers has been reported.[14,17] Heat illness is a common complication of MNM mining.[33] Studies of cardiovascular mortality have been mixed. Studies that showed no increased cardiovascular mortality among miners might have been influenced by the healthy worker effect.[17,19,21] In a Swedish study, when cardiovascular mortality rates of miners were compared with those of Swedish national rates for working males, the SMR was significantly elevated at 1.3, but information on confounders was not available.[34]

Age and specific work history seem to influence cardiovascular risk among miners. Standardized mortality ratios for myocardial infarction (MI) were elevated among iron-ore miners aged ≤60 years but not iron-ore miners aged >60 years.[35] Iron-ore miners aged ≤60 years exposed to hand-arm vibration had significantly increased risk of MI mortality with increased vibration doses, whereas those aged >60 years with the same exposure had no increased MI mortality risk compared with unexposed workers.[36] However, relative risk of MI mortality among iron-ore miners exposed to whole-body vibration was increased in the total population.[36]

Methodologic issues and a narrow disease focus limit the ability to use current literature to effectively understand the health status of the MNM mining population. Therefore, other sources of information regarding MNM miner health are necessary for the planning and implementation of this new health initiative.

National surveys

National Survey of the Mining Population

The National Survey of the Mining Population was designed to obtain information on mining workforce demographics and job descriptions. Health-related questions were not asked in this survey. Tables 1–3 demonstrate the demographic characteristics, work locations, and occupation categories for metal and nonmetal miners during 2008. Although this survey provides useful information about the mining industry, the weighted response rates for metal and nonmetal mines were 34.9% and 48.8%, respectively,[3] and responses might therefore not be representative of the entire MNM mining population.

National Health Interview Survey

Data from the 1997–2007 National Health Interview Surveys were previously analyzed to estimate the proportion of workers in each industry with specified chronic health conditions. Table 4 demonstrates the estimated proportion of workers in the mining industry with chronic

Table 1. National estimates of demographic characteristics for metal and nonmetal miners, National Survey of the Mining Population, employees, 2008.[3]

	Metal				Nonmetal			
Demographic characteristic	National estimate	National estimate 95% CI	National percent	National percent 95% CI	National estimate	National estimate 95% CI	National percent	National percent 95% CI
Sex								
Male	33,562	15,620–51,504	86.2	81.9–90.4	17,241	12,526–21,956	89.3	86.6–91.9
Female	5,383	1,152–9,615	13.8	9.6–18.1	2,074	1,174–2,973	10.7	8.1–13.4
Age (mean, years)	41.5	39.3–43.8			42.0	40.2–43.8		
Education								
<9th grade	63	0–153	0.2	0.0–0.4	193	80–305	1.1	0.4–1.8
9–12th grade	1,030	276–1,784	2.9	0.9–4.9	1,154	720–1,589	6.6	3.6–9.6
High school graduate	18,934	9,552–28,317	53.3	44.0–62.6	11,242	6,837–15,647	64.2	58.1–70.3
Some college or technical school	12,377	4,629–20,125	34.9	27.2–42.5	2,956	2,371–3,540	16.9	11.6–22.1
College graduate	3,104	1,515–4,692	8.7	6.1–11.3	1,958	922–2,993	11.2	7.9–14.5
Ethnicity								
Hispanic or Latino	9,483	1,132–17,834	24.6	14.4–34.9	1,368	854–1,883	8.3	5.7–10.9
Non-Hispanic or Non-Latino	29,008	14,213–43,803	75.4	65.1–85.6	15,171	12,851–17,491	91.7	89.1–94.3
Race								
American Indian /Alaska Native	1,073	0–2,156	3.3	1.3–5.4	87	24–150	0.5	0.1–0.8
Asian	*	*	*	*	*	*	*	
Black	1,492	0–3,059	4.7	0.6–8.7	2,479	1,483–3,474	13.6	8.0–19.3
Pacific Islander	†	†	†	†	†	†	†	
White	29,276	16,297–42,255	91.4	86.8–96.0	15,567	10,412–20,721	85.6	79.8–91.4

*No estimates possible because not represented at all in sampled population.
†Data suppressed because of insufficient numbers within sampled population.

health conditions such as cancer, heart disease, and tobacco use. In 2010, NIOSH sponsored an occupational health supplement to the NHIS, in which approximately 17,500 adults interviewed for NHIS had been employed in the past 12 months and answered more detailed questions regarding selected occupational exposures and illnesses.[37] The sample size for miners was too small to reliably estimate prevalences of dermatitis, carpal tunnel syndrome, and current asthma, but estimated prevalences among miners of exposures to potential skin hazards or vapors, gas, dust, or fumes were 35.2% and 86.4%.[37] The prevalence of exposure to vapors, gas, dust, or fumes among miners was significantly higher than that of all US workers.[37]

This survey and supplement provide useful information on health conditions and risk factors that affect the general mining population but do not differentiate this population into mining subsectors and so are not specific to MNM miners.

