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Overview of the National Occupational Mortality Surveillance (NOMS) System: Leukemia and Acute Myocardial Infarction Risk by Industry and Occupation in 30 US States 1985–1999, 2003–2004, and 2007

Cynthia F. Robinson
Centers for Disease Control and Prevention, cfr2@cdc.gov

James T. Walker
Centers for Disease Control and Prevention

Marie H. Sweeney
Centers for Disease Control and Prevention

Rui Shen
SRA International

Geoffrey M. Calvert
Centers for Disease Control and Prevention

Authors
Cynthia F. Robinson, James T. Walker, Marie H. Sweeney, Rui Shen, Geoffrey M. Calvert, Pam K. Schumacher, Jun Ju, and Susan Nowlin

Overview of the National Occupational Mortality Surveillance (NOMS) System: Leukemia and Acute Myocardial Infarction Risk by Industry and Occupation in 30 US States 1985–1999, 2003–2004, and 2007

Cynthia F. Robinson, PhD,[1]* James T. Walker, PhD,[1] Marie H. Sweeney, PhD,[1] Rui Shen, PhD,[2] Geoffrey M. Calvert, MD, MPH,[1] Pam K. Schumacher,[1] Jun Ju,[1] and Susan Nowlin[1]

Background *Cancer and chronic disease are leading causes of death in the US with an estimated cost of $46 billion.*
Methods *We analyzed 11 million cause-specific deaths of US workers age 18–64 years in 30 states during 1985–1999, 2003–2004, and 2007 by occupation, industry, race, gender, and Hispanic origin.*
Results *The highest significantly elevated proportionate leukemia mortality was observed in engineers, protective service, and advertising sales manager occupations and in banks/savings &loans/credit agencies, public safety, and public administration industries. The highest significantly elevated smoking-adjusted acute myocardial infarction mortality was noted in industrial and refractory machinery mechanics, farmers, mining machine operators, and agricultural worker occupations; and wholesale farm supplies, agricultural chemical, synthetic rubber, and agricultural crop industries.*
Conclusions *Significantly elevated risks for acute myocardial infarction and leukemia were observed across several occupations and industries that confirm existing reports and add new information. Interested investigators can access the NOMS website at http//: www.cdc.gov/niosh/topics/NOMS/.* Am. J. Ind. Med. 58:123–137, 2015.

***KEY WORDS:* occupational mortality; surveillance; occupational cancer; occupational heart disease; leukemia; acute myocardial infarction**

[1]The National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Division of Surveillance, Hazard Evaluation and Field Studies, Cincinnati, Ohio
[2]SRA International, Fairfax, Virginia

Abbreviations: AK, Alaska; CO, Colorado; GA, Georgia; HI, Hawaii; ID, Idaho; IN, Indiana; KS, Kansas; KY, Kentucky; ME, Maine; MI, Michigan; NE, Nebraska; NV, Nevada; NH, New Hampshire; NJ, New Jersey; NM, New Mexico; NC, North Carolina; ND, North Dakota; NY, New York; OH, Ohio; OK, Oklahoma; PA, Pennsylvania; RI, Rhode Island; SC, South Carolina; TN, Tennessee; TX, Texas; UT, Utah; VT, Vermont; WA, Washington; WV, West Virginia; WI, Wisconsin.

*Correspondence to: Dr. Cynthia Robinson, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluation, and Field Studies, MS R-18, 4676 Columbia Parkway, Cincinnati, OH 45226.
E-mail: cfr2@cdc.gov; siebercynthia@gmail.com

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INTRODUCTION

The Occupational Safety and Health Act of 1970 (29 US C. § 651 et seq.; 29 C.F.R. Part 1903.1 et seq.) directed the secretary of the Department of Health, Education, and Welfare to conduct research, experiments and innovations that call for inventive methods, techniques, and approaches for dealing with occupational safety and health issues. The National Institute for Occupational Safety and Health (NIOSH) was created to assume these duties, and one of its responsibilities was developing a national occupational safety and health surveillance system. Since 1984, NIOSH has developed and maintained the NIOSH National Occupational Mortality Surveillance (NOMS) system. Originally developed in collaboration with the National Center for Health Statistics (NCHS), the National Cancer Institute, the US Census, and the State health departments, it is now maintained solely by NIOSH. NOMS is designed to facilitate the epidemiologic analysis of US occupational death data and to produce timely national US occupational mortality statistics for acute and chronic disease for the purpose of surveillance [Melius et al., 1989]. The NOMS project provides periodic surveillance of acute and chronic occupational disease and injury mortality by industry and occupation. During the last 25 years, findings based on NOMS data have been used in more than 140 peer-reviewed publications and have contributed to the development of national occupational health policies [Dubrow et al., 1987; Blair et al., 1993; CDC, 1995; Burnett et al., 1997; Savitz et al., 1998; Colt et al., 2001; Luckhaupt and Calvert 2008; ILO, 2010].

The availability of occupation and industry-coded death data from 30 US states for the years 1999, 2003–2004, and 2007 and earlier data 1985–1998, recent updates to the NOMS database and refinements to the proportional mortality ratio analysis system (PMRAS) permitted the present analysis of NOMS data for 1985–1999, 2003–2004, and 2007. Recent updates to the database included adding the edited file updated with NCHS causes of death and demographic codes for 1999, 2003–2004, and 2007. (Mortality data containing industry and occupation narratives for 2000–2002 and 2005–2006 were not available.) The purpose of the analysis on which this report is based was to use the updated NOMS system to report and interpret any elevated proportionate mortality by occupation and industry for 1985–1999, 2003–2004, 2007 in order to generate hypotheses about preventable occupational exposures or conditions that can cause acute and chronic disease and cancer. We conducted proportionate mortality ratio (PMR) analysis for 550 occupations, 310 industries, and 250 cause of death categories.

The primary objective of this report was to further evaluate proportionate mortality ratios (PMRs) for two causes of death (leukemia and acute myocardial infarction) by occupation and industry, race, gender, and ethnicity, using the criteria of statistical precision, biological plausibility and comparison with previously published reports. Leukemia and acute myocardial infarction, two diseases that are often fatal, were selected for study because reports of mortality due to these two diseases by industry and occupation are limited to known leukemogens (benzene, cytotoxic drugs, or ionizing radiation) [Kipen and Wartenberg, 2005] and cardiotoxins (carbon disulfide, solvents, or carbon monoxide) [Fine and Rosenstock, 2005]. Additionally, leukemia (and non-Hodgkin's lymphoma) has been associated with pesticides and formaldehyde [Cantor et al., 1992; Beane et al., 2009]. As a secondary objective, the recent improvements to the NOMS database, the refined NOMS PMRAS, a new internet-based system for coding occupation and industry, and the updated NOMS queriable internet website are described.

