THE RELATIONSHIP BETWEEN VENTILATORY CAPACITY AND SIMPLE PNEUMOCONIOSIS IN COALWORKERS

THE EFFECT OF POPULATION SELECTION

BY

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The diagnosis in life of coalworkers' pneumoconiosis is based on the industrial history and the chest radiograph. The most striking complaint is excessive breathlessness on exertion. The relationship of this symptom to radiological abnormality is of practical importance in assessing compensation; in most schemes the assumption is made that if a readily diagnosable degree of pneumoconiosis is present and the man is breathless, then the breathlessness is caused by the pneumoconiosis if no other cause is apparent. This assumes a reasonably close relationship between radiological abnormality and breathlessness after allowing for the effects of age.

In full reviews of the literature, Worth and Schiller (1954), and Gilson, Hugh-Jones, Oldham, and Meade (1955), conclude that complicated pneumoconiosis is a cause of moderate or severe breathlessness and the extent of the radiological abnormality relates reasonably well to the degree of breathlessness when age is taken into account.

The position in the case of simple pneumoconiosis is far less certain. A number of investigators (Jéquier-Doge and Lob, 1945; Martin and Roche, 1946; Lob, 1947; McVittie, 1949; Theodos, Gordon, Lang, and Motley, 1950; Wright, 1942 and 1946; Gilson, and others, 1955) have found this relationship is not particularly close. At least part of the variability between the findings of different investigators may be ascribed to the effect of bias introduced in the method of selection of the subjects studied. It has, therefore, been our aim to assess the likely magnitude of this effect and obtain a more certain relationship by studying representative groups of miners and ex-miners.

The reproducibility of the radiological diagnosis of coalworkers' pneumoconiosis and the measurement of observer variability have been discussed in previous papers from this Unit (Fletcher and Oldham, 1949 and 1951).

Other aspects of the significance of simple pneumoconiosis in coalworkers' pneumoconiosis

have been considered elsewhere: its relation to the development of complicated pneumoconiosis (Fletcher, 1948; Mann, 1951; Cochrane, Davies, and Fletcher, 1951); its relation to life expectancy (Carpenter and Cochrane, 1956); to dust exposure (Roach, 1953), and to dust content in the lungs (King, Maguire, and Nagelschmidt, 1956).

The most direct assessment of breathlessness is by questionnaire, but there are difficulties in its use, particularly in men applying for compensation. Objective measurements, if they are sufficiently highly correlated with the man's principal symptom, have great advantages for studying large and varied groups of subjects. In an evaluation of tests of the main aspects of lung function in miners with pneumoconiosis, Gilson and others (1955) found that ventilatory capacity measured by maximum voluntary ventilation was better related to an independent assessment of breathlessness ($r = 0.77$) than any other single test, and only slightly less well correlated than the index obtained by expressing the ventilation on exercise as a percentage of the maximum voluntary ventilation—a test which has been shown by many workers to be reasonably well related to dyspnoea (Cournand and Richards, 1941; Wright, 1942; Warring, 1949). The physiological tests were more sensitive than the clinical assessments.

The maximum voluntary ventilation is a simple test, but it takes longer and causes rather more discomfort to the subject than measuring the ventilatory capacity by a single forced expiration. A number of studies of the relationship between the maximum voluntary ventilation and the volume expelled during the first part of a forced expiration (Roche and Thivolle, 1949; Tiffeneau, Bousser, and Drutel, 1949; Kennedy, 1953; McKerrow, 1955; Bernstein and Kazantzis, 1954; Leuallen and Fowler, 1955) have in general shown a high correlation between the two. Direct comparison of both tests, and a study of the relation of the results of the single breath method with the clinical grading of dyspnoea

have led us to choose the single breath method on account of its simplicity, slightly better repeatability, and very small observer error under field survey conditions (Carpenter and others, to be published). Even though the physiological assessment may not be an ideal measure of breathlessness, we believe it gives more valid information about the prevalence of respiratory disability than could be obtained by questionnaire alone.

POPULATION GROUPS

In the prevalence type of survey, the following groups of miners can be examined:

- (1) Patients in hospital.
- (2) Men attending for compensation assessment at the Pneumoconiosis Medical Panel.
- (3) Miners working in a colliery
 - (i) underground workers only
 - (ii) surface workers only
 - (iii) both surface and underground workers.
- (4) Miners and ex-miners from a geographically defined area.