National Occupational Mortality Surveillance System

The National Occupational Mortality Surveillance System was used to estimate the most common causes of death among MNM miners. In general, MNM miners seem to die of the same health conditions as the rest of the population. Heart disease, cancer, chronic lower respiratory disease, cerebrovascular disease, and unintentional injuries are the top 5 causes of death among both the general

Table 2. National estimates for number of metal and nonmetal miners by primary work location, National Survey of the Mining Population, employees, 2008.[3]

	Metal				Nonmetal			
Work location	National estimate	95% CI	National percent	National percent 95% CI	National estimate	95% CI	National percent	National percent 95% CI
Underground mine: underground	6,152	876–11,428	15.8	2.0–29.5	1,971	1,050–2,892	10.3	5.5–15.0
Underground mine: surface shops or yards	1,252	327–2,177	3.2	0.6–5.8	422	94–751	2.2	0.5–3.9
Surface mine: strip, open pit, or quarry	16,624	0–34,516	42.7	20.9–64.4	2,483	1,515–3,450	13.0	6.9–19.0
Surface mine: dredge	†	†	†	†	49	0–130	0.3	0.0–0.7
Surface mine: other	1,876	405–3,348	4.8	0.5–9.1	4,673	0–9,870	24.4	5.2–43.6
Independent shops or yards	*	*	*	*	159	5–313	0.8	0.0–1.7
Mill operations, preparation plants, or breakers	9,307	4,644–13,970	23.9	9.1–38.7	7,088	4,880–9,296	37.0	24.0–50.0
Office	3,751	782–6,720	9.6	6.9–12.4	2,324	1,502–3,146	12.1	7.2–17.0

†Data suppressed because of insufficient numbers within sampled population.
*Not applicable to metal mines.

Table 3. National estimates for number of metal and nonmetal miners by occupation category, National Survey of the Mining Population, employees, 2008.[3]

	Metal		Nonmetal	
Occupation category	National estimate	National estimate 95% CI	National estimate	National estimate 95% CI
Administration/professional	10,652	5,754–15,550	7,066	3,597–10,536
Office staff	1,889	726–3,053	1,504	901–2,107
Professional (engineer, technician, etc)	3,368	1,260–5,475	987	618–1,355
Safety	303	87–519	147	0–314
Supervisory	5,092	2,545–7,640	4,429	1,704–7,154
Maintenance	7,238	3,058–11,418	2,836	1,781–3,890
Production	17,581	5,896–29,266	6,426	5,142–7,710
Service and utility	3,339	1,155–5,523	2,968	2,236–3,699

population and metal miners. The order of the top 5 causes of death is slightly different among nonmetal miners, with deaths from cancer more common than deaths from heart disease. One limitation of the use of mortality data to determine intervention priorities among miners is that they do not provide information on diseases or conditions that are not likely to increase the risk of mortality, such as arthritis, back pain, and hearing loss.

Mine Safety and Health Administration Accident and Injury Reporting (7000–1)

Another data source that provides some insight into morbidity is the MSHA Accident, Injury, and Illness database. MSHA analyses have demonstrated decreased injury rates over time in all mining sectors over the past decades; in 2011, injury fatality rates for the coal and MNM mining sectors were 0.016 and 0.008 per 200,000 hours worked, respectively.[38] Although injury rates among the various mining sectors can be directly compared, the rates of occupational illnesses among noncoal miners are not well delineated. To evaluate the utility of analyzing MSHA data for occupational illness incidence, MNM mining sector adverse events reported during 2007–2011 were aggregated by disease category. Table 5 illustrates the results of this analysis. Over a 5-year period, few noninjury incidents were reported.

Interpretation of MSHA data has caveats. MSHA data are limited by underreporting of illnesses.[39] Few disease categories are recorded; many occupational illnesses are of long latency, and miners might not develop symptoms during their working years, further decreasing the likelihood of disease reporting.[39] Illnesses that do not occur during work hours, such as myocardial infarction, are also likely to be underreported. Finally, some illnesses have both occupational and personal risk factors, and identifying occupational illness can be difficult. As a result, analysis of MSHA data does not provide meaningful information regarding the health status of MNM miners.