MATERIALS AND METHODS

Study Population and Data collection

The NOMS database is populated with data collected from death certificates that are filed in state registration offices at the time of death, and transmitted to the NCHS. These data were shared by NCHS and the states with NIOSH for the NOMS study. No personal identifiers were collected or maintained in NOMS. Variables in the NOMS database include underlying and contributing causes of death, usual (i.e., longest held) occupation and industry, age, date of birth, date of death, state, race, gender, education, and ethnicity. Because race, gender, ethnicity vary by occupation and by cause of death, stratification on race and gender helps to control confounding and associated disparities in outcomes [Kogevinas et al., 1997]. National death data are reported by the NCHS by age, race, ethnicity, cause of death, and other variables. The NCHS race and ethnic categories are consistent with the changes to the 1977 Office of Management and Budget (OMB) standards [US Office of Management and Budget, 1997]. NCHS reports ethnicity as Hispanic origin—defined to include persons of Mexican, Puerto Rican, Cuban, Central and South American, and other or unknown Latin American or Spanish origins. Persons of Hispanic origin may be of any race. However, the NOMS Hispanic totals always refer to the total number of White and Black Hispanics.

Cause of Death on the Death Certificate

Underlying and contributing causes of death are entered on the death certificate by the attending physician, medical examiner, or coroner [NCHS, 2003]. Demographic and cause of death data were coded and edited by NCHS using standardized rules for demographic [NCHS, 2012] and medical classification (record axis) according to the applicable revision of the International Classification of Diseases [WHO, 1978, 1992].

Occupation and Industry on the Death Certificate

Usual occupation and industry are recorded on death certificates by funeral directors, medical examiners, or coroners, based on information supplied by next of kin or others. These data are important in the surveillance of acute and chronic occupational illnesses, because usual or lifetime occupation and kind of business or industry are used as indicators of work-based exposures. In the NIOSH guidelines document, usual occupation is defined as the type of job performed during most of the decedent's lifetime or is the job held for the longest time; and industry is defined as the type of business where the individual worked related to the usual occupation. The guidelines were recently updated and reissued to improve quality and consistency of occupation and industry information on death certificates [Robinson et al., 2012] and were widely disseminated to funeral directors, medical examiners, coroners, and others with responsibility for the accuracy of the US vital statistics registration system.

Coding and Quality Control of Industry and Occupation

For purposes of analysis, occupation and industry variables require standardized coding for use in mortality studies. The narrative text entered onto the death certificate for usual occupation and industry was coded manually by state health departments and/or NIOSH using the Census classification system [US Bureau of the Census, 1982, 1992, 1998, 2003] until 2006 when computerized coding became available. Quality control of occupation and industry coding is performed at NIOSH by trained coders and the coding specialist. The overall error rate range for the states (Fig. 1) that coded occupation and industry for 1985–99, 2003–2004, and 2007 was 5–10%. For more information about the NIOSH Industry and Occupation Computerized Coding System (NIOCCS), see the AJIM journal website.

Proportionate Mortality Ratio Analysis System (PMRAS) 2011

The NOMS PMRAS was designed to calculate PMRs by usual occupation, industry, or cause of death, specifically for population-based data [Dubrow and Spaeth 1987; Ju and Robinson, 2011]. In 2011, PMRAS was developed as a personal computer (PC)-based system in order to provide an efficient statistical analysis for NOMS data collected after the Tenth Revision of the ICD was implemented in 1999 [WHO, 1992]. PMRAS can accommodate both Ninth and Tenth revision cause of death codes used in the same study over the period 1984–2007 and beyond. In contrast to the mainframe based version, the PC-based PMRAS contains the following advantageous features: it is written in SAS statistical software and utilizes a Server database that uses a structured query language to record all the activities in the system [SAS, 2009]. PMRAS computes PMRs by comparing the observed number of deaths from a particular cause in an

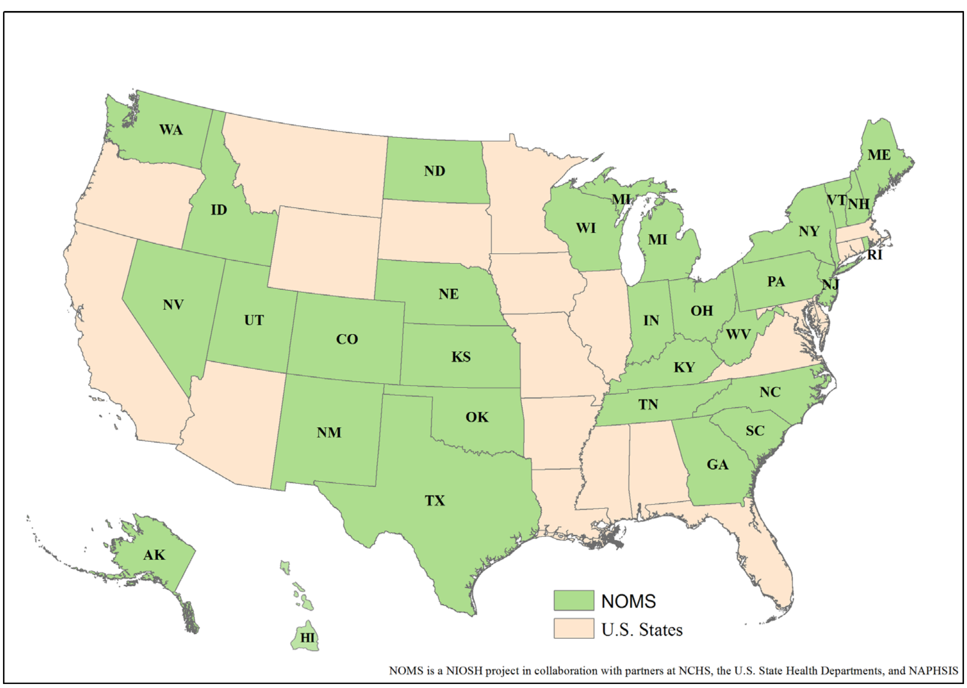

FIGURE 1. National Occupational Mortality Surveillance (NOMS): US deaths with usual occupation and industry from 30 states, 1984–2007.

occupation or industry group with the expected number of deaths from that cause based on the proportion of all deaths due to that cause in a standard population, and age adjusts after stratification on age, race, gender, and ethnicity [Robinson et al., 2011]. The standard population used in NOMS occupational mortality surveillance is the total number of decedents who resided and died in the US states included in the analysis. If the observed number of deaths was 1,000 or less, the 95% confidence interval (CI) was computed based on the Poisson distribution [Bailar and Ederer, 1964]; otherwise, test-based CIs were calculated using the Mantel and Haenszel chi-square test [Mantel and Haenszel, 1959].

