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Results From a Ukrainian-US Collaborative Study: Prevalence and Predictors of Respiratory Symptoms Among Ukrainian Coal Miners

J.M. Graber, MS,[1]* R.A. Cohen, MD, FCCP,[1] A. Basanets, MD,[2] L.T. Stayner, PhD,[1] Y. Kundiev, MD,[2] L. Conroy, PhD,[1] V.V. Mukhin, MD,[3] O. Lysenko, MD,[4] A. Zvinchuk, MS,[5] and D.O. Hryhorczuk, MD, MPH[1]

Background *Underground coal mining is an expanding industry in Ukraine, yet little is known about the burden of respiratory disease among Ukrainian miners.*

Methods *A Fogarty International Center-supported collaboration between researchers at the University of Illinois and the Institute of Occupational Health in Kyiv, Ukraine formed to improve capacity for conducting and monitoring medical surveillance among Ukrainian coal miners. A cross-sectional survey among a random sample of working and former miners was conducted; demographic, work, and health information were collected using a standardized questionnaire. Weighted prevalence rates were calculated and predictors of respiratory symptoms explored.*

Results *Improvements in infrastructure, including spirometry and chest radiography testing, transformed medical surveillance among these miners. Results from the health study included that the prevalence of respiratory symptoms was higher among former compared to current miners (shortness of breath 35.6% vs. 5.1%; chronic bronchitis 18.1% vs. 13.9%, respectively). A statistically significant exposure–response relationship was observed between years mining and respiratory symptoms in former miners and between years mining at the coal face and respiratory symptoms among current miners. Evidence of downward bias from the healthy worker survivor effect was observed.*

Conclusions *This successful international collaboration built a sustainable infrastructure for conducting workplace medical surveillance and research. The resulting study was the first in the western literature to report on respiratory symptoms in this population; likely underestimation of disease rates due to selection and measurement biases was demonstrated. Efforts should continue to build this collaboration and to characterize and reduce respiratory illness among Ukrainian coal miners.* Am. J. Ind. Med. 55:1099–1109, 2012. *© 2011 Wiley Periodicals, Inc.*

KEY WORDS: coal mining; Ukraine; respiratory symptoms

[1]School of Public Health, University of Illinois, Chicago, Illinois
[2]Institute of Occupational Health, Kyiv, Ukraine
[3]Research Institute for Medico-Ecological Problems of Donbass and Coal Industry, Donetsk, Ukraine
[4]Hospital #25, Donetsk, Ukraine
[5]University of Illinois Louise Hamilton Data Management Center, Kyiv, Ukraine

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*Correspondence to: J.M. Graber, MS PhD, Division of Epidemiology and Biostatistics, School of Public Health, University of Illinois at Chicago MC923, 1603 West Taylor Street, Chicago, IL 60612-4392. E-mail: jgrabe2@uic.edu

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BACKGROUND

Occupational exposure to coal-mine dust continues to cause respiratory disease including pneumoconiosis, lung function impairment, and increased frequency of respiratory symptoms worldwide [NIOSH, 1995; Cohen et al., 2008]. There are over 300,000 workers employed in the coal mining industry in Ukraine (http://www.euracoal.be/pages/layout1sp.php?idpage=269, accessed May 20, 2011). Ukraine's current energy plan, ''Energy Strategy to 2030,'' proposes a significant increase in coal production by the year 2015. However, there is a paucity of information on the burden of respiratory disease among Ukrainian coal miners.

This study was conducted through a Fogarty International Center-supported collaboration between researchers at the Great Lakes Centers of the University of Illinois-School of Public Health (UIC) and the Institute of Occupational Medicine (IOM) in Kyiv, Ukraine. The UIC Fogarty grant for ''International Training and Research in Environmental and Occupational Health'' (ITREOH) supported the research training of Ukrainian investigators in epidemiologic methods, exposure assessment, pulmonary function testing, and standardized reading of pneumoconiosis chest X-rays. The specific aim of this study was to estimate the prevalence of, and risk factors for, respiratory symptoms and disease among Ukrainian underground coal miners.

An exposure–response relationship between cumulative coal-mine dust exposure and chronic bronchitis has been demonstrated in cross-sectional and longitudinal studies from the United States and the United Kingdom [Kibelstis et al., 1973; Marine et al., 1988; Seixas et al., 1992; Lewis et al., 1996; Henneberger and Attfield, 1997]. An excess of respiratory symptoms has been observed even among U.S. miners who had the majority of their exposure after the enactment of the current permissible exposure limit of 2 mg/m^3 [Seixas et al., 1992]. The deleterious effects of coal-mine dust exposure on pulmonary function have been found both among smokers and nonsmokers. In an autopsy study including lung sections from 722 U.S. coal miners, coal-mine dust accumulation significantly predicted emphysema after adjusting for smoking, age at death and race [Kuempel et al., 2009].