Patients in hospital are a highly selected group and tend to be biased towards those who are disabled. They are admitted for two main reasons: a minority for diagnostic or physiological investigation, and the majority because of an exacerbation of acute respiratory infection or the onset of congestive heart failure. They are, therefore, quite unsuitable for our present purpose and are not considered in this paper.

Miners attending for compensation may also be a biased group. Those most likely to apply for compensation are either the disabled or men in whom radiological abnormality has been detected (for example, during mass miniature radiological surveys). In addition miners who are "compensation minded" may also attend though they feel fit. The results on examining such a group will depend on the proportions of each class in the population.

A working population at a colliery is likely to be more representative but is not ideal because it excludes those who have left the industry. As respiratory disability is in some areas an important cause of a man giving up mining, the exclusion of ex-miners may introduce a serious bias into the results. Restriction to a group working underground or on the surface cannot be recommended, since miners too disabled to work underground are often given lighter employment on the surface (McCallum and Browne, 1955).

A community of miners and ex-miners within a geographically defined area is in our view the group in which bias is least likely to occur, and, provided the area is not too large, it is a practical group to study. Differential death rates within the group may still

upset the results but in the cases of simple pneumoconiosis this is not likely to be important (Carpenter and Cochrane, 1956). The results may not apply to miners and ex-miners in all areas on account of regional differences including climate, overcrowding, type of mining, and the extent of emigration from the area, so there is need to study several mining communities.

In the present paper, after considering the effect of age on ventilatory capacity, we describe the results of studies in groups of miners applying for compensation and of a working pit population, and then of three random samples of miners and ex-miners, two of the samples drawn from the population of the Rhondda Fach (a mining valley in South Wales) and one from the town of Leigh in Lancashire.

METHODS

Radiological

Full-size chest films were obtained for all subjects. The films were classified on the I.L.O. International Classification (1950) grading (Cochrane and others, 1951; Fletcher, 1955) into four groups: category 0—no evidence of pneumoconiosis; category 1, a few characteristic opacities 0.5-3 mm. in diameter in at least two rib spaces and extending over 1 sq. cm. or more; category 2, more numerous opacities distributed throughout the lung field; category 3, profuse opacities throughout both lung fields.

In order to minimize errors of classification the films were read by four observers working in pairs. Each pair read the films separately. Those films about which there was a difference of opinion were then reviewed by all four observers in consultation and an agreed reading decided. Standard films were used in cases of doubt.

Ventilatory Capacity Test: Maximum Voluntary Ventilation (Indirect) M.V.V.

The ventilatory capacity was measured by recording the volume of gas expelled during the first 0.75 second of a forced expiration starting from maximum inspiration using a modified Gaensler (1951) apparatus. (The timing started after 100 ml. had been expelled; this makes some allowance for variations in the abruptness of the start of expiration.)

The first reading was rejected and the mean of three or four subsequent readings (corrected to B.T.P.S.) was taken. The results have been expressed in l./min. by multiplying by 40 in the way suggested by Kennedy (1953), but we have followed Tiffeneau's terminology by referring to the measurement as maximum voluntary ventilation (indirect) in place of the expiratory flow rate (E.F.R.₄₀) used by Kennedy. In the population samples including miners and others the observers were unaware of the subjects' occupations.*

* Sitting height, which is correlated with M.V.V. (indirect) (1 in. being equivalent to 6.8 l./min.) was measured to the nearest 0.5 in. Correction of our results for the small differences in average sitting height of our groups did not affect our findings and was, therefore, omitted.

RESULTS

Effect of Age on the Ventilatory Capacity

The effect of age on the ventilatory capacity is so striking that full allowance for age is essential. Fig. 1 and Table 1 show the decline in the maximum voluntary ventilation (indirect) with increasing age in a non-mining male population aged 20-69 years examined in the first Rhondda Fach study. The mean M.V.V. values are plotted against the mean age of the group. The regression of M.V.V. on age was 1.36 ± 0.141 l./min. for each year, and testing

FIG. 1.—Relation of age to maximum voluntary ventilation (indirect) in a random sample of non-miners living in the Rhondda Fach.