Statistical Analysis

Two statistical analyses of the 11 million NOMS deaths that occurred in 30 US states during 1985–1999, 2003–2004, and 2007 were conducted. Both an underlying cause of death and a multiple cause of death analysis were done to identify any elevated mortality risks and uncover gaps in the knowledge of chronic occupational disease. For the NOMS study, causes of death were grouped into 250 categories of acute and chronic disease and injury using the Tenth Revision to the International Classification of Disease (WHO, 1992). (Please refer to the Table IA–C available in the supplemental materials on the AJIM website).

TABLE I. Number of Deaths With Occupation and Industry by Race and Gender, 30 US States, 1985–1999, 2003–2004, and 2007, National Occupational Mortality Surveillance (NOMS)

State of occurrence	White males	Black males	White females	Black females	Total
AK	1,695	61	926	40	2,722
CO	165,504	6,567	159,665	5,506	337,242
GA	289,677	117,277	278,591	106,325	791,870
HI	11,664	362	8,561	177	20,764
ID	61,540	146	57,943	99	119,728
IN	314,682	28,830	325,845	25,963	695,320
KS	178,484	10,181	189,726	9,183	387,574
KY	278,367	21,441	267,001	20,844	587,653
ME	71,198	134	72,299	89	143,720
MI	33,416	5,901	35,881	5,579	80,777
MO	44,144	5,293	42,782	4,497	96,716
NC	345,199	110,683	330,489	96,706	883,077
NE	20,429	674	21,635	649	43,387
NH	57,657	186	62,374	125	120,342
NJ	421,068	70,736	455,893	63,451	1,011,148
NM	94,040	1,852	82,682	1,395	179,969
NV	104,167	6,975	81,980	5,205	198,327
NY	216,872	37,264	216,399	30,624	501,159
OH	604,723	78,462	626,400	70,214	1,379,799
OK	132,279	10,062	127,201	9,154	278,696
PA	381,585	42,837	381,349	37,251	843,022
RI	63,417	2,250	69,511	1,863	137,041
SC	156,637	73,522	147,755	65,417	443,331
TN	76,317	15,709	67,810	13,842	173,678
TX	65,248	9,287	64,238	8,882	147,655
UT	92,093	738	87,606	472	180,909
VT	27,465	50	28,722	53	56,290
WA	90,463	2,739	88,307	1,864	183,373
WI	304,418	11,789	304,713	9,228	630,148
WV	134,652	5,024	133,626	5,084	278,386
Total	4,839,100	677,032	4,817,910	599,781	10,933,823

*Includes deaths by state of occurrence truncated for analysis to ages 18–90 years.
Not all states are included for all years, except for the period 1999, 2003–2004, and 2007 which included data for 23 US states. Data were collected for 87,927 Asian and Pacific Islanders, but were not included in the analysis due to small sample size.

For the analysis, the Census industry codes were aggregated into 310 categories that were further condensed into ten industry sectors corresponding to those found in the NIOSH National Occupational Research Agenda (NORA) http://www.cdc.gov/niosh/nora/ [NIOSH, 2012]. The ten sectors included: agriculture/forestry/fishing; mining; oil and gas extraction; construction; manufacturing, trade; transportation/warehousing/utilities; services; justice, public order and safety; and health care/social assistance. The 310 analysis categories were cross walked through three revisions of US Census occupation and industry codes 1980, 1990, and 2000 and the North American Industrial Classification System 1997 [US Bureau of the Census, 1982, 1992, 1998; NIOSH, 2014] (Table IA–C available in the supplemental materials in the AJIM journal website or on request to authors). (A crosswalk is a table that shows equivalent elements or codes in more than one database) The Census occupation codes were aggregated into 550 categories that were cross walked through the same three Census revisions. Examples of the analysis categories used in the crosswalks are shown in Table I available on the AJIM journal website. The crosswalks provided comparability of occupation and industry categories between the revisions when several years of deaths are analyzed; for example, for this analysis, the deaths occurred across three revisions, the 1980, 1990, and 2000 censuses. In rare instances the death certificate did not provide useful occupation and industry narratives (<1% of deaths) and instead mentioned "unemployed," "part-time worker," "unknown," "unpaid," or "retired." These deaths were excluded from the analysis. In addition, all deaths with missing or erroneous data (<1%) in any variable were excluded as well.

Underlying Cause PMR Analysis

We produced age-adjusted PMRs for men and women by race and ethnicity age 18–64 based on the underlying cause of death for 550 occupation, 310 industry and 250 cause of death categories using the PMRAS computer program [Ju and Robinson, 2011]. We evaluated mortality patterns for 11 million decedents ages 18–90 that both resided and died in one of 30 US states during the period 1985–1999, 2003–2004, and 2007 (Fig. 1). To evaluate mortality over time, the analysis was stratified by three multi-year intervals (1985–1991, 1992–1996, and 1997–1999, 2003–2004, 2007). We computed age-adjusted PMRs and 95% confidence intervals for all causes of death stratified by three age groups (18–54, 18–64, and 65–90 years) for White, Black, and Hispanic men and women by usual or lifetime occupation and industry (Table II).