Our study of Ukrainian coal miners employed a cross-sectional design. In occupational settings, cross-sectional studies of diseases with long latencies, such as chronic respiratory illness, are especially prone to downward selection bias from the healthy worker survivor effect (HWSE) [Checkoway et al., 2004]. The HWSE may result when workers who are more susceptible to the effects of work-related exposures either leave employment or move to jobs with lower levels of exposure more frequently than workers who are not as susceptible to the exposure effects. Employment status is a key component of the HWSE [Fox and Collier, 1976; McMichael, 1976] hence we studied both current and former coal miners, and from the latter group collected information on reason for leaving work as a coal miner.

We present the lessons learned from our collaboration and the results from our study of the respiratory status of Ukrainian coal miners.

METHODS

The Collaboration: Goals and Approach

This study was the result of a capacity-building collaboration started by the American International Health Alliance (AIHA), a grantee of the United States Agency for International Development (USAID). The collaboration was developed between Hospital #25, which is the large primary care hospital and clinic in the city of Donetsk, Ukraine, and U.S. partners that included the Magee Women's Hospital, the University of Pittsburgh School of Public Health, the University of Pittsburgh Medical Center Department of Family Medicine and Clinical Epidemiology, the University of Illinois School of Public Health, and the Health and Safety Department of the United Mine Workers of America. The goal of this collaboration was to develop sustainable infrastructure for coal miners' health clinics including proper medical surveillance for respiratory disease. Staff members from Hospital #25 completed NIOSH certification in spirometry, B-reading training, and training in questionnaire development. Relationships were fostered between the scientists from IOM, UIC, and personnel from Hospital #25. The research training was further supported by the Fogarty ITREOH grant.

Study Location

The study was conducted in the heart of the Ukrainian coal-mine industry, the Donbass, within the city of Donetsk. Three coal mines were selected for the study based on their long standing association with City Hospital #25 where the mandatory annual medical surveillance examinations were conducted. The selected mines were deep-shaft anthracite coal mines typical of the region; they ranged in depth from 800 to 1,500 m. All three mines used long-wall mining, Mine 2 also used conventional mining techniques, including drilling and blasting to create tunnels; Mine 3 used a combination of conventional and modern mining methods.

An assessment of coal-mine dust levels was conducted in concert with the health survey and found that respirable dust exposures in the three mines were high compared to those in the U.S.: 75% of all samples exceeded the current US permissible exposure level (PEL) of 2 mg/m^3 and 37% of samples exceeded the PEL for

quartz. During mining activities no significant differences in coal-mine dust levels were observed at different locations within the mines. However, in Mine 2 total dust concentrations were significantly lower during mining activities and concentrations of quartz were significantly lower during development activities (such as digging tunnels) compared to the other two mines. Production levels, reported by mine management, were also lower for Mine 2 compared with the other two mines. The sampling did not include enough job categories or conditions to facilitate estimation of exposure for the study miners [Kathleen Kennedy MPH, Chicago, 2002, written communication].

Study Design and Sampling Strategy

Separate cross-sectional surveys of working and former underground coal miners were conducted in 2000 and 2002, respectively. Personnel departments at each study mine provided lists of current and former miners.

Miners age 30 or older were eligible for enrollment into the study of currently working underground coal miners (current miners). Older miners were oversample to ensure that stable estimates of disease rates could be obtained for that group. The population of miners was stratified by mine and then by the following age tertiles: 30–45, 46–61, and $\geq$62–72 years. A random sample was drawn from each mine-age strata so as to have an approximately equal number of potential participants from each stratum. For former miners, the sampling was designed to ensure stable estimates of symptom prevalence within each of three categories of the reason for employment termination: pensioned, disabled, or other (included any other reason for employment termination). A random sample was drawn from each strata of reason for leaving work.

Data Collection

A survey modeled on the American Thoracic Society and the U.S. National Institute for Occupational Safety and Health (NIOSH) instruments was administered to participants by trained interviewers. The survey collected information on demographics, respiratory symptoms and illnesses, work histories, history of tobacco use, and among former miners, reason for leaving work. Study participants underwent spirometry testing and received chest X-rays, results of which will be reported elsewhere.

