Prevalence of Bronchitis and Airway Obstruction in American Bituminous Coal Miners[1,2]

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SUMMARY

As part of an epidemiologic study, 8,555 bituminous coal miners underwent a limited medical examination consisting of spirometry, a posteroanterior radiograph of the chest, and a respiratory questionnaire. The relationship of bronchitis and airway obstruction to dust exposure and cigarette smoking was determined.

The prevalence of bronchitis was significantly higher in smoking miners than in their nonsmoking or exsmoking co-workers. Surface workers had less bronchitis than face workers, reflecting their lower dust exposure. This difference was statistically significant only for nonsmokers and exsmokers. Measurements of the ratio of 1-second forced expiratory volume to forced vital capacity were less than predicted in 37.6 per cent of nonsmokers, 50.5 per cent of exsmokers, and 58.8 per cent of smoking miners. Airway obstruction occurred in surface workers less frequently than in face workers. When the difference between smoking face workers and nonsmoking surface workers was analyzed, the effect of smoking was five times that of coal dust.

Introduction

Chronic bronchitis and its associated ventilatory impairment are important causes of morbidity and mortality in coal miners. While there is general agreement that cigarette smoking is the most important factor in the etiology of bronchitis in miners, it has been suggested in several British and European studies that chronic dust inhalation also plays a role. However, few attempts have been made to study the problem of bronchitis in U. S. coal miners and correlations with mining duties and dust levels have not been published. The purpose of the present investigation is to ascertain whether "industrial bronchitis" is a significant problem in U. S. coal miners.

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Materials and Methods

In 1969, the U. S. Public Health Service and the Bureau of Mines of the U. S. Department of Interior selected for study 31 coal mines that were widely scattered throughout the United States. The mines were chosen to represent different mining methods. Other criteria for inclusion were that the mine should have at least 100 miners, that it should have an expected working life of approximately 10 years, and that, as often as possible, dust exposure data should be available retrospectively.

Two anthracite mines were included in the

study. Since available evidence suggests that anthracite miners are exposed to a different mine environment than are their bituminous counterparts (1), and since the 523 anthracite miners examined constituted too small a group for independent statistical analysis, they were excluded from this report.

In the 29 bituminous mines, 8,555 men (90.8 per cent of the men employed in these mines) were subjected to a limited medical examination. This consisted of the administration of the Medical Research Council (M. R. C.) of Great Britain long questionnaire (2) on chronic bronchitis, and occupational history, and standard posteroanterior and lateral chest films. In addition, after 2 practice maneuvers, 3 forced expiratory volume maneuvers were performed. These were recorded as flow-volume loops on a recording oscilloscope and then photographed with a Polaroid camera. From the loops, the largest forced expiratory volume in one second (FEV_1) and largest forced vital capacity (FVC) were derived. If data were incomplete for any subject, his results were excluded.

Although individual measurements of dust exposure were not available for the participants in the study, it can be assumed that the magnitude of their exposure to dust was related to their job and working place in the coal mines. Previous measurements made by the Bureau of Mines (3) showed that face workers are exposed to the greatest and the surface workers to the least concentrations of respirable coal dust (coal dust particle size: 0.5–5.0 μm). In general, based on declining order of dust exposure, the working force can be divided into five groups, i.e., face workers, transportation workers, maintenance workers, those who are employed in miscellaneous underground work, and surface workers.

For the purposes of this study, chronic bronchitis was defined either as persistent phlegm production regardless of complaints of coughing, or as moderate phlegm production coupled with persistent coughing. Subjects were asked no further questions regarding the duration of their symptoms because the M. R. C. found that more than 95 per cent of those who give positive replies have had their symptoms for more than two years.[3]

Obstruction to airflow was considered to be present whenever the observed FEV_1/FVC was less than the mean value of the Europaische Gemeinschaft für Kohle und Stahl (4), as shown below.

Predicted FEV_1 as Per Cent of Vital Capacity, by Age

Age, years	18-19	20-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64
Mean FEV_1/FVC, %	82	80	78	77	75.5	74.5	73.5	72	70
Lower Limit (−2 SD), %	71	69.5	68	67	66	65	64	62.5	61

All statistical differences were regarded as significant if P was < 0.05.

Results

Prevalence of bronchitis: The prevalence of bronchitis and its relationship to age and smoking habits are shown in figure 1. As expected, both age and smoking habits influenced the percentage of miners with bronchitis.