TABLE 1
EFFECT OF AGE ON M.V.V. (INDIRECT) IN A RANDOM SAMPLE OF NON-MINERS FROM THE RHONDDA FACH

Age Group	No. Tested	Mean Age (years)	Mean M.V.V. (l./min.)
20-	20	24.8	143.6
30-	19	34.0	116.3
40-	19	44.8	112.2
50-	31	55.6	97.3
60-	34	63.1	86.8

Regression of M.V.V. on age is -1.36 ± 0.141 l./min. for each year S.D. of M.V.V. of one subject about regression line is 22.5 l./min.

the means of the five-year age groups showed no evidence that the relationship (within this age range) is non-linear ($0.2 > P > 0.1$).

The rate of decline with age agrees well with that reported for the two-second timed vital capacity by Needham, Rogan, and MacDonald (1954).

Relation between Radiological Category and Ventilatory Capacity

Compensation Group.—Three hundred and twenty-seven miners and ex-miners attended the Pneumoconiosis Medical Panel in Cardiff between February 16, 1953, and February 26, 1953. Of these, 316 (96.6%) were examined and 11 (3.4%) refused to cooperate. Men with progressive massive fibrosis (P.M.F.) were excluded and the average M.V.V. for the 204 men remaining aged 25-64 by 10-year groups are given in Fig. 2 and Table 2. There is a general trend for the M.V.V. to rise with category of simple pneumoconiosis. This unexpected result could be due either to the effect of selection or to a real trend in this direction. It was impossible to say which of these two explanations was correct. This survey showed the need for further study.

Working Miners (Colliery L).—A radiographic survey of all miners in a Lancashire colliery was carried out; of the total population, the following groups were studied:—

(1) All miners over the age of 40; (2) all miners under the age of 40 whose radiographs showed pneumoconiosis; (3) a random sample of miners under 40 with normal radiographs. Of the whole group 87% were seen, giving a lapse rate of 13%.

The results of the M.V.V. for men aged 25-64 in 10-year groups are shown in Fig. 3 and Table 3. These show that there was in the main a fall in the mean ventilatory capacity with increasing category of simple pneumoconiosis. When all age groups are taken together the fall in M.V.V. is 5.25 ± 1.73 l./min. with each radiological category, and is significant ($0.01 > P > 0.001$). In the 55-64 age group, though the numbers were small, miners with categories 1 and 2 simple pneumoconiosis recorded a higher average M.V.V. than those without pneumoconiosis.

The results of this survey were those that common sense would have predicted. They do, however, conflict strikingly with the results in the compensation group. This is well seen in Fig. 4 which shows the mean values of all the men examined in both surveys standardized to an arbitrary age of 45 years. (This standardization is justified because the effects of increasing radiological category are reasonably similar at different ages.)

The population studied was, we thought, a good

FIG. 2.—Relation of age and radiological category of simple pneumoconiosis to maximum voluntary ventilation (indirect) in compensation group of miners and ex-miners.

TABLE 2

MEAN AGE AND M.V.V. (INDIRECT) ACCORDING TO RADIOLOGICAL CATEGORY IN A COMPENSATION GROUP OF MINERS AND EX-MINERS AGED 25-64 YEARS

Age Group	Radiological Category	Number	Mean Age	Mean M.V.V.
25-	0	7	29.9	116.3
	1	6	30.8	133.8
	2	12	30.3	138.3
	3	9	29.8	147.0
35-	0	12	39.2	115.4
	1	6	40.6	99.5
	2	27	40.0	116.7
	3	14	38.2	126.1
45-	0	24	49.2	90.9
	1	12	48.2	99.4
	2	26	48.1	117.6
	3	10	48.2	98.3
55-	0	13	60.5	71.3
	1	7	58.6	80.6
	2	9	59.8	75.3
	3	10	59.9	81.4

FIG. 3.—Relation of age and radiological category of simple pneumoconiosis to maximum voluntary ventilation (indirect) in a sample of miners working in Colliery L.