Definitions of Symptom and Illness

Chronic bronchitis was defined as having both usual cough and phlegm, defined thusly:

- *Usual cough*: Having a cough on most days of the week for 3 consecutive months or more during the year, and having one or more of the following: coughing as much as 4–6 times a day; usually coughing at all on getting up; or, any usual coughing during the rest of the day.
- *Usual phlegm*: Bring up phlegm on most days of the week for 3 consecutive months or more during the year, as well as one or more of the following: usually bringing up phlegm as much as twice a day; usually bringing up phlegm at all on getting up; or, usually bringing up phlegm at all during the rest of the day.
- *Shortness of Breath* (SOB): Being ''troubled by shortness of breath when hurrying on the level or walking up a slight hill'' and one or more of the following: having to walk slower than people of your age on the level because of breathless; having to stop for breath after walking about 100 yards on the level; or, being too breathless to leave the house or breathless on dressing or undressing.

Statistical Methods

Overall study response rates were calculated as the percentage of miners who completed a survey among those whom were selected to participate, as well as within major sampling strata (i.e., by mine for current miners and by reason for leaving work for former miners).

Prevalence of respiratory symptoms and sample weights

Characteristics of study miners including demographics, mining history, and smoking were described for current and former miners. Weighted prevalence rates and 95% confidence intervals were calculated for chronic bronchitis and SOB among former and current miners alone and within levels of demographic, work, and smoking characteristics. Because a stratified sampling design had been used, relative sample weights were developed and assigned to each observation and used for all analyses. These sample weights were used in order to present estimates of population characteristics (rather than sample characteristics) and to obtain correct standard errors for statistical testing. The population weights were calculated by taking the inverse of the selection probability for the sampling strata. Relative weights were then obtained by dividing the population weight by the average population weight [Kalton, 1983].

Current miners lacked data on smoking quantity, so for that group years-of smoking was used for analysis rather than pack-years of smoking. Missing data values represented $<$3% of any one variable; they were recoded to the most prevalent level for categorical variables and the median for continuous variables by employment status.

Multivariate analysis of prevalence and risk factors

Because of the cross-sectional study design, binomial regression was used to assess the exposure–response association between duration of coal mining and chronic bronchitis and SOB and to evaluate risk factors. Since there were no reliable estimates of coal-mine dust levels from the study mines, duration of mining was used as a proxy for coal-mine dust exposure. Because exposures are generally highest at the coal face, the relationship between duration of mining at the coal face and respiratory symptoms was also explored. Different forms of the exposure–response relationship (e.g., categorical, log-linear, adding a quadratic term) were assessed while including all covariates in the model. Best model fit was determined using the likelihood ratio test (LRT). Effect modification with the exposure terms was evaluated by including a cross-product term of each covariate with the exposure and considered present if the associated *P*-value was significant at the alpha level of <0.10. Covariates or combinations of covariates were included in the model if their addition resulted in a change of $>10\%$ in the estimate of the prevalence ratio (PR) or if the model fit was improved as demonstrated by the LRT. A priori all models included age and smoking. In multivariate models, PRs are presented for a 10-year increase in exposure duration.

Evaluation of reason for leaving work

The role of reason for leaving work was explored as a potential confounder or effect modifier of the exposure–response relationship observed between years mining and respiratory symptoms. This analysis included former miners aged 65 and younger and excluded the subgroup of miners who reported previously working in another dusty industry.

Human Subjects' Protection

The study was approved by the University of Illinois at Chicago, Institutional Review Board (protocol #2000-0578.) and by the Scientific Council of the IOM, Academy of Medical Sciences of Ukraine through a Single Project Assurance (SPA# S-022277-01). All participants were administered and signed informed consent.

RESULTS

Accomplishments and Lessons Learned From the Collaboration

The team of U.S. and Ukrainian investigators was able to successfully leverage the modest resources provided through the AIHA USAID grant and Fogarty ITREOH grant to establish a research program that addressed public health and scientific issues of importance for both countries. The key success factors were the individual investigators' commitment to promoting the health and safety of coal miners; the high-level endorsement of the research program by Ukrainian IOM and the Ukrainian Academy of Medical Sciences; the significantly lower cost for scientific manpower in Ukraine; and the strategic investment in research training that could support a long-term research program. Salary support for Ukrainian collaborators was provided in large part by the Ukrainian Ministry of Health and Academy of Medical Sciences and, in part, through the Fogarty ITREOH grant.

