CHRONIC RESPIRATORY DISEASE IN MINING COMMUNITIES *

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INTRODUCTION

The role of coal mine dust exposure in the development of chronic respiratory disease and disability among miners needs to be accurately assessed if we are to practice wisely, set sound dust standards, or compensate justly. In the present paper, the community studies bearing on this problem with which I have been associated during the past two decades will be reviewed. Between 1953 and 1963, surveys were carried out in communities in England and Wales by the British Medical Research Council's Pneumoconiosis and Epidemiological Research Units. More recently, I have conducted similar studies in communities in Marion County, West Virginia, under contract with the Bureau of Occupational Health. The community approach was adopted because we realized that patients in hospital, miners applying for compensation, and working miners constitute selected groups. Only by studying the whole geographically defined community or a representative sample of it could this selectivity be avoided. The community approach facilitates the study of exminers as well as working miners. It also provides the investigator with perhaps the most appropriate group for comparison, namely, men who have lived in the same area but who have never worked in mining.

The Communities

The communities differed considerably in respect to air pollution. Leigh, the most densely populated, was also the most polluted. Staveley was moderately polluted, and the Rhondda, less so. The towns in Marion County, West Virginia, are situated in rural surroundings and are very much less polluted than the British communities. Other characteristics of the communities are shown in TABLE 1.

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TABLE 1

SALIENT FEATURES OF THE MINING COMMUNITY STUDIES REVIEWED

Country	Area	Year Studied	Population (Approximate)	Main Occupations	Sample Size *	Age Groups	Miscellaneous
England	Leigh (Lancashire)	1954	48,000	Mining Cotton	245	55–64	Men
	Staveley (Derbyshire)	1957	18,000	Mining Foundry Chemicals Railway	776	25–34 55–64	Men Wives of Men aged 55–64
	Staveley (Derbyshire)	1966	18,000	Mining Foundry Chemicals Railway	990	25–74	Men
Wales	Rhondda (Glamorgan)	1959	30,000	Mining	600 200	35–64 55–64	Men Women
U.S.A.	3 Towns in Marion County, West Virginia	1964/5	4,000	Mining	1173	20–69	White Males Women

* In Leigh the sample was drawn from the register of electors. In all the other communities a census was carried out and the samples were drawn from information obtained at the census. In Marion County, all men aged 20–69 were seen. Response rates have varied from 84 to 92%.

Methods and Procedure

Similar methods have been used in each survey. They are summarized as follows:

1. questionnaire: symptoms, illnesses, smoking habits;
2. occupational and residential histories;
3. lung function test: forced expiratory volume (FEV) and forced vital capacity (FVC);
4. P.A. chest x-ray;
5. sputum volume and quality;
6. height and weight;
7. E.C.G. and B.P.

The questionnaire was similar to that recommended by the Medical Research Council [6] to record respiratory symptoms, past chest illnesses, and smoking habits. The forced expiratory volume (FEV) and forced vital capacity (FVC) were measured using a direct reading Poulton Spirometer.[7] In Marion County, we measured the one-second forced expiratory volume ($FEV_{1.0}$); in the second Staveley survey, we recorded both the $FEV_{1.0}$ and the $FEV_{0.75}$. In the other communities, we recorded the $FEV_{0.75}$.

The great majority of subjects were seen by appointment at a center. A small number were visited in their own homes. In Leigh and the Rhondda, I completed all the questionnaires and carried out all the lung function measurements; in the first Staveley survey, the sample was randomized between Dr. John Gilson and me; in the second Staveley survey, in addition to Dr. Gilson and me, the sample was randomized between Dr. Millicent Higgins and Dr. Ben Ferris; in Marion County, the observations were made by Dr. Higgins, Dr. Michael Lockshin, and me.

The sample seen in Staveley in 1957 was followed up nine years later, in 1966. A follow-up by home interview of those seen in Marion County was carried out after approximately five years. Some of the findings about mortality are included in this paper. Limited information was also obtained about women in certain areas. In 1957, Dr. Christopher Wood interviewed all the wives of the men aged 55–64 in their homes in Staveley. He completed a respiratory symptoms questionnaire and measured the peak expiratory flow rate with a Wright flow meter. In the Rhondda and in Marion County small, age-stratified random samples of women were seen.