In figure 2, years of mining experience is substituted for age, and the prevalence of bronchitis is compared by smoking habits and principal job of the miners. In each age group, cigarette-smoking face workers had a significantly higher prevalence of bronchitis than did their nonsmoking counterparts. A significant difference existed between the

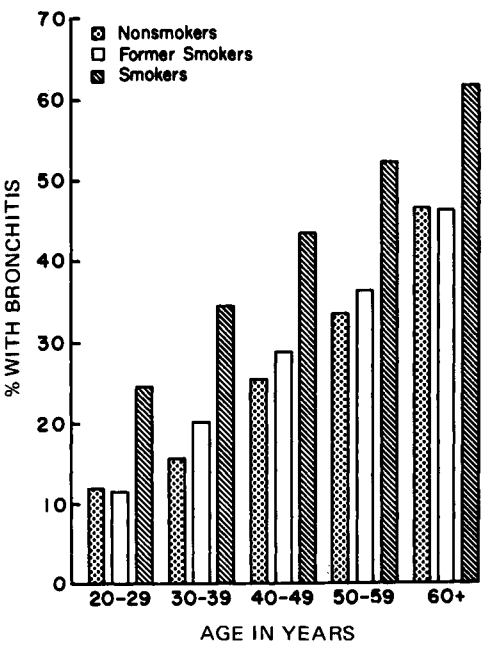

Fig. 1. Prevalence of bronchitis by age and smoking status in 8,492 bituminous miners.

[3] Instruction for the Use of the Questionnaire on Respiratory Symptoms, 1966, p. 7.

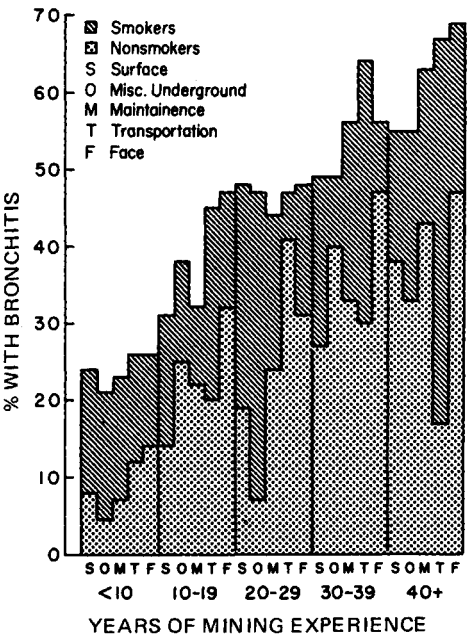

Fig. 2. Prevalence of bronchitis by smoking history, years of mine work, and principal job.

prevalence of bronchitis in nonsmoking face and surface workers for men who had mined for 10 to 39 years. In each group, work at the coal face was associated with a higher prevalence of bronchitis in nonsmokers. The same general trend existed for the smokers; however, the influence of cigarette smoking appeared to outweigh and submerge the effects of dust exposure, bronchitis not being significantly more common in face as opposed to surface workers except in the 10- to 19-year group. However, when the prevalence of bronchitis in all smoking face workers was compared to that in all smoking surface workers, face workers had a statistically higher prevalence than surface workers. Since age was strongly related to years of mining experience, the same results were seen when age was used instead of years of mining experience.

The relationship of cumulative smoking habits and the prevalence of bronchitis is shown in table 1. In each group, current cigarette smokers had the highest prevalence of bronchitis. Exsmokers had a slightly higher

TABLE 1

PREVALENCE OF BRONCHITIS IN BITUMINOUS COAL MINERS BY AGE AND CIGARETTE SMOKING HISTORY

Smoking History (pack-years)	Age, Years															
	20–29			30–39			40–49			50–59			60+			
	Total (no.)	Bronchitis (no.)	Bronchitis (%)	Total (no.)	Bronchitis (no.)	Bronchitis (%)	Total (no.)	Bronchitis (no.)	Bronchitis (%)	Total (no.)	Bronchitis (no.)	Bronchitis (%)	Total (no.)	Bronchitis (no.)	Bronchitis (%)
Nonsmokers:	335	40	11.9	262	41	15.6	419	105	25.1	526	175	33.3	142	66	46.5
Exsmokers:															
0–9	124	14	11.3	106	19	17.9	188	54	28.7	172	63	36.6	49	23	46.9
10–19	27	4	14.8	87	18	20.7	197	55	27.9	173	61	35.3	44	23	52.3
20–29	3	0	0	42	10	23.8	181	51	27.7	155	54	34.8	26	16	61.5
Smokers:															
0–9	674	146	21.7	235	71	30.2	159	51	32.1	126	51	40.5	40	26	65.0
10–19	204	61	29.9	381	120	31.5	261	109	41.8	295	166	56.3	41	31	75.6
20–29	29	13	44.8	160	62	38.8	467	196	42.0	245	130	53.1	42	24	57.1