The partnership developed during this work transformed the surveillance examinations performed for coal miners. Spirometry testing was improved from use of a non-recording Wright type spirometer to the standards recommended by the ATS and the European Respiratory Society. Chest radiography was improved from mass miniature X-ray screening to full size 14×17 in. PA chest radiographs, read using ILO standards. Standardized respiratory questionnaires were developed based on NIOSH and ATS standards. These techniques were incorporated into the routine medical examinations for coal miners conducted by Hospital #25.

Data management for the study was done by the UIC Data Management Center in Kyiv. The ITREOH-supported Data Management Center provides research support services for several collaborative U.S.-Ukrainian studies, including the current study.

This research collaboration model on coal miners' health was officially adopted as a part of the work plan of the World Health Organization network of Collaborating Centers in Occupational Health.

Study Enrollment

Potential participants included 1,061 current and 1,124 former miners of whom 53.9% ($n = 592$) and 42.1% ($n = 473$), respectively, completed the survey. Response rates varied by sampling strata: among active miners the rates were highest from Mine 1 (68.9%) and lowest among enrollees from Mine 3 (47.3%); among former miners response rates were 33.0% among retired miners and 44% among miners who left work because of disability or for another reason.

Prevalence of Respiratory Symptoms

As expected, current miners were on average younger than former miners (mean age 47.1, range 30–

72 years, and mean 56.7 years range 29–81, respectively; Table I). The two groups were otherwise similar in terms of smoking habits, nationality and by average years mined and worked at the coal face. The similar tenure in the current and former miners may, in part, be due to the latter having a relatively high proportion of miners (38%) who left work before being pensioned and hence presumably accumulated less tenure.

The prevalence of SOB was seven times higher among former compared to current miners, while the prevalence of chronic bronchitis was similar (Table II). Respiratory symptoms increased with age and years mining. Interestingly among men who worked at the coal face a bimodal distribution was observed, with the highest prevalence rates among miners who had worked at the face for <10 and >25 years. Rates of respiratory symptoms were lowest among miners who had left work for a reason other being pensioned or disabled.

Multivariate Analysis of Prevalence and Risk Factors

Current miners

Duration of working at the coal face was a strong predictor of chronic bronchitis among current miners while duration of work in coal mines was not. The associations between SOB and the two exposures were of borderline significance. Age, years of smoking, and working in Mine 2 were each positively associated both outcomes; being of other than Ukrainian or Russian descent was positively associated with the prevalence of chronic bronchitis (data not shown).

TABLE I. Characteristics of Miners Who Completed the Survey by Employment Status

	Current miners (n = 592)		Former miners (n = 473)	
Variable (unit = years)	**Weighted mean[a]**	**Std. dev.**	**Weighted mean[a]**	**(Std. dev.)**
Age at survey	47.1	9.3	56.7	11.2
Duration of work as a coal miner	22.6	9.5	20.6	10.6
Duration of work at the coal face	8.1	11.0	7.7	12.0
Cigarette smoking	19.6	13.8	26.3	17.2

	Current miners (n = 592)		Former miners (n = 473)	
Variable	**Weighted percent[a]**	**Count**	**Weighted percent[a]**	**Count**
Smoking status				
Current	64.0	351	64.9	313
Former	15.1	108	18.5	83
Never	20.9	133	16.6	77
Mine				
Mine1	39.4	258	31.8	128
Mine 2	31.9	117	28.3	144
Mine 3	28.6	217	40.0	201
Nationality				
Ukrainian	53.1	332	53.8	248
Russian	42.2	231	39.2	196
Other	4.7	29	7.0	29
Worked in other dusty industry				
Yes	11.1	62	6.3	30
Reason left work				
Disabled			7.4	137
Pensioned	n/a		31.9	157
Other[b]			60.7	179

[a]All analyses used relative sample weights, that is, the population sample weight (the inverse of the selection probability for the sampling strata) divided by the average population weight.

[b]Other reasons for leaving work, which included voluntary termination (quitting) or involuntary termination (being laid-off or fired).

TABLE II. Prevalence of Respiratory Symptoms of Current and Former Miners Within Levels of Demographic, Work, and Smoking Characteristics