Results

Comparison of Chronic Bronchitis, Breathlessness, and Forced Expiratory Volume in Miners, Exminers, and Nonminers

The whole range of respiratory symptoms, either alone or in combination, can be used to compare different groups of people. In this presentation, for the sake of simplicity, I shall use a standardized index of chronic bronchitis that I have found useful in the past, breathlessness and the level of the forced expiratory volume (FEV).

Persons were categorized as having chronic bronchitis if they had persistent sputum for some part of the day for at least three months in the year and had had at least one chest illness with increased cough and sputum during the

past three years. Breathlessness applies to all who were short of breath when walking at a normal pace on the level (grade three and over).

The prevalence of chronic bronchitis and breathlessness, as well as the mean forced expiratory volume ($FEV_{0.75}$) in miners; exminers, and nonminers are shown in TABLE 2. In every survey, miners and exminers had a higher prevalence of chronic bronchitis of breathlessness and a lower average FEV than nonminers. The magnitude of the difference has varied in different places. Sometimes, as in the men aged 55–64 in the first Staveley survey and in Marion County, the differences have been quite small; in other areas they have been much larger. The overall difference has been about twofold.

We can compare our findings with those of Enterline and Lainhart.[8] In Mullens, in southern West Virginia, a community survey carried out by the Public Health Service showed a higher prevalence of symptoms and lower lung function among miners and exminers than among nonminers. On the other hand, in a further study carried out in Richwood, in central West Virginia, in which the samples were standardized for education, there were no differences between miners and nonminers. A higher frequency of symptoms or bronchitis has also been noted by others both in this country and in Europe.[10-15] Occupational mortality and morbidity statistics also show higher rates for chronic respiratory disease in miners. These figures have been considered at length by others.[16-19] I do not intend to dwell on them here.

Comparison of Chronic Bronchitis, Breathlessness, and F.E.V. in Miners and Exminers With and Without Simple Pneumoconiosis

Evidence strongly suggests that progressive massive fibrosis (PMF) leads to an increased prevalence of respiratory symptoms and reduced ventilatory lung function, especially in its more advanced stages.[20, 21] My present concern is with the influence of simple pneumoconiosis on symptoms and FEV (TABLE 3).

In contrast to the consistent differences between miners and nonminers, miners with simple pneumoconiosis do not differ consistently in their prevalence of chronic bronchitis, breathlessness, or FEV from miners without pneumoconiosis. No matter which we consider, the values found are largely independent of the chest x-ray. Indeed, it has often appeared that those with simple pneumoconiosis are fitter in respect to respiratory symptoms and lung function than those without.

Since there is a clear correlation between the x-ray category of pneumoconiosis and the weight of dust found in the lungs at autopsy,[22-23] these findings indicate that chronic obstructive lung disease is not closely related to long-term dust exposure.

Number of Years Spent Working Underground or on the Coal Getting Shift in Relation to Chronic Bronchitis, Breathlessness, and FEV

We have explored the dose/response relationship further by considering chronic bronchitis, breathlessness, and FEV in relation to lifetime dust exposure. In epidemiological surveys two indices have been used: the number of years spent working underground and the number of years spent working

TABLE 2

PREVALENCE OF CHRONIC BRONCHITIS AND MODERATE AND SEVERE BREATHLESSNESS (GRADE THREE AND OVER) AND MEAN FORCED EXPIRATORY VOLUME AMONG MINERS, EXMINERS, AND NONMINERS IN MINING COMMUNITIES IN ENGLAND, WALES, AND U.S.A.