State health departments

Our preliminary investigation suggests that most public health organizations do not have health data on mine workers; 10 western state health departments reported

Table 4. Proportions and estimates of total numbers of miners and workers from all occupational sectors reporting health conditions, risk factors, and health promotion activities, 1997–2007 National Health Interview Survey.[7]

Disease or risk factor	Miners percent	Estimated number of miners with condition†	All workers percent*	Estimated number of workers with condition*
Cancer	3.1	15,956	4.0	5,075,921
Hypertension	23.2	119,410	17.7	22,460,951
Heart disease	7.1	36,544	6.5	8,248,372
Asthma (ever diagnosis)	6.8	35,000	9.4	11,928,415
Diabetes	5.3	27,279	3.9	4,949,023
Psychological distress	0.7	3,603	0.5	634,490
Current smoker	33.1	170,365	23.8	30,201,731
Current alcohol drinker	70.5	362,863	70.2	89,082,417
Obesity	27.0	138,969	22.8	28,932,751
Insufficient physical activity	68.8	354,113	65.9	83,625,802
Ever tested for HIV	29.6	152,351	37.8	47,967,455
No influenza vaccine past 12 months	77.8	400,436	79.1	100,376,342
No pneumococcal vaccine in workers aged ≥60 years	57.1	15,018	70.2	6,281,057

† Based on NHIS estimates of the US miner population: approximately 514,699 total miners (26,301 aged ≥60 years), may be overestimate of miner population.
* Based on NHIS estimates of the US worker population: approximately 126,898,030 (8,947,375 aged ≥60 years).

Table 5. Total counts of metal and nonmetal miner illnesses and injuries reported to Mine Safety and Health Administration, 2007–2011.

Illness	Metal miners	Nonmetal miners	Total
Myocardial infarction	11	21	32
Cerebral hemorrhage	0	1	1
Dermatitis	6	7	13
Dust in eyes	129	56	185
Cold exposure	1	2	3
Heat exposure/heat illness	52	11	63
Hearing loss	60	82	142
Joint inflammation	121	61	182
Pneumoconiosis	9	15	24
Infectious disease	0	0	0
Poisoning	62	29	91
Occupational disease not otherwise specified	6	3	9
Unclassified illness	132	134	266
Injury	5,045	2,837	7,882

that they have no specific data on miner health status, although some collect occupational injury and illness data by using workers' compensation data.

Comment

Substantial gaps exist in our understanding of the current health status of MNM miners. Although data regarding general health status, chronic diseases, and some occupational illnesses in the general mining industry can be obtained from national health surveys such as NHIS, health data specific to each mining sector are not collected. Very little information is available regarding chronic disease risk factors, occupational diseases, as well as nonfatal illnesses that cause substantial morbidity among MNM miners. Many of the cohort studies evaluating MNM miner health status were performed in other countries, and the representativeness of these miners' working conditions to those of US miners is questionable. Current surveillance systems are inadequate to monitor the health of this population. The usefulness of NHIS occupational data for assessing the health of MNM miners is limited.

To improve our knowledge of MNM miner health, a surveillance system focused specifically on this population is necessary. This system will include secondary data collection from sources that already have MNM miner health data, with active data collection to supplement this information. For active surveillance, NIOSH plans to use a mobile clinic to perform miner health assessments at MNM mines and in mining communities. The most likely sources of secondary data are occupational health programs sponsored by employers, and health care providers, including occupational medicine clinics in MNM mining communities. Primary care and occupational medicine providers, including private practices, rural health centers, federally qualified health centers, and Indian Health Service clinics, might evaluate and treat substantial numbers of MNM miners if located near MNM mine sites. Data from these facilities could provide information on health issues that impact MNM miners and other community members. Exploring the possibility of data sharing with these facilities might provide useful information on current health issues among MNM miners.

Another NIOSH priority is the establishment of worksite health improvement programs to enhance the overall health of workers by developing or strengthening existing organizational health promotion, worker safety, and disease prevention. As we develop a better understanding of the health risks among this population, we hope to collaborate with employers and workers in the development of pilot health improvement programs that use a Total Worker Health approach to integrate health promotion and worker safety. As these programs are tailored to accommodate the priorities of the MNM mining industry, lessons learned and evaluations of the health and economic outcomes of these programs will be used to expand to other MNM mines and potentially to other mining sectors.

We are looking for collaboration with public health organizations, community-based organizations, health care facilities, employers, and trade and labor organizations for data on MNM miner health, suggestions for program implementation and improvement, and information on other important stakeholders. Collaboration with stakeholders such as mining trade associations and labor organizations is crucial for the success of this program and is a potential avenue to access data. As we collaborate with partners in this endeavor, we hope to develop a robust passive and active population health assessment system that will be used to identify occupational safety and health research priorities and approaches for Total Worker Health programs, with the ultimate goal of improving the health of MNM miners.

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