The present report provides PMRs for age 18–64 over the periods 1985–1999, 2003–2004, and 2007 and the three intervals described above for two major causes of death (leukemia, ICD-10 codes C92–95, C910–C913, C915–919 and acute myocardial infarction, ICD-10 code I-21) by

TABLE II. Number of Hispanic Deaths With Occupation and Industry by Gender Contributed to NOMS By 30 US States, 1985–1999, 2003–2004, and 2007*, National Occupational Mortality Surveillance (NOMS)

	Ethnicity/gender		
State	**Hispanic male**	**Hispanic female**	**Total**
CO	14,980	10,010	24,990
GA	1,947	1,036	2,983
HI	1,602	1,079	2,681
ID	1,273	634	1,907
IN	2,518	1,573	4,091
KS	2,643	1,694	4,337
KY	835	538	1,373
ME	66	34	100
MI	647	440	1,087
NC	1,370	383	1,753
NE	245	161	406
NH	88	68	156
NJ	20,742	14,682	35,424
NM	30,281	21,055	51,336
NV	4,510	2,489	6,999
NY	13,319	7,954	21,273
OH	3,100	1,915	5,015
PA	1,452	856	2,308
RI	654	392	1,046
SC	416	175	591
TN	62	26	88
TX	13,905	10,660	24,565
UT	3,057	1,933	4,990
VT	45	32	77
WA	1,630	861	2,491
WI	1,137	577	1,714
WV	136	81	217
Total	122,660	81,338	203,998

Hispanic deaths age 18–64 years, with coded occupation and industry.
*Hispanic ethnicity included Mexican, Puerto Rican, Cuban, Central or South American, and other ethnic groups indicated on the death certificate. Race and ethnicity are two separate categories coded on the death certificate; they are not mutually exclusive.

ethnicity in White and Black males. PMRs for all occupations, industries, and age groups, analyzed for other cancer, chronic disease, and fatalities could not be listed due to limitations of space but interested investigators may view them at http://www.cdc.gov/niosh/topics/NOMS/ [NIOSH, 2014].

Multiple Cause Analysis and PMR Charts

In addition to results presented in this paper, we used multiple cause PMR analysis to associate cancer and acute and chronic disease with 10–15 of the largest industries within each of the ten US industry sectors, all races and genders combined. All results for PMR charts may be found on the NOMS internet site [NIOSH, 2014]. More information about the NOMS multiple cause analysis and charts may be found in the supplemental materials on the AJIM journal website.

Adjustment for Smoking

In this study, acute myocardial infarction PMRs were adjusted for smoking using data from the National Health Interview Survey (NHIS) and the American Cancer Society's Cancer Prevention Study II [Thun et al., 2000]. The statistical methodology is briefly described in the supplemental materials on the AJIM journal website.

The study protocol was reviewed by the NIOSH Human Subject Review Board and determined to be exempt because (i) it did not meet the criteria of research and (ii) the data did not contain personally identifiable information. In addition, the individual state Human Subject Review Boards reviewed and approved the study protocol.

RESULTS

As of 2013, the NOMS database contained a total of 11,076,221 deaths that occurred in 30 states over the period of 1985–1999, 2003–2004, and 2007. The current study examined proportionate mortality patterns for the 10,933,823 deaths that occurred in 30 US states during the 18 year period (Table I, Fig. 1) that included 4,839,100 White males, 677,032 Black males, 4,817,910 White females, and 599,781 Black females. Additionally, there were deaths among 62,594 Asian/American Indian/Pacific Islander (AIP) males and 25,333 AIP females (not shown on the table) that were not included in the analysis due to insufficient sample size. When stratified by ethnicity, 122,660 Hispanic male and 81,338 Hispanic female deaths were observed (Table II). PMRs were computed after the individuals whose occupation (or industry) was housewives or homemakers and whose industry was not reported were excluded. The entire results of our analyses of PMRs based on 250 underlying causes of death, 550 occupations, and 310 industries for 1985–1999, 2003–2004, and 2007 may be accessed online by occupation, industry, race, gender, and age group (18–54, 18–64, 65–90) at http://www.cdc.gov/niosh/topics/NOMS/ [NIOSH, 2014]. The statistically significant PMRs for leukemia and acute myocardial infarction whose confidence intervals excluded 100 and were greater than 115, based on a number of deaths greater or equal to 10, are shown in Tables III and IV by gender, race and ethnicity and three multi-year strata (1985–1991, 1992–1996, and 1997–1999, 2003–2004, 2007).

Leukemia Mortality by Industry

Significant elevated age-adjusted leukemia mortality before age 65 was noted for several smaller industries within three sectors—manufacturing, service, and public safety (Table III) during 1985–2007. It was surprising that the highest leukemia PMRs were noted among the service sector. Black and White men employed in banks/savings & loans/credit agencies experienced over two-fold significant excess risk. Black and White men in the public safety industry and White men employed in the insurance industry experienced significantly elevated leukemia mortality. Similarly elevated leukemia mortality was observed in the public administration industry among Hispanic, Black, and White males; and the machinery manufacturing industry (not electrical). In US population rates, men have a higher leukemia incidence and death rate than women; and, Black men have a higher death rate than White men [ACS, 2007]. This was consistent with NOMS data. (Table III). When analyzed across the overall time period, all leukemia PMRs described above increased or stayed the same.

Leukemia Mortality by Occupation

Table III shows the highest significantly elevated PMRs for leukemia for a variety of smaller occupations within the three large categories of professional and specialty, management/business/finance, and protective service occupations. White male and Hispanic female operation specialty managers experienced significant excess risk. Black and White male engineers, White male electrical engineers and advertising/sales managers, and Black men who worked in the protective services occupations experienced significantly elevated proportionate mortality. When analyzed over time, all PMRs increased in strength and remained significantly elevated during 1999, 2003–2004, and 2007.

Smoking Adjusted Acute Myocardial Infarction Mortality by Industry

Significantly elevated smoking-adjusted PMRs for acute myocardial infarction were found for a variety of smaller industries in four sectors: manufacturing, mining, trade, and agriculture on Table IV. The highest PMRs were observed in Black men employed in the wholesale farm supplies industry, a new finding. White men employed in another farming-related industry, agricultural chemical production, also had significantly elevated proportionate mortality, which increased over the time interval 1985–2007.