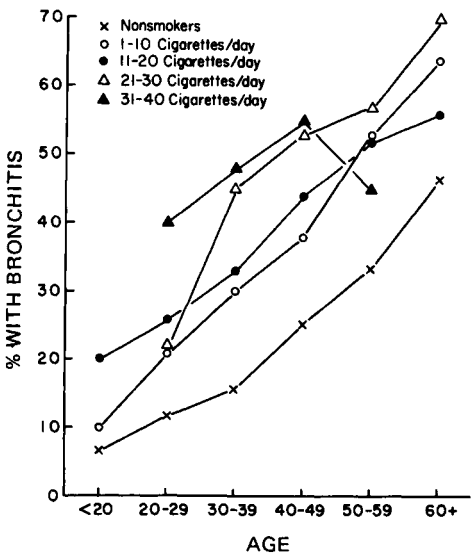

Fig. 3. Prevalence of bronchitis by age and current cigarette consumption in 4,592 smoking and 1,712 nonsmoking bituminous coal miners.

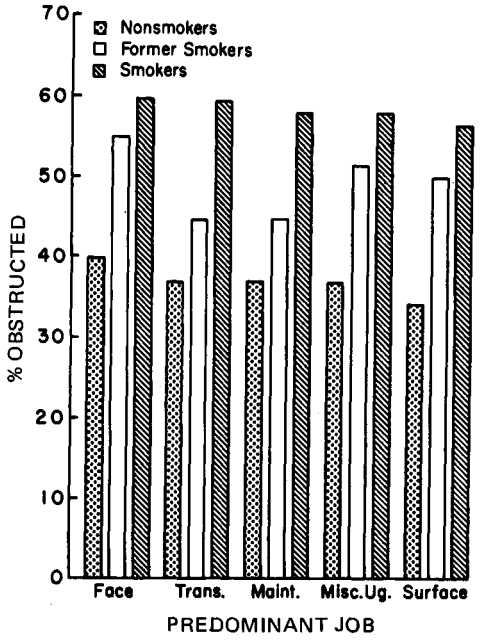

Fig. 4. Prevalence of airway obstruction in 8,487 coal miners by smoking history and predominant job.

prevalence than did nonsmokers. Since bronchitis appeared to be related more to the miner's smoking habits at the time of the examination than to his cumulative smoking history, the prevalence of bronchitis was plotted against age and current cigarette consumption (figure 3). Again, the greater the number of cigarettes smoked daily, the greater was the prevalence of bronchitis.

Prevalence of obstruction: The relationship of airway obstruction to the miner's job and smoking habits is shown in figure 4. Smoking was the most important factor associated with obstruction. The miner's working place

TABLE 2

MEAN RATIO OF OBSERVED TO PREDICTED VALUES OF 1-SECOND FORCED EXPIRATORY VOLUME/FORCED VITAL CAPACITY* FOR BITUMINOUS COAL MINERS BY SMOKING STATUS AND PRINCIPAL JOB

Principal Job	Smokers			Exsmokers			Nonsmokers		
	Total (*no.*)	FEV_1/FVC (*% pred*†)		Total (*no.*)	FEV_1/FVC (*% pred*)		Total (*no.*)	FEV_1/FVC (*% pred*)	
		Mean	SD		Mean	SD		Mean	SD
Face	2,046	96.1	11.44	952	97.3	12.02	759	101.5	10.11
Transportation	868	95.9	12.21	331	98.8	13.02	244	102.5	10.07
Maintenance	772	96.7	11.72	347	100.2	10.46	289	102.2	9.71
Miscellaneous	389	96.8	11.29**	156	98.1	11.34	159	102.2	9.69**
Surface	563	96.6	11.96	387	99.3	11.43	268	102.6	8.60

*Mean of (observed FEV_1/FVC)/(predicted FEV_1/FVC).

†Pred = predicted normal value.