Area	Age Group	Numbers in Samples		% Bronchitis			% Breathlessness (Grade 3 & Over)			Forced Expiratory Volume (Liters)		
		Miners & Ex-miners	Non-miners	Miners & Ex-miners	Non-miners	Ratio *	Miners & Ex-miners	Non-miners	Ratio *	Miners & Ex-miners	Non-miners	Difference †
Leigh	55–64	132	84	23.5	10.7	2.2	23.5	7.2	3.3	2.17	2.39	—0.22
Staveley 1957	25–34	94	114	10.6	1.8	5.9	0	0		3.35	3.58	—0.23
	55–64	149	81	20.8	14.8	1.4	11.4	11.1	1.0	2.44	2.52	—0.12
Staveley 1966	25–74	179	159	17.4	2.7	6.4	13.9	1.5	9.3	2.56	2.84	—0.28
Rhondda	35–64	275	262	28.5	9.2	3.1	24.5	6.9	3.6	2.53	2.87	—0.34
Marion County, W. Va.	20–69	426	402	4.8	4.0	1.2	8.6	6.5	1.3	3.41	2.53	—0.12

* $\frac{\text{Miners \& Exminers}}{\text{Nonminers}}$

† (Miners & Exminers) — Nonminers

TABLE 3

PREVALENCE OF CHRONIC BRONCHITIS AND MODERATE AND SEVERE BREATHLESSNESS (GRADE THREE AND OVER) AND MEAN FORCED EXPIRATORY VOLUME ACCORDING TO PRESENCE OR ABSENCE OF SIMPLE PNEUMOCONIOSIS IN MINING COMMUNITIES IN ENGLAND, WALES, AND U.S.A.

Area	Age Group	Numbers		% Bronchitis			% Breathlessness			Forced Expiratory Volume		
		0	Simple	0	Simple	Ratio †	0	Simple	Ratio †	0	Simple	Difference ‡
Leigh	55–64	101	21	26.7	14.3	0.5	24.8	9.5	0.4	1.90	2.13	+0.23
Staveley	25–34	89	5	11.2	0	—	0	0	—	3.33	3.75	+0.42
1957	55–64	96	53	18.8	24.5	1.3	8.3	17.0	2.0	2.18	2.18	0.0
Staveley * 1966	25–74	113	19	14.8	19.2	1.3	12.1	27.4	2.3	2.58	2.64	+0.06
Rhondda *	35–64	88	123	27.0	25.0	0.9	23.5	19.9	0.8	2.33	2.39	+0.06
Marion County, W. Va.*	20–69	393	28	6.3	1.7	0.3	9.9	6.5	0.7	3.24	3.16	—0.08

* Age adjusted to the total population by direct method.

† Ratio: $\frac{\text{Simple}}{0}$

‡ Difference: Simple —0.

TABLE 4

RELATIONSHIP OF CHRONIC BRONCHITIS * TO NUMBER OF YEARS SPENT WORKING ON THE COAL FACE IN MINING COMMUNITIES IN ENGLAND AND WALES

Chronic Bronchitis	Years on the Coal Face				
	< 1	1–9	10–19	20–29	30 & Over
Observed	35	53	43	40	11
Expected	39.4	51.1	42.3	33.9	15.2
Ratio $\frac{\text{Observed}}{\text{Expected}} \times 100$	88.8	103.7	101.7	118.0	72.4

* Persistent sputum and at least one chest illness during the past 3 years.

on the coal getting shift. In Britain the duration of face work is probably the better index; but in this country the duration of underground work seems to be equally good. The findings in these communities are shown in TABLES 4 to 7. In each dust category the expected numbers are those which would have occurred had duration of exposure had no effect, but differences in age between the categories have been allowed for. The deviations from expection are not very impressive. In the British studies there is a slight trend both for bronchitis and breathlessness. In West Virginia there is no trend for bronchitis; but a suspicion of a trend for breathlessness. The numbers are, however, very small, and the deviation from expectancy is statistically insignificant.

The relation of FEV to duration of coal face work in the British surveys is shown in TABLE 8. The mean FEV declined with increasing duration of coal face work in some areas but not in others. In Marion County a lower average FEV was found in those who had worked for 30 years or more underground (TABLE 9). But most of this reduction can be accounted for on the basis of age, since the men in that category were ten years older than the men in the previous category.