TABLE 3

MEAN AGE AND M.V.V. (INDIRECT) ACCORDING TO RADIOLOGICAL CATEGORY IN A SAMPLE OF WORKING MINERS AGED 25-64 YEARS AT COLLIERY L

Age Group	Radiological Category	Number	Mean Age	Mean M.V.V.
25-	0	56	29.2	134.5
	1	12	30.4	129.9
	2	14	29.4	138.6
	3	0	—	—
35-	0	39	39.1	122.3
	1	20	40.0	117.6
	2	7	37.6	114.6
	3	6	40.5	104.7
45-	0	27	47.5	107.7
	1	4	47.0	89.8
	2	5	48.4	75.8
	3	14	49.1	74.2
55-	0	9	59.1	72.1
	1	6	58.2	88.2
	2	3	55.7	83.7
	3	1	61.0	72.0

FIG. 4.—Relation of radiological category of simple pneumoconiosis to age standardized maximum voluntary ventilation in Colliery L and the compensation groups. (M.V.V.s. are standardized to age 45.)

one of working miners and the results were considered to be more likely to be correct than those found in the compensation group. The findings in the compensation group could not, however, be ignored and a further survey was designed to find out which of the previous two investigations, if either represented the true picture.

Random Sample of Radiographed Population of the Rhondda Fach.—We considered (wrongly as it turned out) that the effect of simple pneumoconiosis on the ventilatory capacity would best be shown by considering radiological extremes. Two main groups of miners and ex-miners were, therefore, examined: those without pneumoconiosis (category 0) and those with advanced simple pneumoconiosis (category 3). Men from these two groups were sampled in each of two age groups, 25-34 and 55-64 years. Comparable groups of non-miners were also studied. This sampling on the basis of known

radiological reading was possible since 90% of the population (about 30,000) of the valley had been recently radiographed (Cochrane, Cox, and Jarman, 1955).

One hundred and twenty-four (95%) of the 130 non-miners and 187 (94%) of the 199 miners and ex-miners drawn in the sample from the radiographed population were seen. The overall lapse rate was, therefore, 5% of the radiographed population. Seventy-two of the non-miners were in age groups comparable with the miners and ex-miners. The remaining 52 gave the additional data to establish the relationship of M.V.V. (indirect) to age.

The results are shown in Fig. 5 and Table 4. In each age group miners recorded a lower ventilatory capacity than non-miners. The difference of 11.5 l./min. between the mean M.V.V. of the non-miners and the miners and ex-miners without pneumoconiosis aged 25-34 years is significant at the 5% level ($0.05 > P > 0.01$); that of 24.4 l./min. between the groups aged 55-64 is highly significant ($P < 0.001$). Little difference was observed between the men with category 0 and category 3 simple pneumoconiosis in the younger age group. In the older men, however, those with pneumoconiosis

FIG. 5.—Relation of age, occupation, and radiological category of simple pneumoconiosis to maximum voluntary ventilation (indirect) in first random sample from the Rhondda Fach. (NM = non-miners.)

TABLE 4

MEAN AGE AND M.V.V. (INDIRECT) ACCORDING TO OCCUPATION AND RADIOLOGICAL CATEGORY IN A RANDOM SAMPLE OF THE RADIOGRAPHED POPULATION OF THE RHONDDA FACH AGED 25-34 AND 55-64 YEARS

Age Group	Occupation	Radiological Category	No.	Mean Age	Mean M.V.V.	S.E. of Mean M.V.V.
25-34	Non-miners	—	22	28.9	137.2	±4.06
	Miners	0	47	31.1	125.7	±2.78
	ex-miners	3	47	31.0	122.2	±2.78
55-64	Non-miners	—	50	59.6	92.9	±3.54
	Miners	0	47	59.7	68.5	±3.66
	ex-miners	3	46	59.6	77.1	±3.69

had a higher average M.V.V. than those without (77.1 compared with 68.5 l./min.), but the difference is not quite statistically significant. The standard deviation of the M.V.V. is 19.0 l./min. in the 25-34 and 24.1 l./min. in the 55-64 age groups.

The clinical significance of a reduction in M.V.V. is very different at opposite ends of its range. A fall from 140 to 120 l./min. is unlikely to be noticed except on very severe exertion, whereas a fall from 60 to 40 l./min. is likely to be associated with a noticeable increase of breathlessness on slight exertion. When the value falls to 50 l./min. and below a material limitation of activity on account of dyspnoea is to be expected.