	Current coal miners (n = 592)								Former coal miners (n = 473)							
	Chronic bronchitis				Shortness of breath				Chronic bronchitis				Shortness of breath			
	n	%[a]	(SE)[b]	*P*-value	n	%[a]	(SE)[b]	*P*-value[c]	n	%[a]	(SE)[b]	*P*-value[c]	n	%[a]	(SE)[b]	*P*-value[c]
Respiratory symptoms																
Chronic bronchitis	69	13.9	1.9						90	18.1	2.1					
Shortness of breath					36	5.1	1.2						174	35.6	2.6	
Age at survey																
≤45	28	14.6	3.0		7	3.8	1.7		13	12.3	3.8		16	9.4	3.0	
46–55	17	14.5	3.3		8	6.1	2.2		29	21.2	4.1		35	26.0	4.4	
56–65	13	10.1	3.1		11	4.6	1.8		21	18.3	4.6		48	42.1	6.1	
65+	11	22.0	6.0	0.3175	10	17.0	5.3	0.0161	27	18.4	3.7	0.5177	75	51.9	4.9	<0.0001
Years mined																
5–14	8	10.7	4.1		1	1.0	0.9		17	6.5	2.0		39	19.2	3.6	
15–24	26	14.2	2.9		11	5.6	2.0		35	20.0	3.6		59	30.5	4.2	
25–34	15	16.2	4.2		5	4.5	2.2		20	27.5	6.0		40	54.4	6.7	
≥35	20	14.8	3.7	0.7955	19	9.8	2.8	0.0621	16	23.8	5.9	0.0019	36	54.2	7.0	<0.0001
Years working at the face																
None	27	9.6	2.1		7	1.9	1.1		37	15.1	2.6		82	32.6	3.5	
>0–10	12	24.4	7.2		7	11.0	5.4		14	23.3	6.4		27	42.2	7.1	
11–20	13	17.5	5.0		6	4.9	2.2		14	14.3	5.0		18	21.8	6.5	
>20	17	19.9	4.0	0.0703	16	8.5	3.3	0.0246	25	23.3	4.9	0.2868	47	45.2	5.9	0.0544
Smoking status																
Current	48	16.9	2.5		18	5.8	1.6		65	19.9	2.6		103	32.9	3.2	
Former	13	10.7	3.3		11	4.9	1.7		11	14.8	4.8		36	43.9	6.4	
Never	8	7.4	3.2	0.0653	7	2.9	1.2	0.3387	14	14.4	4.6	<0.0001	35	37.0	6.7	<0.0001
Years smoked																
None	8	7.4	3.2		7	2.9	1.9		14	14.1	4.5		36	38.0	6.7	
≤20	13	6.7	1.9		7	2.2	1.0		6	9.7	5.1		14	17.6	6.0	
21–30	27	24.7	4.7		12	9.6	3.2		19	15.4	3.8		29	22.9	4.6	
>30	21	16.1	3.7	0.0005	10	5.0	1.9	0.0372	51	22.8	3.3	0.0202	95	45.4	4.0	0.0147
Mine																
Mine1	23	8.7	1.8		5	1.6	0.7		23	18.2	3.9		40	32.1	4.7	
Mine 2	28	25.2	4.2		15	9.7	3.1		46	17.0	3.7		67	47.7	5.1	
Mine 3	18	8.6	2.1	<0.0001	16	4.8	1.4	0.0012	41	18.7	3.3	0.3286	67	29.8	3.9	<0.0001
Nationality																
Ukrainian	37	12.2	2.2		30	7.7	1.7		41	15.2	2.6		95	38.7	3.7	
Russian	27	14.8	3.0		4	2.1	1.4		38	19.4	3.5		68	30.3	4.0	
Other	5	26.0	10.9	0.2797	2	2.5	1.6	0.0243	11	32.8	9.9	0.1007	11	41.7	10.9	0.2774
Reason left work																
Disabled									28	22.2	3.7		63	50.0	4.4	
Pensioned					n/a				37	22.4	3.7		67	43.7	4.0	
Other[d]									25	15.2	2.9	0.1043	44	29.6	3.7	0.0011

[a]All analyses used relative sample weights, that is, the population sample weight (the inverse of the selection probability for the sampling strata) divided by the average population weight.

[b]Standard errors of the weighted percentage, calculated using relative sample weights.

[c]The *P*-value for nominal variables is associated with the Rao–Scott chi-square statistic, it was computed from the Pearson chi-square statistic with a design correction based on the design effects of the proportions; the *P*-value for ordinal variables is associated with the chi-square test for nonzero correlation with a design correction and can be interpreted as a test for trend.

[d]Other reasons for leaving work included voluntary termination (quitting) or involuntary termination (laid-off or fired).

Former miners

A history of work in another dusty industry was found to be a significant modifier of the exposure–response association between years of working as a coal-miner and chronic bronchitis ($P = 0.009$). Among the 443 men without prior work in a dusty industry the association was positive and significant; among the 30 miners with prior work in a dusty-industry no association was observed, although this latter observation may be due to small numbers. In the best fitting model among men without prior work in a dusty industry, age, pack years of smoking and being a nationality other than Ukrainian or Russian were positive predictors of chronic bronchitis ($P = 0.0080$, <0.0001, and 0.0140, respectively, data not shown).