TABLE 5

RELATIONSHIP OF MODERATE AND SEVERE BREATHLESSNESS * TO NUMBER OF YEARS SPENT WORKING ON THE COAL FACE IN MINING COMMUNITIES IN ENGLAND AND WALES

Breathlessness (Grades Three & Over)	Years on the Coal Face				
	< 1	1–9	10–19	20–29	30 & Over
Observed	28	51	49	40	20
Expected	40.7	46.1	45.3	35.8	20.0
Ratio $\frac{\text{Observed}}{\text{Expected}} \times 100$	68.8	110.6	108.2	111.7	100.0

* M.R.C. Breathlessness Grades 3 & Over.

TABLE 6

RELATIONSHIP OF CHRONIC BRONCHITIS TO NUMBER OF YEARS SPENT WORKING UNDERGROUND IN MINERS AND EXMINERS AGED 20–69 IN THREE TOWNS IN MARION COUNTY, WEST VIRGINIA

	Number of Years Spent Working Underground				
Chronic Bronchitis	< 1	1–9	10–19	20–29	30 & Over
Observed	4	4	2	7	10
Expected	3.4	2.9	3.7	7.6	9.4
Ratio $\frac{\text{Observed}}{\text{Expected}} \times 100$	117.6	137.9	54.1	92.1	106.4

Regional Variation in Chronic Respiratory Disease Frequency

Our community studies have shown that there may be considerable regional variation in the frequency of chronic respiratory disease. TABLE 10 compares the prevalence of pneumoconiosis in each area.

The prevalence of pneumoconiosis was much higher, particularly of PMF, in the Rhondda than in either Leigh or Staveley. In Marion County pneumoconiosis was less prevalent than in Leigh. A higher prevalence of respiratory symptoms and bronchitis and lower ventilatory lung function was also found in the Rhondda than in the other areas. Evidence is increasing that considerable regional variation exists in this country, also. [24–26]

Validation of the Findings in Relation to Mortality

Cochrane and his colleagues [27] studied death rates among miners, exminers, and nonminers living in the Rhondda fach during a six-year period, 1950–1956. Miners and exminers had a higher mortality from all causes, and particularly

TABLE 7

RELATIONSHIP OF BREATHLESSNESS TO NUMBER OF YEARS SPENT WORKING UNDERGROUND IN MINERS AND EXMINERS AGED 20–69 IN THREE TOWNS IN MARION COUNTY, WEST VIRGINIA

	Number of Years Spent Working Underground				
Breathlessness (Grades Three & Over)	< 1	1–9	10–19	20–29	30 & Over
Observed	3	2	6	8	24
Expected	5.2	4.8	5.2	8.0	20.0
Ratio $\frac{\text{Observed}}{\text{Expected}} \times 100$	57.7	41.7	115.4	100.0	120.0

TABLE 8

RELATIONSHIP OF FORCED EXPIRATORY VOLUME TO NUMBER OF YEARS SPENT WORKING ON THE COAL GETTING SHIFT

Area	Age Group	Mean FEV According to Number of Years Spent on the Coal Getting Shift							
		< 1		1–9		10–19		20 & Over	
		No.	Mean	No.	Mean	No.	Mean	No.	Mean
Leigh	55–64	40	1.98	18	2.00	33	2.00	41	1.80
Staveley 1957	25–34	41	3.35	38	3.33	10	3.37		
	55–64	41	2.33	25	2.28	40	2.10	43	2.05
Rhondda	35–44	16	2.80	46	2.83	18	2.58	6	2.55
	45–54	6	2.80	38	2.23	23	2.03	28	2.08
	55–64	10	2.25	33	1.88	28	1.82	23	1.78
	All Ages *	32	2.61	117	2.30	69	2.13	57	2.12
Staveley 1966	24–34	11	3.56	11	3.54	8	3.68	0	—
	35–44	10	3.32	5	2.94	9	2.76	8	3.13
	45–54	12	2.12	1	1.63	3	2.89	20	2.74
	55–64	9	1.60	8	2.02	2	2.18	18	1.88
	65–74	6	2.07	2	2.28	9	1.54	26	1.65
	All Ages *	48	2.46	27	2.43	31	2.53	72	1.91

* Age-adjusted to the total population.