**Significant differences were found between smokers and nonsmokers in every work category except miscellaneous underground workers.

appeared to have much less effect. Nonetheless, when nonsmoking miners who worked exclusively underground were compared to their counterparts who had worked exclusively on the surface, the former had more obstruction. This trend was less evident for the smokers and former smokers (table 2). Significant differences were present between smokers and nonsmokers in each category except miscellaneous underground workers. The differences across work categories for smokers and exsmokers and nonsmokers were not significant. Nonsmoking face workers had a slightly lower mean ratio of observed FEV_1/FVC to predicted FEV_1/FVC than surface workers.

Statistically significant differences in mean ratio of observed FEV_1 to predicted FEV_1 were found between smokers and nonsmokers, exsmokers and smokers, and exsmokers and nonsmokers in the same underground work categories, except in maintenance workers, exsmokers, and nonsmokers (table 3). Smokers had consistently lower mean FEV_1 as compared to predicted values than exsmokers and nonsmokers in all job classifications. Similarly, exsmokers had lower values than nonsmokers. Within each smoking category, transportation workers had significantly lower values than surface workers but did not differ from face workers in exsmoking and nonsmoking groups. Exsmoking and nonsmoking face workers had significantly lower FEV_1 as compared to their predicted value than did surface workers. These differences were relatively minor and were unlikely to be associated with respiratory disability by themselves.

In each work category, mean ratio of observed FVC to predicted FVC was significantly higher in nonsmokers than smokers. Except in face worker groups, exsmokers also had higher mean FVC as compared to predicted values than smokers. Among ex- and nonsmokers, surface workers had higher mean FVC as compared to predicted FVC than face workers, but similar results were not found in smokers.

The FEV_1/FVC ratios of miners in this study were compared to figures representing two standard deviations below the mean FEV_1/FVC values of the Europaische Gemeinschaft für Kohle und Stahl. As reflected by this measurement, obstruction was almost 3 times as frequent in current smokers as in nonsmokers. Former smokers had twice the frequency of obstruction by this index as nonsmokers.

Discussion

In 1966, the Medical Research Council of Great Britain (5), in reviewing the evidence regarding whether there was such an entity as industrial bronchitis, observed that there was no way to distinguish clinically between

TABLE 3

MEAN RATIO OF OBSERVED TO PREDICTED VALUES OF 1-SECOND FORCED EXPIRATORY VOLUME ACCORDING TO PRINCIPAL JOB

Principal Job	Smokers			Exsmokers			Nonsmokers		
	Total (no.)	FEV_1 (% pred*) Mean	SD	Total (no.)	FEV_1 (% pred) Mean	SD	Total (no.)	FEV_1 (% pred) Mean	SD
Face	2,046	92.1	17.05	952	93.9	18.30	759	98.1	16.33
Transportation	868	89.8	17.64	331	94.2	18.90	244	97.9	15.12
Maintenance	772	93.0	16.45	347	98.0	15.62†	289	100.0	16.93†
Miscellaneous	389	92.9	15.41	156	96.8	15.44	159	101.6	15.32
Surface	563	91.8	17.07	387	98.1	17.07	268	102.4	16.17

*Pred = predicted normal value.

†Except between these two groups, statistically significant differences were found between smokers and exsmokers, exsmokers and nonsmokers, and smokers and nonsmokers in each work category.

Exsmoking and nonsmoking face workers were significantly different from surface workers and were not statistically different from transportation workers. Smoking transportation workers had significantly lower values than surface workers.

TABLE 4

PERCENTAGE OF BITUMINOUS COAL MINERS WITH SIGNIFICANT AIRWAY OBSTRUCTION* BY AGE AND SMOKING STATUS (8,523 MINERS)

Smoking Status	Age, Years									
	19†	20–29	30–34	35–39	40–44	45–49†	50–54†	55–59†	60–64†	All†
	Significant Airway Obstruction, %									
Smokers	7.7	7.6	11.4	12.1	18.3	17.8	25.0	27.9	32.4	17.8
Exsmokers	25.0	5.7	5.6	5.6	9.0	11.8	19.3	18.4	19.7	13.8
Nonsmokers	0.0	4.5	7.1	2.9	6.0	5.6	7.1	8.0	11.4	6.3

*The ratio of 1-second forced expiratory volume to forced vital capacity was lower than 2 SD below mean of Europaische Gemeinschaft für Kohle und Stahl (4).

†Significant difference between exsmokers and nonsmokers.