The choice of 50 l./min. is based on evidence on the relationship of dyspnoea to exercise ventilation (E.V.) and M.V.V. In our previous report it was shown that a dyspnoeic index ($\frac{E.V.}{M.V.V.} \times 100$)

of 50% corresponded to an average clinical assessment of breathlessness between grades 2 and 3 (Gilson and others, 1955). Seventy per cent of men with an M.V.V. (direct) of 50 l./min. or less (17 subjects) did not complete five minutes of moderate stepping exercise standardized at 350 kg./m./min., whereas only 6% of those with an M.V.V. greater than 50 l./min. (140 subjects) failed to do so. Also Courmand and Richards (1941) showed that when the breathing reserve (M.V.V.—E.V.) fell to 60 to 70% of the M.V.V., dyspnoea was usually present. Thus exertion which produces an average ventilation of 25 l./min. will cause definite dyspnoea in the majority of those with an M.V.V. of 50 l./min.

Frequency distributions of the ventilatory capacity measurements in the 55-64 age group are given in Fig. 6. None of the non-miners, but 10.9% of the miners with category 3 and 34.0% of miners without pneumoconiosis recorded an M.V.V. of under 50 l./min. The excessive proportion of those with an M.V.V. of 50 l./min. and below among the miners without pneumoconiosis is striking and when tested

FIG. 6.—Histograms of the distribution of maximum voluntary ventilation (indirect) for non-miners, miners, and ex-miners, aged 55-64, categories 0-3, in a random sample from the radiographed population of the Rhondda Fach.

statistically is significant. Within age groups the effect of age is quite insignificant and the spread of these histograms would not be noticeably altered were individual M.V.V. values adjusted for age. Thus examination of the distribution of the ventilatory capacity in these two groups shows a higher proportion of those who are materially disabled in category 0 than in category 3. This is the reverse of what has often been supposed.

We have had an opportunity of studying the intermediate groups, namely categories 1 and 2 simple pneumoconiosis, in two subsequent surveys.

Second Random Sample of Miners and Ex-miners from the Rhondda Fach.—A private census of the valley was carried out in March, 1953, at the time of the second radiological survey (Cochrane and others, 1955). From this census a sample of 55 miners and ex-miners aged 55-64 was drawn in May, 1954. Of the 55, two had died, two had left the area, and four refused to cooperate. The remaining 47, 85.5% of the sample or 92.2% of

FIG. 7.—Relation of occupation and radiological category of simple pneumoconiosis to maximum voluntary ventilation (indirect) in men aged 55-64 in two random samples from the Rhondda Fach and one from Leigh.

TABLE 5
MEAN AGE AND M.V.V. (INDIRECT) ACCORDING TO RADIOLOGICAL CATEGORY IN SECOND RANDOM SAMPLE OF MINERS AND EX-MINERS AGED 55-64 YEARS FROM THE RHONDDA FACH

Age Group	Radiological Category	Number	Mean Age	Mean M.V.V.	S.E. of Mean M.V.V.
55-64	0	19	60.6	75.1	±5.43
	1	6	60.0	89.2	±9.67
	2	10	58.9	73.1	±7.49
	3	1	64.0	40.0	±23.67

those still living in the valley, were examined (Thomas, Cotes, and Higgins, 1956). The results of the M.V.V. related to radiological category (excluding 11 with P.M.F.) are shown in Fig. 7 and Table 5. These results will be discussed with those of the next survey.

Random Sample of Miners and Ex-miners and Non-miners of Leigh, Lancashire.—In November, 1954, a sample of 245 men aged 55-64 was obtained by selecting houses at random from the electoral rolls, visiting the houses so drawn and inviting any man aged 55-64 living in them to cooperate with

us in our investigation. Details of this sampling technique in Leigh will be published elsewhere (Higgins, Oldham, Cochrane, and Gilson, 1956).

Of the 245 men in the sample, 146 were miners or ex-miners who had had one or more years of mining, and of these 135 (92.5%) were examined. Of the 99 who had never worked in mines 86 (86.9%) were examined. Twenty-one miners and ex-miners had P.M.F. Three miners and ex-miners and two non-miners had significant respiratory disease other than emphysema or simple pneumoconiosis. The results of the M.V.V., after exclusion of these men, are shown in Fig. 7 and Table 6. There is good agree-

TABLE 6
MEAN AGE AND M.V.V. (INDIRECT) ACCORDING TO OCCUPATION AND RADIOLOGICAL CATEGORY IN RANDOM SAMPLE OF MEN AGED 55-64 EXAMINED IN LEIGH