TABLE 9

MEAN FEV ACCORDING TO NUMBER OF YEARS SPENT WORKING UNDERGROUND IN MINERS AND EXMINERS AGED 20–69 IN THREE TOWNS IN MARION COUNTY, WEST VIRGINIA

Mean Values	Number of Years Spent Working Underground				
	< 1	1–9	10–19	20–29	30 & Over
$FEV_{1.0}$	3.48	3.48	3.43	3.37	2.64
Age	45.2	44.0	45.6	48.1	58.8
Height	174.9	174.5	173.7	174.3	170.5
Adjusted FEV *	3.16	3.11	3.17	3.21	3.15

* To age 50, height 172.5 cm.

from respiratory diseases, than nonminers. The highest mortality rates were among miners with PMF. Miners and exminers without PMF had slightly increased death rates from all causes and moderately increased (roughly 60%) death rates from respiratory diseases. But radiological category of simple pneumoconiosis was not related to mortality. If anything, the respiratory mortality rates were lower in those with simple pneumoconiosis than in those without.

In the nine year follow-up of men aged 55–64 in Staveley no excess mortality was found among the miners compared with the men who were not exposed to dust at work. Nor did mortality rates differ between those with and those without simple pneumoconiosis. In West Virginia the follow-up of mortality so far shows only a small difference between the mining and nonmining groups in the oldest age category. These observations on mortality therefore agree quite well with the findings which I have presented.

Unlike the chest x-ray, respiratory symptoms and the level of the FEV appear to be useful predictors of mortality. TABLE 11 shows the standardized

TABLE 10

COMPARISON OF PNEUMOCONIOSIS PREVALENCE IN MINERS AND EXMINERS IN DIFFERENT COMMUNITIES

Place	Age Group	No. x-rayed	% Pneumoconiosis		
			Simple	PMF	Total
Leigh	55–64	135	16	7	23
Staveley	55–64	149	36	0	36
	35–44	440	33	8	41
Rhondda	45–54	210	27	24	51
	55–64	411	32	25	57
Marion County,	40–49	139	1	0	1
West Virginia	50–59	145	14	0	14
	60–69	87	7	5	11

TABLE 11

MORTALITY IN FIVE YEARS IN RELATION TO SYMPTOMS. MEN AGED 20–69 IN THREE TOWNS IN MARION COUNTY, WEST VIRGINIA

Symptoms	Number Seen	Number of Deaths	Expected Number of Deaths	Ratio: $\frac{\text{Expected}}{\text{Observed}} \times 100$	Relative Risk
None	317	14	19.5	72.8	1.0
Cough &/or Sputum	149	8	10.1	79.6	1.1
Wheeze	160	9	10.0	90.0	1.2
Chest Illness	14	1	1.0	100.0	1.4
Cough &/or Sputum & Wheeze	214	19	16.9	118.3	1.6
Cough &/or Sputum & Chest Illness	9	1	0.8	125.1	1.7
Chest Illness & Wheeze	19	2	1.3	153.8	2.1
All Three	44	9	3.6	250.0	3.4
Chronic Bronchitis	50	10	4.2	238.1	3.3
Breathlessness					
Grade 1	550	28	33.0	84.8	1.0
Grade 2 & Over	376	35	30.2	116.2	1.4
Grade 3 & Over	82	16	9.0	177.8	2.1
Grade 4	23	10	2.8	357.2	4.2

mortality ratios for men reporting various symptoms in Marion County. If the risk of death in the next five years for those without respiratory symptoms is taken as one, then relative risks for those with various symptoms and combinations of symptoms can be calculated. These relative risks are shown in the last column of the table. The relative risk increased progressively as the prevalence of symptoms increased.