Statistically significant differences existed between smokers and nonsmokers and between smokers and former smokers in each age group.

bronchitis produced by dust, air pollution, or cigarette smoking. In one person, this statement usually holds true; however, epidemiologic studies provide a means of determining the respective roles of the various factors that might be involved in its etiology. The M. R. C. observed that in Britain, bronchitis was most prevalent in coal miners and least prevalent in farmers. Ashford and his colleagues (6) studied 4,000 British miners and concluded that bronchitis occurred 17 years earlier in smokers as compared to nonsmokers. Similarly, Enterline (7) in his Mullens and Richwood study found that bronchitis was more common in West Virginia coal miners than in the 2 groups he used as controls.

The relationship between the prevalence of bronchitis and cigarette smoking has been studied on many occasions. The M. R. C. found that British miners who smoked 25 or more cigarettes a day had a mortality from bronchitis six times that of nonsmoking miners. In Northern West Virginia, Higgins and his colleagues (8) found that cough and sputum production were present in almost 47 per cent of the smoking miners in their study. Comparable figures for ex- and nonsmokers were 31 and 28.5 per cent. Airway obstruction was also significantly more common in their smoking miners. Hyatt and associates (9) made similar observations but related the frequency in symptoms to the number of pack-years. They noted that the symptoms and ventilatory capacity of former smokers resembled more closely those of the nonsmokers.

Studies of the prevalence of bronchitis and airway obstruction in various industrial populations were carried out by Ulmer and his colleagues (10, 11), who concluded that smoking and dust exposure had an additive effect on the prevalence of the symptoms of chronic bronchitis. They were unable, however, to show that simple pneumoconiosis had an effect on either the severity or the prevalence of the symptoms of chronic bronchitis or that there was more airway obstruction in miners who had both bronchitis and simple coal workers' pneumoconiosis.

Only a crude estimate of dust exposure in the miners included in this study was available; nevertheless, the Bureau of Mines (3) found that dust exposure was related to the location of a miner's job. In almost every age group and work-experience category, face workers had a significantly higher prevalence of bronchitis than did surface workers. Since it was shown that face workers are exposed to more respirable dust than surface workers, it can be assumed that bronchitis which occurs in the non- and exsmoking underground miners is at least partially a consequence of dust exposure. The same relationship in smoking miners was far less obvious, presumably because the effects of cigarette smoking overshadowed and obscured the effects of dust exposure. Somewhat similar findings were reported by Rae and co-workers (12) in younger British miners.

Some observers (13, 14) have pointed out

that bronchitis and pneumoconiosis often appear to develop independently. A possible explanation for this lies in the fact that coal workers' pneumoconiosis is produced by the inhalation and retention of coal particles in the respirable range (0.5 to 5 μm). In contrast, there is reason to believe that dust-produced bronchitis is more likely to be an effect of the larger particles (6 to 15 μm) since it is the latter that are deposited in the bronchi and bronchioles. Since the dust measurement program is currently directed exclusively at the respirable fraction in U. S. coal mines, no data are being collected on the larger particles.

The significance of the symptoms of chronic bronchitis needs further study. There is little doubt that when bronchitis is associated with airway obstruction, there is a definite reduction in life expectancy. Simple bronchitis, i.e., that which is not associated with ventilatory impairment, appears to be a much more benign condition and appears to have little effect on life expectancy (15, 16). The data in this study suggest that dust is associated mainly with the symptoms of bronchitis and that although the exposure may be associated with a small reduction of ventilatory capacity, the latter is relatively minor compared to the effects of cigarette smoking.

It is evident that smoking had a greater effect on ventilatory capacity than did dust exposure. Lacking a control group, the ventilatory capacity of the miners included in this study was compared to the predicted value (Europaische Gemeinschaft für Kohle und Stahl). When the mean observed FEV_1/FVC ratios were compared to the predicted values, the coal miners in this study had lower values; however, many of these "obstructed miners" had relatively minor reductions in ventilatory capacity that were not likely to affect their capacity for work. An FEV_1/FVC of 2 SD below the predicted value can reasonably be assumed to be abnormal, and when this criterion was used, sharp differences in the prevalence of obstruction in smokers, exsmokers, and nonsmokers became apparent. Moreover, the difference between former smokers and nonsmokers in the extent of the obstruction suggested that obstruction, unlike the symptoms of bronchitis, was not reduced to a negligible quantity by the cessation of smoking.

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