Age Group	Occupation	Radiological Category	No.	Mean Age	Mean M.V.V.	S.E. of Mean M.V.V.
55-64	Non-miners	—	84	59.4	85.0	±2.53
	Miners and ex-miners	0	101	59.1	76.0	±2.30
		1	6	57.3	91.5	±9.45
		2	7	59.0	86.0	±8.75
		3	8	58.8	79.8	±8.18

ment between the mean M.V.V. for the miners and ex-miners who had category 0 and category 1 simple pneumoconiosis respectively in the Rhondda and Leigh. In both areas the men aged 55-64 with early simple pneumoconiosis (category 1) recorded a higher mean M.V.V. than those without evidence of pneumoconiosis. The agreement in the case of the men with category 2 simple pneumoconiosis is less good. Since there was only one man in the second Rhondda Fach sample with category 3 pneumoconiosis this category cannot be compared.

At Leigh 7% of the non-miners and 17% of the miners and ex-miners with category 0 recorded an M.V.V. of less than 50 l./min.

The results of these two samples of complete populations may be compared with those obtained for the men aged 55-64 with category 0 and category 3 simple pneumoconiosis from the sample of the radiographed population in the Rhondda Fach. Fig. 7 shows that for the men with category 3 the agreement is remarkably close between the first Rhondda Fach and Leigh samples—a difference of only 2.8 l./min. In the case of the miners without pneumoconiosis the agreement is not quite so close. The mean for the Rhondda sample was 7.5 litres lower than for that in Leigh but the difference is not statistically significant.

Combined Results in Three Random Samples.—The results in these three random samples are, however, sufficiently similar to justify pooling them in order to

FIG. 8.—Relation of occupation and radiological category of simple pneumoconiosis and "bronchitis" to maximum voluntary ventilation (indirect) in the three random samples combined (age 55-64).

TABLE 7

MEAN AGE AND M.V.V. (INDIRECT) ACCORDING TO OCCUPATION AND RADIOLOGICAL CATEGORY IN THREE RANDOM SAMPLES COMBINED (NON-MINERS, MINERS, AND EX-MINERS AGED 55-64 YEARS)

Age Group	Occupation	Radiological Category	Number	Mean Age	Mean M.V.V.
55-64	Non-miners Miners and ex-miners	—	134	59.5	88.0
		0	167	59.5	73.8
		1	12	58.7	90.3
		2	17	58.9	78.4
		3	55	59.5	76.8

obtain the best measure of the true relation between radiological category of simple pneumoconiosis and ventilatory capacity in the age group 55-64. This has been done in Fig. 8 and Table 7. A representative sample of non-miners of the same age from the same geographical areas was studied at Leigh and in the Rhondda. The mean M.V.V. in this group has also been included.

The characteristics of the curve are that the miners and ex-miners without pneumoconiosis record a lower mean M.V.V. than non-miners and that those with category 1 simple pneumoconiosis a *higher* value than those with category 0. Those with categories 2 and 3 simple pneumoconiosis have lower

values than those with category 1. It is well recognized that other respiratory diseases, notably bronchitis and emphysema, often cause a reduction in the ventilatory capacity (Courmand, Richards, and Darling, 1939; Wright, 1946; Lavenne and Belayew, 1953; Foubert, Nadiras, and Batique's, 1954). In the three random samples studied, respiratory symptoms were recorded using a questionnaire. Those men who had had a chest illness with cough and sputum during the past three years, and also persistent cough and/or sputum were considered for the purposes of this study to have "bronchitis". The mean ventilatory capacities in each group, excluding these "bronchitics", are given in Table 8 and are indicated in Fig. 8 by the

TABLE 8

MEAN AGE AND M.V.V. (INDIRECT) ACCORDING TO OCCUPATION AND RADIOLOGICAL CATEGORY IN THREE RANDOM SAMPLES COMBINED, EXCLUDING "BRONCHITIC" (NON-MINERS, MINERS, AND EX-MINERS AGED 55-64 YEARS)

Age Group	Occupation	Radiological Category	Number	Mean Age	Mean M.V.V.
55-64	Non-miners Miners and ex-miners	—	115	59.3	91.2
		0	121	59.4	78.8
		1	8	58.8	97.9
		2	14	59.5	82.1
		3	33	59.3	81.9

interrupted line. It will be seen that the exclusion of "bronchitics" does not affect the shape of the ventilatory capacity/radiological category curve, although for the first Rhondda Fach sample alone removing the "bronchitics" did bring the mean M.V.V. for those with categories 0 and 3 nearer together. The observation that in the older age group men without pneumoconiosis have a lower ventilatory capacity than men with category 1 simple pneumoconiosis is a consistent one throughout our surveys. Table 9 shows the mean values for the two groups in six investigations.