Significantly elevated acute myocardial infarction mortality was found in several other industries within the manufacturing sector (Table IV), that is, White female plastics and synthetic rubber workers, White male dairy

TABLE III. Significantly Elevated Leukemia[a] Mortality y Industry and Occupation in 30 US States[b], 1985–1999, 2003–2004, 2007, Ages 18–64, National Occupational Mortality Surveillance (NOMS)

	Race/Gender	1985–2007			1985–1991			1992–1996			1997–2007		
INDUSTRY (BOC[c] CODE)	**Ethnicity**	**PMR[d]**	**Deaths**	**95% CI**	**PMR**	**Deaths**	**95% CI**	**PMR**	**Deaths**	**95% CI**	**PMR**	**Deaths**	**95% CI**
Manufacturing													
Machinery except electrical (307–336)	White male	117	299	104,131	107	128	89,127	118	94	96,145	136	77	105,177
Services (199, 647–789, 837–839, 948-959)	Black male	124	164	106,145	111	55	84,144	135	55	101,175	129	54	97,168
	White male	126	1496	120,131	124	607	115,135	127	468	116,139	124	421	112,136
	White female	116	1332	111,121	114	58	105,125	104	339	93,115	127	465	116,139
	Black female	123	198	106,141	121	71	94,153	125	59	95,161	124	68	96,157
	Hispanic female	140	52	105,184	168	12	87,294	98	10	47,181	151	30	102,216
Public administration exc. protective service (937–939, 948–959)	White male	121	627	112,131	115	263	102,130	124	195	107,143	125	169	107,145
	Black male	147	85	118,182	124	29	83,179	125	22	79,190	203	34	141,284
	Hispanic male	156	30	105,223	165	10	79,304	113	5	87,263	174	15	97,286
Insurance (711)	White male	142	150	120,166	135	65	104,172	149	50	111,197	143	35	100,199
Bank/savings & Loan/credit agency (687–689)	White male	153	105	125,185	139	37	98,191	149	34	103,208	172	34	119,240
	Black male	215	10	103,395	0	0		388	6	142,844	–	<5	–
Public safety (947)	White male	119	227	104,135	108	84	86,134	121	70	95,153	130	73	102,163
	Black male	190	29	127,273	104	5	34,242	166	8	72,328	270	16	154,439
OCCUPATION (BOC[c] CODE)													
Management, business, finance (001–095, 110, 370–373, 401–415, 471, 420)	White male	126	1470	120,131	117	557	107,127	129	459	117,141	135	463	123,148
	Black Male	141	69	110,179	117	18	70,186	153	22	96,231	145	29	97,208
	Black female	133	57	101,173	158	19	95,247	131	15	74,217	117	23	74,176
Operations specialty managers (012–020, 033–043, 072, 110, 430, 620)	White male	123	912	115,131	116	409	105,128	125	262	111,142	134	241	118,152
	Hispanic female	214	13	114,365	–	<5	–	–	<5	–	206	6	76,449
Advertising/Sales manager (036, 090, 093, 370–373, 942)	White male	156	72	122,197	138	77	91,201	165	24	106,245	174	21	108,267
Professional and specialty (120–326)	White male	141	1160	135,148	143	456	130,157	145	382	131,160	132	322	118,147
	Black male	131	72	102,165	113	20	69,175	115	20	70,177	158	32	108,223
	White female	125	938	117,133	123	356	110,136	117	247	103,133	135	335	121,150
	Hispanic female	156	29	104,224	279	10	134,512	150	7	60,308	116	12	60,203
Engineers (132–153)	White male	154	337	138,171	148	120	123,178	151	107	124,183	161	110	132,194
	Black male	203	13	108,347	–	<5	–	–	<5	–	333	10	160,612
Electrical engineers (141)	White male	162	88	130,200	157	34	109,220	141	25	91,208	192	29	129,276

(*Continued*)

TABLE III. (*Continued.*)

	Race/Gender	1985–2007			1985–1991			1992–1996			1997–2007		
INDUSTRY (BOC[c] CODE)	Ethnicity	PMR[d]	Deaths	95% CI	PMR	Deaths	95% CI	PMR	Deaths	95% CI	PMR	Deaths	95% CI
Protective services (370–378, 380–386, 390–395)	Black male	166	48	122,220	154	15	86,253	150	13	80,256	182	20	111,280

[a]Leukemia ICD-10 codes were C910-C913, C915-C919, C92-C95.
[b]US States that contributed data for 1984–1998 were: Alaska, Colorado, Georgia, Hawaii, Idaho, Indiana, Kansas, Kentucky, Maine, Michigan, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Utah, Vermont, Washington, West Virginia, and Wisconsin.
[c]US Bureau of the Census, 1998. North American industry classification system (NAICS). United States 1997. Washington DC. US Government Printing Office. 1,200 p. US Bureau of the Census, 2003. Industry and occupation classification system. (electronic resource). http://www.census.gov/hhes/www/ioindex.html. Accessed December 3, 2009.
[d]Proportionate mortality ratio (PMR); Confidence interval (CI).

production workers and yarn/thread/fabric mill workers. The textile industry experienced many deaths, and mortality increased over time. The mining industry displayed significantly elevated acute myocardial infarction mortality, specifically among Black and White male coal mining workers. These rates decreased over time in Black men; but increased slightly in White men. The Agriculture industry experienced significantly increased mortality that involved many excess deaths during each time period, particularly in Black and White male and Black female crop production workers.

Smoking-adjusted Acute Myocardial Infarction Mortality by Occupation

The highest age and smoking adjusted significantly elevated PMRs for acute myocardial infarction (Table IV) occurred among Hispanic and Black men employed as mechanics on industrial or refractory machinery. It is noteworthy that proportionate mortality for both increased strongly, rising to over a twofold significant excess during the most recent time period whereas male mining mortality risk decreased. White women who had been employed as textile/apparel/furnishings operators experienced a PMR of 128, with over 1186 deaths.

It's of interest that Black and White male farmers experienced significant excess acute myocardial infarction mortality with over 5000 deaths. Acute myocardial infarction mortality was also significantly elevated for Black female and Hispanic male agricultural workers (not previously reported) and Black male loggers. It is notable that all PMRs rose during the recent time interval, 1997–1999, 2003–2004, 2007, except for Black female agricultural workers which decreased (Table IV).