Prior work in a dusty industry was also found to modify the association between years mined and SOB, but the interaction was not as strong as for that observed with chronic bronchitis ($P = 0.0470$). Among men without prior work in a dusty industry, increased years of mining at the coal face was a significant predictor of SOB (Table III) as were age and pack-years-of smoking ($P = 0.0020$ and 0.0360, respectively, data not shown).

Reason for Leaving Work

Reason for leaving work was not a confounder or a significant effect modifier of the exposure–response relationship between duration of coal mining work with either chronic bronchitis or with shortness of breath. However, for both outcomes when stratifying on reason for leaving work, a log-linear statistically significant exposure–response relationship was only observed among miners who terminated employment for a reason other than being pensioned or disabled (Table IV).

DISCUSSION

This successful research collaboration was due in part to the research training supported by the Fogarty ITREOH grant. The scale of the research program required substantial in-kind contributions from the Ukrainian Institute of Occupational Medicine as well as leveraging the capacity-building provided by USAID through the International Health Alliance. The ITREOH-supported Data Management Center provided coordination of field research activities as well as state-of-the-art data management.

TABLE III. Prevalence Ratios (PRs) for Respiratory Symptoms Estimated for Predictor Variables in Binomial Multivariate Models Among Former Underground Ukrainian Coal Miners With and Without a History of Work in Another Dusty Industry*

Current miners (n = 592)[a]	PR[b]	Std. err.	95% CI	P > z
Chronic bronchitis				
Year of coal-mine dust exposure	1.30	0.31	0.94–1.93	0.3350
Years working at the coal face	1.12	0.46	1.03–1.21	0.0070
Shortness of breath				
Year of coal-mine dust exposure	2.01	0.46	1.35–3.20	0.1330
Years working at the coal face	1.10	0.063	0.99–1.23	0.0970

	Without a history of previous work in a dusty industry (n = 443)				With a history of previous work in a dusty industry (n = 30)			
Former miners (n = 473)[a]	PR[b]	Std. err.	95% CI	P > z	PR[b]	Std. err.	95% CI	P > z
Chronic bronchitis								
Year of coal-mine dust exposure	1.96	0.32	1.41–2.70	<0.0001	0.77	0.65	0.15–4.00	0.7580
Years working at the coal face	1.10	0.13	0.84–1.37	0.6220	0.76	0.55	0.18–3.12	0.7040
Shortness of breath								
Year of coal-mine dust exposure	1.55	0.24	1.11–2.04	0.0050	0.86	1.10	0.06–10.77	0.9060
Years working at the coal face	0.95	0.10	0.77–1.17	0.6680	0.72	1.17	0.46–11.4	0.1570

*All analyses used relative sample weights, that is, the population sample weight (the inverse of the selection probability for the sampling strata) divided by the average population weight.

[a]All models controlled for age pack-years smoking, nationality and mine.

[b]The prevalence ratio (PR) represents an increase in the prevalence of the outcome for every 10 years of exposure, adjusted for all other variables in the model (age pack-years smoking, nationality, and mine).

TABLE IV. The Effect of Reason for Leaving Work as a Coal Miner on the Exposure Response Association Between Respiratory Symptoms and Years Working as a Coal Miner Among Former Miners Aged 65 and Younger With No Previous Work in a Dusty Industry (n = 340)*

	Chronic Bronchitis				Shortness of Breath			
Model structure and covariates[a]	PR[b]	Standard error	95% confidence interval	*P*-value	PR[b]	Standard error	95% confidence interval	*P*-value
Without conditioning on reason for leaving work	1.57	0.24	1.16–2.12	0.0040	2.07	0.46	1.35–3.18	0.0010
Controlling for reason left work	1.74	0.35	1.16–2.59	0.0060	2.08	0.46	1.35–3.22	0.0010
Stratifying by reason left work								
Pensioned (n = 103)	1.33	0.39	0.74–2.35	0.3390	1.61	0.47	0.91–2.87	0.1030
Disabled (n = 98)	0.95	0.47	0.36–2.50	0.9210	0.72	0.22	0.40–1.32	0.2980
Other[c] (n = 139)	2.41	0.92	1.13–5.12	0.0220	3.00	1.35	1.22–7.26	0.0160

*All analyses used relative sample weights, that is, the population sample weight (the inverse of the selection probability for the sampling strata) divided by the average population weight.

[a]Models controlled for years mined at the coal face, pack years of smoking, and mine.