It is important to bear in mind the wide scatter of values of the M.V.V. that are recorded in each of the groups. Fig. 9 shows the mean and scatter

TABLE 9

VENTILATORY CAPACITY IN CATEGORY 0 AND MEAN CATEGORY 1 SIMPLE PNEUMOCONIOSIS IN SAMPLES OF ELDERLY MINERS AND EX-MINERS

	Sample	Category 0	Category 1
M.V.V. (indirect) Age 55-64	Compensation group	71 (13)*	81 (7)
	Colliery L	72 (9)	88 (6)
	Rhondda Fach	75 (19)	89 (6)
	Leigh (Lancs.)	76 (101)	92 (6)
M.V.V.† (direct) Age 50-59	Main experiment	94 (8)	100 (8)
	Colliery B	80 (23)	92 (23)

*Numbers in each sample.

†Gilson and others (1955).

FIG. 9.—Relation of occupation and radiological category of simple pneumoconiosis to maximum voluntary ventilation (indirect) in a random sample from Leigh (age 55-64).

in the random sample of the population in Leigh. This shows that men with severe limitation of ventilatory capacity, and, by implication, a marked degree of breathlessness, will be found in all radiological categories, and that only a small proportion of their disability is related to the extent of their pneumoconiosis as described by their radiological category.

Discussion

The conflicting results for the compensation and working miner groups show clearly how the method of selection can influence investigations of this kind. By studying random samples from geographically defined populations and only having a small refusal rate, we believe we have established the relationship between the category of simple pneumoconiosis and ventilatory capacity with much greater certainty than was previously known.

Our earlier findings (Gilson and others, 1955) that miners with and without simple pneumoconiosis have a lower average maximum voluntary ventilation than men of the same age who have never worked at mining is confirmed. Also the observation that

elderly working miners without radiological evidence of pneumoconiosis have a slightly lower average M.V.V. (p. 129) than miners with category 3 simple pneumoconiosis has been shown to apply to random samples of miners and ex-miners.

The review of the literature up to 1953 (Gilson and others, 1955) revealed how unrepresentative were the groups of subjects studied by most workers in attempting to relate radiological category to lung function study in pneumoconiosis. Worth and Schiller (1954) in another review have also shown the conflicting results reported by different workers. Recently Foubert and others (1954) reported the results of applying spirometry at rest to 1,500 miners. They observed no important change of ventilatory capacity with simple pneumoconiosis and stressed the importance of other factors causing disability. Direct comparison with our findings is, however, not possible as their results are all expressed in terms of percentages of predicted values. Lavenne and Belayew (1953) studied a group of 205 working miners more comparable with ours at Colliery L. They found no change of ventilatory capacity with the degree of simple pneumoconiosis. They comment that their findings are probably influenced by selection, the more disabled men having left the mine. Newell and Browne (1955) in a study of 5,117 working miners were unable to show any relationships between radiological category of pneumoconiosis and respiratory disability estimated from symptoms and change of job.

Our findings raise a number of points to which definite answers cannot yet be given. For example, why should miners have a low average ventilatory capacity and why should those with normal films in the age group 55-64 be more affected than those with early simple pneumoconiosis?

It is possible that one or more of such factors as occupational selection, nutrition, housing, and medical care might be the cause of the difference between the miners and those without mining experience. We doubt if the main cause is to be found in these factors. By making comparisons with non-miners living in the same area we have to some extent compensated for the effects of housing and medical care. Also in Leigh the observed differences in respiratory symptoms in the miners and non-miners could not be accounted for by differences in social class (as defined by the Registrar General) or by differences in the amount of tobacco smoked (Higgins and others, 1956). It seems more probable that mining itself is responsible either as a result of pollution of the atmosphere by dust and fumes, or on account of the type and severity of physical exertion required. An attempt to assess the

importance of some of these factors is now being made by making a comparison with agricultural workers (Cochrane and others, 1956).