PMR Charts for Chronic Disease by Industry

Age-adjusted multiple cause PMRs were computed for single causes of death that included 23 sites of cancer and 17 chronic work-related disease categories for up to 15 of the largest industries within each industry sector and all races and genders combined. Multiple cause PMRs for selected chronic diseases and cancer for the period 1997–1999, 2003–2004, 2007 may be accessed and viewed by other investigators in over 6000 PMR charts by industry sector on the NOMS website http://www.cdc.gov/niosh/topics/NOMS/ [NIOSH, 2014].

DISCUSSION

Acute Myocardial Infarction in Farming Occupations

Significant excess proportionate mortality for smoking-adjusted acute myocardial infarction mortality was observed

TABLE IV. Significantly Elevated, Smoking-Adjusted, Acute Myocardial Infarction[a] Mortality y Industry and Occupation in 30 US States[b], 1985–1999, 2003–2004, 2007, Ages 18–64 Years, National Occupational Mortality Surveillance (NOMS)

INDUSTRY (BOC[c] CODE)	Race/gender	1985–2007			1985–1991			1992–1996			1997–1999, 2003–2004, 2007		
	Ethnicity	PMR[d]	Deaths	95% CI	PMR	Deaths	95% CI	PMR	Deaths	95% CI	PMR	Deaths	95% CI
Agriculture/forestry/fishery	White male	122	6581	119,124	119	3708	115,122	124	1715	119,128	120	1158	114,126
(017–029, 748, 777)	Black female	133	148	112,156	106	77	84,133	162	54	123,213	125	17	76,208
Crop production (017)	White male	135	4337	132,138	126	2665	122,131	132	1022	125,138	138	650	128,149
	Black male	119	796	111,128	116	470	106,128	109	221	95,125	119	105	98,146
	Black female	137	139	115,163	105	71	83,134	171	52	129,227	145	16	86,245
Logging (027)	Black male	119	271	105,134	110	127	92,131	117	93	95,144	139	51	105,185
Mining (680–694)	Black male	163	73	129,206	158	37	113,220	169	20	107,269	164	16	97,276
Coal mining (038)	White male	121	1794	116,126	117	860	110,125	129	525	118,140	125	409	114,138
	Black male	167	36	119,235	185	24	121,282	170	9	84,346	–	<5	–
Manufacturing													
Dairy production (117)	White male	120	348	108,134	105	213	92,120	106	73	84,134	169	62	131,219
Textiles & apparel (147–169)	White male	121	3212	117,124	116	1794	111,120	116	963	109,123	125	455	113,137
	White female	133	1416	128,139	121	769	112,131	127	431	116,140	146	216	128,167
	Black male	127	542	117,138	123	259	109,139	118	172	101,137	148	111	122,178
	Black female	120	367	108,133	115	155	98,135	117	130	98,139	129	82	103,160
Yarn, thread, and fabric mills (147–148)	White male	122	2420	117,126	116	1367	110,121	119	730	110,128	126	323	112,141
	White female	138	761	129,149	125	422	114,138	131	237	115,149	148	102	122,181
	Black male	132	448	120,144	128	217	111,146	122	144	103,144	151	87	121,187
	Black female	122	197	106,140	122	83	98,152	118	74	93,149	127	40	92,175
Agricultural chemicals (210)	White male	150	65	117,193	140	31	97,202	142	18	87,232	190	16	113,321
Plastics & synthetic rubber (237–239)	White female	146	30	101,212	–	0	–	181	20	114,287	144	10	73,283
Trade													
Farm supplies wholesale (457)	Black male	251	19	156,404	217	11	114,410	240	6	98,585	–	<5	–
OCCUPATION (BOC[c] CODE)													
Farming/forestry/fishery (020–021, 608–613)	White male	122	6927	119,124	118	3927	115,121	122	1823	1117,126	121	111,177	115,127
	Black female	126	145	107,148	100	74	79,126	161	54	122,213	113	17	68,188
Farmers (021)	White male	149	4678	146,152	139	2835	135,143	148	1157	141,155	156	686	144,168
	Black male	145	506	132,158	142	311	126,158	126	130	106,149	152	65	118,196
Agricultural workers (600–605)	Black female	135	83	108,168	121	44	89,164	152	31	106,220	96	8	45,205
	Hispanic male	124	117	103,150	106	37	75,148	118	27	80,175	142	53	107,187
Logging (613)	Black male	119	212	104,137	117	114	97,141	111	67	86,142	123	31	85,177
Mining and extractive 680–694)	Black male	150	49	112,201	163	27	110,242	176	15	102,302	92	7	41,208
Mining machine operators (684)	Black male	154	40	111,212	166	24	109,253	162	11	86,307	98	5	37,262
Mechanics/repairers													

(Continued)

TABLE IV. (*Continued.*)

INDUSTRY (BOC[c] CODE)	Race/gender Ethnicity	1985–2007 PMR[d]	1985–2007 Deaths	1985–2007 95% CI	1985–1991 PMR	1985–1991 Deaths	1985–1991 95% CI	1992–1996 PMR	1992–1996 Deaths	1992–1996 95% CI	1997–1999, 2003–2004, 2007 PMR	1997–1999, 2003–2004, 2007 Deaths	1997–1999, 2003–2004, 2007 95% CI
Industrial refractory machinery mechanics (733, 821)	Black male	159	76	126,200	148	28	101,217	145	22	93,225	209	26	139,313
	Hispanic male	210	11	111,398	–	<5	–	–	<5	–	–	<5	–
Textile/apparel/furnish ops (844, 846)	White female	123	1186	117,129	111	652	103,120	116	351	104,129	139	183	120,162

[a]Acute Myocardial Infarction ICD-10--21.
[b]US States that contributed data for 1985–2007 were: Alaska, Colorado, Georgia, Hawaii, Idaho, Indiana, Kansas, Kentucky, Maine, Michigan, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Utah, Vermont, Washington, West Virginia, and Wisconsin.
[c]US Bureau of the Census, 1998. North American industry classification system. United States 1997. Washington, DC. US Government Printing Office. 1200 p. US Bureau of the Census, 2003. Industry and occupation classification system.(electronic resource).http://www.census.gov/hhes/www/ioindex.html.Accessed December 3, 2009.
[d]Proportionate mortality ratio (PMR); Confidence interval (CI).

for farmers, crop production workers, and agricultural workers that persisted over time (1985–2007) (Table IV). Elevated risk in crop production workers has been previously reported in males but not Black females; although, a significant excess was reported in female spouses (race not specified) of farmers and pesticide applicators in Iowa and North Carolina but not males, during 1999–2003 [Dayton et al., 2010]. Occupational cardiovascular risk factors in farm and office environments include shift work, extreme heat, cold, noise, carbon disulfide, nitroglycerin, carbon monoxide, and stress [Shalat et al., 2005].