This increase is seen especially clearly in the case of breathlessness in the men aged 55–64 in Staveley (TABLE 12). TABLE 13 shows the mortality accord-

TABLE 12

RELATION OF BREATHLESSNESS TO MORTALITY. MEN AGED 55–64 IN STAVELEY, 1957–1966

Breathlessness Grade in 1957	Number	Percentage Dead by 1966
1 (None)	229	13.5
2	97	35.1
3	33	45.5
4	18	66.7
2 & Over	148	41.2
3 & Over	51	52.9

TABLE 13

MORTALITY IN NINE YEARS ACCORDING TO INITIAL $FEV_{0.75}$ STRATIFIED SAMPLE OF MEN AGED 55–64 SEEN IN 1957 IN STAVELEY, U.K. REVIEWED IN 1966.

$FEV_{0.75}$ in 1957 (liters)	Number in Range in 1957	Dead by 1966: Respiratory Causes No.	%	Other Causes No.	%	Total No.	%
Under 1.0	25	9	36.0	8	32.0	17	68.0
1.0–	40	8	20.0	15	37.5	23	57.5
1.5–	74	3	4.1	12	16.2	15	20.3
2.0–	124	2	1.6	22	17.7	24	19.4
2.5–	96	1	1.0	15	15.6	16	16.7
3.0 and over	28	0	—	1	3.8	1	3.8
Total	387	23	5.9	73	18.9	96	24.8

ing to level of FEV. The lower the FEV, the worse the outlook. Curiously, nonrespiratory as well as respiratory causes of death appear to be involved, possibly because of the confusion of heart and lung failure.

DISCUSSION

It is unlikely that the differences between miners and nonminers in the frequency of chronic obstructive lung disease could be due to general air pollution because, while working underground, the miner is spared some of the pollution experienced by the nonminer. Tobacco smoking cannot explain the findings since smoking habits of miners and nonminers in these areas did not differ appreciably. Furthermore, the differences persisted after standardizing for smoking.

Social class differences in Britain are possibly more important. They were supported in the Rhondda by the higher prevalence of respiratory symptoms and lower FEV among the wives of miners and exminers than among the wives of nonminers. In Staveley we also found a higher prevalence of symptoms and a lower mean peak expiratory flow rate in the wives of men who worked in dust than in wives of the nondust-exposed groups. In Marion County, however, there were no differences in symptom prevalence or mean FEV between the wives of miners and those of nonminers.

Other factors in mining such as heavy work, exposure to fumes from shot firing, and changes of temperature have sometimes been suggested as explanations for a high prevalence of bronchitis among miners. We have no evidence to present on these factors, which perhaps merit further study.

It is possible that various types of occupational selection could conceal an association between dust exposure and chronic respiratory disease. This possibility has been considered by Cochrane and his colleagues.[21] Briefly, fitter men may tend to work in dustier jobs, for example at the coal face, because the pay is better; and those who are affected by the dust may tend to move to less dusty employment within the industry or to leave mining altogether.

Thus, those who are still working underground after long periods would be the fitter survivors.

The inconsistent dose/response relations between dust and bronchitis should not lead to the conclusion that dust exposure is unimportant. There is no doubt that dust is important in pneumoconiosis; in bronchitis dust exposure can hardly be beneficial. There should be no relaxation in measures to reduce dust levels in the mines and improve the working conditions of the coal miner.

It also seems desirable to monitor respiratory symptoms and measure lung function, at least when chest x-rays are taken. In this way, any man who is unduly susceptible to dust could be identified early and could be advised appropriately. The Mine Health and Safety Act would appear to offer an excellent opportunity for collecting scientifically valuable information through periodic examinations.

Summary

Studies of chronic respiratory disease that have been carried out in mining communities in England, Wales, and the state of West Virginia, in the United States, are reviewed in the present paper. In each community, miners and exminers have been compared with nonminers, using standardized methods. The influence of pneumoconiosis and dust exposure on respiratory symptoms and lung function has been assessed. A higher prevalence of symptoms and a lower average forced expiratory volume has consistently been found in miners compared with nonminers. Miners with simple pneumoconiosis have not, however, been found to differ consistently either in symptom prevalence or in lung function from miners without pneumoconiosis. An increasing prevalence of symptoms and decreasing lung function with increasing duration of work either underground or at the coal face has been found in some surveys but not in others. These findings suggest that long term dust exposure cannot explain all the excess of chronic nonspecific respiratory disease found in miners.

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