The unexpected finding of a higher ventilatory capacity in men with early simple pneumoconiosis than those with normal films might be attributed in part to occupational self-selection: the men with higher ventilatory capacity being capable of greater activity without dyspnoea might be more likely to work on the coal-face and so receive a heavier dust exposure. Our findings do not support this view. At Leigh in the age group 55-64 the mean years on the coal-getting shift of those with category 1 was 5.5 compared with 11.3 years for those with category 0. The differences are not solely due to an increased prevalence of respiratory infection in those with normal radiographs since it is still seen after removing the cases of "bronchitis".

In the miners and ex-miners without pneumoconiosis aged 55-64 the low average M.V.V. and its biphasic distribution might be adduced as evidence that this group was not homogeneous, but consisted of those men with a typical distribution of M.V.V. for their age, with the addition of others selected on the basis of a low M.V.V. It is possible that this may be so for it may include men who had early pneumoconiosis (category 1 and early category 2) in whom the development of emphysema has obscured the dust. If this hypothesis is correct it should be possible to detect a radiological regression of early simple pneumoconiosis in the elderly. In our experience regression of well established simple pneumoconiosis is rare; but a special study in elderly miners with early simple pneumoconiosis has not yet been possible. A follow-up over 10 years between the ages of 50 and 60 would be required. Pathologists have stressed the importance of focal emphysema as a cause of disability (Heppleston, 1953; Gough and Heppleston, 1955). As the condition cannot yet be diagnosed in life (except by biopsy) we are unable to state its significance in relation to our observations.

On the other hand, generalized emphysema of the usual types could account for our findings, but it would be unjustifiable to ascribe the reduced ventilatory capacity to this alone on the basis of a single test of lung function. In addition the lowered ventilatory capacity in the miners aged 25-34 (when emphysema is rare) compared with the normals suggests that other changes may also be occurring. The fall in ventilatory capacity is not caused by a decrease in expiratory muscle force since the maximum static pressure which could be sustained was not significantly related to the M.V.V. in the miners in the Rhondda Fach. There was a significant

correlation ($r = 0.69$) between the M.V.V. and airways resistance of the lungs (McDermott, personal communication).

Our results do not support the hypothesis that the reduced ventilatory capacity is directly related to the severity of dust exposure. The men with category 3 simple pneumoconiosis had spent about twice as long on the coal-face as those with category 0, and within the category 3 group aged 55-64 in the Rhondda Fach there was no relation between M.V.V. and years on the coal-getting shift. In the miners with category 0 both in Leigh and in the Rhondda Fach there was only a weak relationship between years on the coal-getting shift and a decreased M.V.V.

It seems possible that mining does in some ways accelerate, to a marked extent in some individuals, the normal decline in ventilatory capacity which occurs with age. The fall of M.V.V. with each radiological category of simple pneumoconiosis was 6 litres in the Leigh sample and 5.2 litres in the working miners in Colliery L. The regression of M.V.V. on age was 1.4 l./min. for each year of life in the first sample studied in the Rhondda Fach, thus each radiological category of simple pneumoconiosis is about equivalent to four years of life in its effect on ventilatory capacity. What this process is will perhaps be better understood when the underlying changes causing emphysema are elucidated.

Summary

The relation of radiological category of simple pneumoconiosis (I.L.O. Classification, 1950) to ventilatory capacity measured by the volume expelled during the first 0.75 second of a forced expiration (M.V.V. indirect) has been studied in several groups: (i) miners applying for compensation (204); (ii) working miners (223); (iii) randomly selected miners and ex-miners, and non-miners from two communities (553).

The results in the first two investigations were contradictory, indicating the need to study representative groups of miners and ex-miners. In the three random samples the results were concordant.

A linear fall of 1.36 l./min. in M.V.V. for each year of life was observed in non-miners aged 20-69 years.

In the age group 55-64 the miners and ex-miners without pneumoconiosis had a lower average M.V.V. than those with simple pneumoconiosis categories 1 and 2 and about the same as the miners with category 3.

The unexpected relationship is still observed after excluding subjects with "bronchitis"; possible reasons are discussed.

From a study of the proportion of miners and

non-miners with an M.V.V. of 50 l./min. or less in the age group 55-64 it is concluded that respiratory disability of a moderate or severe degree is commonest in miners with category 0 and category 3 films, and also that the proportion among miners is higher than in non-miners in the two communities studied.

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