A significantly elevated prevalence of hypertension and abnormalities on electrocardiogram was found recently in Italian agricultural workers with noise-induced hearing loss exposed to pesticides and noise and vibration from farm machinery [Tomei et al., 2013]. These exposures may have contributed to the elevated acute myocardial infarction mortality in White and Black male and Black female crop production workers and White and Black male farmers observed in NOMS and other data [Blair et al., 1993; Cameron et al., 2001; Lee et al., 2002; Fleming et al., 2003]. As earlier studies based on NOMS data observed increased risk, it is puzzling that studies of male pesticide applicators in the Agricultural Health Study in Iowa, North Carolina, Minnesota and Hispanic California farmworkers have shown no associations with heart disease [Colt et al., 2001; Blair et al., 2005; Mills et al., 2006; Mills et al., 2009]. Regarding study overlap with the current NOMS data, only North Carolina deaths in these studies may have overlapped for 1999 and earlier years. It is interesting that a relationship with pesticide use and cardiomyopathy in male but not female North Carolina pesticide applicators was observed 1993–2007; but overall heart disease was not elevated [Waggoner et al., 2011]. In a study, using crop patterns as surrogates for exposure, greater risk for fatal acute myocardial infarction was reported in US counties with higher wheat production [Schreinemachers, 2006].

It is possible that patterns of pesticide use, noise and vibration from farm machinery may vary with predominant crops grown in these states, potentially altering disease and mortality patterns. Further investigation in farm environments of potential exposures to cardiotoxins and acute myocardial infarction risk factors should be conducted.

Acute Myocardial Infarction Mortality in Manufacturing and Mining

Our study identified significant smoking-adjusted proportionate heart disease mortality risk among the agricultural chemical production and farm supplies (wholesale) industries, as well as dairy production, textiles/apparel, synthetic rubber, and refractory machinery workers. Elevated mortality in the agricultural chemical and farm supplies industry has not been previously reported. White male agricultural chemical production workers' proportionate mortality rose significantly in the most recent time period. This suggests that follow-up studies of the agricultural chemicals and wholesale farm supplies industries are needed to identify potential cardio toxins.

Our observation of a substantial number of excess deaths among yarn, thread and fabric mill workers, with risk that increased during the most recent time period may be associated with environmental exposures in textile or apparel mills such as dusts, shift work, and carbon disulfide. It is of interest that significantly increased acute myocardial infarction mortality in a garment workers cohort exposed to formaldehyde was observed after 20 years exposure [Pinkerton et al., 2004]. Elevated heart disease has been observed among blue collar workers in the textile, rubber, plastics, machinery and other chemical production, and manufacturing industry workers [Price, 2004; Fine and Rosenstock, 2005].

The silica dust exposures of Swedish miners were thought to be a potential cause of their risk for ischemic heart disease [Weiner et al., 2007]. This may help explain our observation of significantly elevated acute myocardial infarction risk among men employed in the coal mining industry in this study.

Higher smoking prevalences have been reported among mining and manufacturing workers, potentially adding to their heart disease risk [Bang and Kim, 2001; Lee et al., 2007]; however, NOMS PMRs were adjusted for smoking. A negative social gradient has been associated with coronary heart disease mortality [Steenland et al., 2004] that could help explain some of the elevated acute myocardial infarction mortality in our study. Although NOMS results for elevated risk for acute myocardial infarction are limited by uncontrolled confounding from cholesterol and other lifestyle factors, it is unlikely that the moderate excess and large number of deaths we observed can be explained entirely by lifestyle risk factors. Case-control studies could further investigate these findings by studying risk factors that include cardio toxic exposures and particularly the precipitants of heart attacks, in conjunction with occupational exposure assessments for crop production/farming, textile mill, farm chemicals, and mining industry workers.

Leukemia in Managerial, Sales, Administrative, Financial, and Professional Occupations

A striking finding of significantly elevated leukemia mortality was noted primarily for men working in the financial and public administrative industries (banks/savings & loan/credit agency and insurance) and for white collar occupations (advertising/sales managers) when compared with other male workers. Results are mixed in other studies of leukemia risk that included office workers. Leukemia mortality was reported to be significantly elevated for several white collar occupations in Washington State, including purchasing agents, buyers managers, sales representatives, and insurance agents during 2000–2010 [Milham and Ossiander, 2001]. A small New Zealand case-control study reported that risk was not elevated in administrators and other occupations [McLean et al., 2009]; and a cancer case control study of acute myeloid leukemia recently reported significantly decreased risk in public administration workers from 1988–2007 [Tsai et al., 2014]. However, German clerical and related office workers had a twofold significant excess of chronic lymphocytic leukemia [Richardson et al., 2008]; and, an Italian case-control study found a significant doubling in risk for male office managers and directive clerks [Constantini et al., 2001]. Nordic cancer incidence studies found significantly elevated leukemia among male administrators, sales agents, and clerical workers. [Anderson et al., 1999; Pukkala et al., 2009].

Yet data on possible etiologic agents are scarce. Potential exposure to emissions from office furniture and equipment have been associated with employment in those environments. Early toxicity studies reported significant emissions of carbon black, styrene, and benzene, during the 1970s–1980s from office machines; although, emissions were reduced in the 1990s. Since 2000, nanoparticles (metals) have been reported primarily in association with emissions from laser jet printers and have been associated with increased systemic inflammation and oxidative stress [Elango et al., 2013; Khatri et al., 2013]. In addition, formaldehyde exposure has been associated with emissions from office and other furniture. The International Agency for Research on Cancer classified formaldehyde as a human carcinogen [IARC, 2006]; although, the National Cancer Institute cohort study of leukemia and formaldehyde producers and product manufacturers observed significantly increased risk for leukemia only at peak exposures [Beane et al., 2009]. Additionally, office workers may work in areas adjacent to production areas where exposure to industrial carcinogens or cardio toxins occur [NIOSH, 1989]. NOMS leukemia PMRs were not adjusted for cigarette smoking, a known risk factor for leukemia [Linet et al., 2006]; however, white collar workers tend to have less passive exposure to cigarette smoke, as measured by serum cotinine levels among nonsmokers [Wortley et al., 2002; Mohr and Shalat, 2005], as well as a lower reported prevalence of smoking 1978–1997 than blue collar workers [Lee et al., 2007].