[b]The prevalence ratio (PR) represents an increase in the prevalence of the outcome for every 10 years of exposure adjusted for all other variables in the model.

[c]Other reasons for leaving work included voluntary termination (quitting) or involuntary termination (laid-off or fired).

Study Results: Prevalence of Respiratory Symptoms

To the best of our knowledge, this study is one of the first studies to report on the burden of respiratory symptoms among underground Ukrainian coal miners in the western literature. The study will help to establish a baseline of disease prevalence in this population from which collaborative prevention efforts can be planned and evaluated. Our study also elucidates some of the challenges of accurately estimating disease rates in working population, including the tendency to underestimated disease rates.

Two studies from the U.S. National Study of Coal Workers' Pneumoconiosis (NSCWP) have reported prevalence rates of respiratory symptoms. The corresponding rate among former miners for chronic bronchitis from our study (18.1%) was lower than those reported from either of those studies, and that for shortness of breath (35.6%) was midway between the US study estimates. These studies enrolled current and former miners aged 58 or less from previous rounds of the NSCWP. Our study did not restrict enrollment by an upper age limit. The study populations differed in that Seixas et al. [1992] reported symptom prevalence rates from miners whose average age was 40 years and average cumulative dust exposure was 16 mg/m^3-year [Seixas et al., 1992]. The report by Henneberger and Attfield [1997] included a group of miners whose average age was 49.9 and average cumulative dust exposure level was 52 mg/m^3-year. The prevalence rates for chronic bronchitis from these studies were 21.0% and 34.8%, respectively; for shortness of breath the corresponding rates were 22.3% and 43.0%.

The rates we observed among currently working miners (chronic bronchitis = 13.9%; shortness of breath = 5.1%) were considerably lower than the prevalence of chronic bronchitis among British coal miners with 10 or more years of working at the coal face which ranged from 9.7% among non-smokers with no coal-mine dust exposure to 41.2% among smokers with an intermediate-level of exposure [Marine et al., 1988]. A 1970 study from the UK reported an overall rate of 38.7% [Rae et al., 1970]. A survey of South African coal miners reported a lower prevalence of chronic bronchitis (6%) than we observed among current miners, and a higher prevalence than we observed among former miners (46%) [Naidoo et al., 2006].

A number of factors may account for the lower prevalence rates of respiratory symptoms which we observed. However, dust exposures were high in the three study mines so we do not believe that lower dust exposure is responsible for the lower disease rates in our sample of miners. Rather many factors, including bias from both selection and measurement issues, likely contributed to a strong downward bias in the estimation of prevalence rates in our sample.

Study Results: Potential Sources of Selection Bias

Participation rates for both surveys were low. Among former miners the reasons for not participating in the study were collected and included being too sick (n = 52, 5.6%), lost to follow-up (n = 259, 27.7%), and having died (n = 303, 32.4%). Hence miners who enrolled in our study may have been healthier than those who did not enroll.

A small study of 478 miners from the first round of the NSCWP examined the potential bias introduced by

self-selection. The authors reported that miners with the longest duration of work at the face had a lower prevalence of airway hyper-responsiveness than those who never worked at the face (39% vs. 12% $P < 0.01$) [Petsonk et al., 1995]. They also reported that miners with greater bronchial hyper-reactivity were less likely to have worked in dusty jobs than those who were less hyper-reactive. Their results provided some evidence for health-related job selection among coal miners and support the hypothesis that studies of workers in dusty jobs may underestimate the effects of dust exposure on respiratory health. These findings may also imply that the higher than anticipated proportion of symptoms observed among miners with lower tenure at the coal face observed in the current study may, in part, represent a hyper-responsive subgroup.

Cross-sectional study designs may be strongly impacted by the healthy worker effect (HWE), a term used to describe selection biases associated with employment status. The healthy-hire effect (HHE) describes the bias attributable to healthier individuals in a population being more likely to both seek and gain employment [Arrighi and Hertz-Picciotto, 1993]. The HHE is sufficiently controlled in analyses such as ours which use an internal reference for exposure. Our exclusion of miners with <5 years of mining tenure (or younger than age 30 as a proxy for tenure among current miners) was also an attempt to reduce this potential bias.

The phenomenon that healthier individuals may be more likely to remain in jobs, while those less healthy may be more likely to either leave employment or move to a position with lower levels of exposure, is referred to as the HWSE. This bias accumulates and varies over time. Because components of this bias such as employment status can be both confounders and intermediate variables, there is no agreed upon satisfactory solution for its control in most observational studies [Robins, 1987; Robins et al., 1992].