Socioeconomic status has been associated with higher leukemia rates in white collar workers and may explain part of the excess observed in management and financial occupations [Pulte et al., 2013]. Also, smoking is a risk factor for leukemia, but is not as strong as for heart disease. If it were causing the excess risk observed in the office workers in our study, one might expect to see excess lung cancer in the occupations that have elevated leukemia risk. However, review of NOMS data revealed only three occupations or industries that had significantly elevated lung cancer risk before age 65 in any of the gender/race groups: Black female machinery (except electrical) industry, White female operations specialty managers, and Black female engineers. However, none of these gender/race groups corresponded to those we have reported with significantly elevated leukemia risk. Although US death rates due to leukemia have been slowly declining in recent years, incidence rates have been slowly rising in men, indicating the need for better etiologic data and prevention [ACS, 2007; Kohler et al., 2011]. The persistence of elevated risk in office occupations together with recent information about potential exposures suggest that an evaluation of office workers, leukemia and environmental exposures is warranted.

Male engineers were observed to have very high leukemia risk; however, electrical engineers have been reported at risk of leukemia in several studies of occupations with exposure to electrical or magnetic radiation fields [Loomis and Savitz, 1990; Bethwaite et al., 2001]. A recent retrospective assessment of exposure to chemicals for a microelectronics and business machine manufacturing facility reported that engineers (and machine operators) were among the occupations exposed to solvents and other chemical processing agents and recommended that occupational exposures be reduced [Fleming et al., 2014].

Leukemia in Protective Services

Black men in protective services occupations were found to have the highest leukemia PMRs that rose to over two-fold risk in the most recent time period. Violanti et al. [1998] reported finding a significantly elevated risk of leukemia in the Buffalo police officers cohort that was highest in officers with 10–19 years of service, but etiology was unknown. The NOMS data for the public safety industry also showed a very high proportionate mortality risk among male protective service officers that increased strongly over time, with over a twofold excess in the most recent time period, 1997, 2003–2004, and 2007. Risk factors for leukemia in police and other protective services officers should be further investigated and evaluated carefully in analytic studies in order to identify opportunities for prevention.

The purpose of the study was to generate hypotheses about occupational exposures that may cause leukemia and acute myocardial infarction. The NOMS database is one of the few available sources of data that is large enough to evaluate risks for site-specific cancer and chronic occupational disease for small or mobile populations and minority and/or vulnerable workers that have not previously been studied [Ward et al., 1994; Loomis and Schulz, 2000]. The flexibility of the NOMS system allows the user to broadly or narrowly define disease, occupation, and industry; and, permits the examination of risk for a wide range of industries, occupations, and causes of death. The NOMS database is a resource that can be used for initial evaluations of possible occupation-mortality links by the scientific community. NOMS data have contributed to many epidemiologic investigations and have provided a basis for over 140 published studies. Other investigators may access and view all PMR results by 310 industries, 550 occupations, and 350 causes of death on the NOMS website at http://www.cdc.gov/niosh/topics/NOMS/ [NIOSH, 2014].

Impact of the NOMS Study

Epidemiologists and other scientists have used occupational mortality surveillance data in a number of ways, the most basic being to profile cause-specific mortality by industry and occupation as evidenced by numerous peer reviewed reports. NOMS-based investigations and studies have been used by NIOSH and others as evidence to establish research programs [Robinson et al., 1995], conduct additional analytic epidemiologic studies and clinical trials [Freedman et al., 1997], provide support for rulemaking and policy recommendations [CDC, 1995; OSHA, 1997; Luckhaupt and Calvert 2008; ILO, 2010], and guide more specific studies [Savitz et al., 1998; Park et al., 2005; Sieber et al., 2014].

Limitations

The limitations of occupational mortality surveillance data have been discussed elsewhere [Checkoway et al., 2004; Robinson et al., 2012]. In brief, mortality data are limited by the misclassification inherent in cause of death, usual occupation, and industry reported on the death certificate, although this tends to lower risk estimates toward the null. Also, statistical limitations in the PMR analysis method can bias risk estimates. For example, if the overall mortality rate of the worker group studied is higher than that of the comparison population, the PMR as an estimator of the SMR or death rate may be artificially decreased [Decoufle et al., 1980]. Another bias could arise because a PMR can be affected by disproportionate increased or decreased mortality from other causes of death. For example, very high PMRs due to prevalent large causes such as heart disease or injury can lower cancer PMRs. [Wong and Decoufle, 1980; McDowall, 1983a, b]. Other statistical approaches such as the mortality odds ratio (MOR) may be useful in overcoming some of the limitations [Miettinen and Wang, 1983]. On the other hand, it has been demonstrated that analytically the PMR statistic is equivalent to a relative SMR, that is, the ratio of the cause of death specific SMR to the SMR for all causes of death [Marsh et al., 1987]. Other studies suggest that PMR analysis, when used to estimate rates for population-based studies of workers, may be less biased than SMR (rate-based) analysis—because PMR comparison with a working population limits the impact of the healthy worker effect—that is, all causes mortality in workers is low during the working years compared to the general population due to selection processes in employment [Park et al., 1991; Checkoway et al., 2004].

Mortality data differ from incidence data and this can result in prevalence-incidence bias that varies by disease [Percy et al., 1981]. The competing risk that results from survival patterns can also alter risk estimates.

CONCLUSION

The elevated risks for acute myocardial infarction mortality in the agricultural chemical manufacturers and wholesale farm supplies industries are new observations and should be confirmed. White males employed in advertising, sales, and managerial occupations and the public administrative and financial industries were noted to have significantly elevated risk of proportionate leukemia mortality that was not fully explained by differences in social status. Elevated levels of formaldehyde, a known leukemogen, have been detected in office settings suggesting a potential association with this outcome. Work is needed to evaluate whether office workers have been exposed to formaldehyde or other leukemogens at levels high enough to cause increased risk for leukemia. Examination by leukemia subtypes may also be informative.

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Dr. Walker retired from NIOSH June, 2011.