Observations from our analysis which supported an influence of the HWSE include: the low prevalence rates of respiratory illness among current compared to former miners, the lack of statistically significant exposure–response associations between duration of mining and respiratory symptoms in current miners in multivariate analysis, and our findings from the analysis of work status, specifically the observation of an exposure–response association between respiratory symptoms and mining tenure only within the subgroup of men who left mining for reasons other than disability or retirement.

Our finding of higher rates of respiratory symptoms among former compared with current miners is consistent with those from other occupational studies, including cohort studies of coalminers in the US [Petersen and Attfield, 1981; Henneberger and Attfield, 1996] and the UK [Soutar and Hurley, 1986], and a cross-sectional study from South Africa [Naidoo et al., 2006].

Another factor possibly related to selection bias is that Ukrainian miners undergo mandatory annual health screening. While the policy of the mining administration was not to use the results of those examinations for employment decisions, it is plausible that the examination resulted in either voluntary or involuntary termination of work for men with signs of disease. We also speculated that it is possible that fear of termination due to disease status may have resulted in lower enrollment rates among symptomatic working miners.

Study Results: Potential Sources of Information Bias

A strength of our study was that we collected information on why former miners left work as coal miner. A limitation of our approach, however, was that the category ''left for another reason'' was heterogeneous, possibly including men who had left work voluntary or involuntary, either of which may have been related to health or exposure status. A study from the NSCWP reported higher rates of respiratory symptoms among former miners who left for health, rather than non-health related reasons [Attfield and Seixas, 1995]. A related consideration is that miners who were disabled because of injury were likely to have had a different exposure and outcome profile than those who were disabled as the result of respiratory illness.

There were also a number of potential measurement issues concerning both the exposure and outcomes which may have reduced the accuracy or precision of our findings. The lack of coal-mine dust measurements is a significant limitation to this research; duration of mining and duration of mining at the coal face were a crude substitute for estimates of individual cumulative coal-mine dust exposure. However, the dust sampling conducted in 2001 in the study mines did not include enough job categories or conditions to make them suitable for exposure estimates. While there are historical data from Ukraine used for compliance monitoring, the poor validity and reliability of those data also rendered them unsuitable for estimating historic exposures.

Study Results: Other Findings

An unexpected finding was that both current and former miners who were ethnic minorities (ethnicity other than Ukrainian or Russian) had higher prevalence rates of chronic bronchitis than the majority populations, after controlling for age and smoking. This was a heterogeneous group comprised of men mainly of Belarusian and Moldavian descent. Among current miners, statistical testing found no differences between these miners and

those of Ukrainian or Russian descent in terms of age, smoking, mine at time of enrollment, or prior work in a dusty industry (data not shown), but the small number of ethnic minorities (n = 29) may have limited our ability to detect differences. Among former miners, those who were ethnic minorities were on average older than other miners (61.9 years, 95% CI 58.8, 64.9 vs. 56.7 years old, 95% CI 55.6, 57.7) and less likely to be current smokers (44.8%, 95% CI 26.6, 63.0; n = 13) than their Ukrainian and Russian counterparts (67.6%, 95% CI 63.2, 71.9; n = 300). The former finding may reflect changes in smoking subsequent to symptom onset. Hence, it is unclear if the findings were due to differential work exposures, underlying health status, or some other unmeasured factor such as differences in culture or language. Given these findings, the burden of disease among ethnic minorities in Ukrainian coal mines may warrant further investigation.

Another intriguing finding was the higher rates of respiratory symptoms among current miners in Mine 2 compared with workers from the other two mines. While the analysis controlled for age and years mining, miners enrolled from Mine 2 were on average older than other miners (mean age 49.0 vs. 46.1, respectively; *P*-value [*t*-test] = 0.0006) and had longer tenure as miners (24.4 vs. 21.6 years, respectively, *P*-value for [*t*-test] = 0.0002), hence there may have been residual confounding in the analysis. Other unmeasured factors such as selective enrollment or differential work practices at the mines may also have contributed to this finding.

Study Results: Other Methodological Considerations

A strength of our analysis was the use of PRs rather than prevalence odds ratios. This decision was made for two reasons. Firstly when disease prevalence is over 10% the odds ratio may substantially over estimate the relative risk [Thompson et al., 1998]. Secondly and as discussed previously, in cross-sectional studies of chronic disease the average duration of observable disease likely differs by exposure status and is typically shorter for more highly exposed miners. In such conditions, the prevalence odds ratio is also likely inflated compare to the PR.

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