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PULMONARY VENTILATORY FUNCTIONS OF COALMINERS IN VARIOUS AREAS IN RELATION TO THE *X*-RAY CATEGORY OF PNEUMOCONIOSIS

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Although medical opinion is in general agreed that progressive massive fibrosis can cause pulmonary disability, there is little evidence from unselected populations and there is considerable difference of opinion about simple pneumoconiosis. The early literature on the subject has been well summarized by Gilson and Hugh-Jones (1955), and Higgins, Oldham, Cochrane, and Gilson (1956), Carpenter, Cochrane, Gilson, and Higgins (1956), and Newell and Browne (1955) have added to our knowledge of the subject. In this paper we are attempting another review, based on the surveys already described by Carpenter and Higgins and their colleagues (1956) in the Rhondda Fach and Leigh, the survey at Staveley (Higgins, Cochrane, Gilson, and Wood, 1959), and a new survey carried out in the summer of 1958 in the Rhondda Fach (Higgins and Cochrane, 1961). In addition, for purposes of comparison, we make use of the two surveys carried out in agricultural areas (Higgins, 1957; Higgins and Cochran, 1958).

Materials and Methods

The areas have all been previously described, as have the populations examined. They all consist of random samples stratified by age, sex, and occupation, of the population enumerated by nominal census, living in a defined area. In the present paper we are concerned only with those members of the population who were "pure" miners, *i.e.* those who had been coalminers and had not been exposed to any other industrial risk likely to produce pneumoconiosis or pulmonary disability. For this reason the number of miners in the Leigh population are smaller than those previously published (Higgins and others, 1956).

For all the surveys the following information has been available:

(1) A detailed industrial history.

(2) A measurement of the indirect maximum breathing capacity (I.M.B.C.). (Forced expiratory volume/0·75 sec. ×40.) (McKerrow, McDermott, and Gilson, 1960).

(3) Answers to a standardized questionnaire about respiratory symptoms and smoking habits (Higgins and others, 1956).

(4) Results of classifying standard postero-anterior chest films, using the International Classification (I.L.O., 1959).

(5) Anthropometry (stem height and weight).

We believe in general that the material obtained from the various surveys is entirely comparable. The refusal rates were all approximately the same (less than 10 per cent.). The anthropometry and the industrial histories have been taken by the same team; one of us (I.T.T.H.) asked all the questions in the questionnaire, except at Staveley where, for experimental purposes, one half of the population was randomly allocated to Dr. J. C. Gilson. The same *x*-ray van and radiographers have been with us throughout and the same standardized I.M.B.C. machine was used. Only a few possible sources of inter-area bias remain:

(1) The effect of the man in charge of the I.M.B.C. machine. This source of bias has been discussed by Higgins and others (1959).

(2) The effect of a secular trend in *x*-ray reading. This was quite likely as the *x*-ray reading covers a considerable period of years (1953–58). The point

was therefore investigated by one of us (A.L.C.), who re-read all the chest films involved after they had been masked to conceal date and place of origin and arranged in random order. The results (see Appendix) suggest that, although temporary biases may have appeared at particular times, no striking overall bias was apparent when all the results were pooled. The average I.M.B.C. results were, however, calculated for the old and the new *x*-ray results, but the "new" were found to differ minimally from the "old" values except in the age-*x*-ray groups which were very small indeed. These "new" readings, when referred to later, are called "randomized readings".

(3) The sampling technique at Leigh was rather different from the others and has been criticized (Gray, 1956). but we do not believe that any serious bias has been introduced (Oldham, 1956).

(4) The industrial history-taking at Leigh was not done by the same people as in the other surveys, and it is possible that comparability is not exact but the error should be small.

(5) In Staveley and Leigh an appreciable number of miners and ex-miners had to be excluded in order to obtain a population of pure miners and ex-miners, whereas in the Rhondda there are so few alternative outside occupations that the number excluded was negligible. It is clearly possible that the exclusion of these men with other dust exposures might have introduced bias. However, Higgins and others (1959) have shown that the addition of the group with a mixed industrial history alters the I.M.B.C. very little, and their retention in the population would lead to even greater difficulties of interpretation. It seems reasonably certain that this type of exclusion has not produced the regional differences by artefact.

This series of comparisons is confined to men aged 55 to 64 years. We have selected this age group as the best compromise between maximal exposure to occupational environment, and minimal bias due to early death.

Results

(*a*) Simple Pneumoconiosis

The questions that we can reasonably hope to answer are:

(1) Is there any relationship between *x*-ray category of simple pneumoconiosis and disability?

(2) Are those without pneumoconiosis more or less disabled than those with simple pneumoconiosis?

(3) Are there any regional differences? If so, what are the reasons for them?

(4) If we exclude the effects of progressive massive fibrosis (P.M.F.), are miners and ex-miners more disabled than they would have been had they never gone into mining?

Table I and Fig. 1 (opposite) give the basic figures relevant to the first two questions. The differences between the totals of the "old" and "randomized" populations (if anyone cares to add them up) are due to the differences in the number read as suffering from P.M.F. on the two occasions. There is clearly very little evidence of any trend of increasing disability with increasing category except at Leigh (old), and the Rhondda Fach, 1954 (2) (old), where the numbers are small and the trend is reversed in the randomized

TABLE I

AVERAGE INDIRECT MAXIMUM BREATHING CAPACITIES OF MINERS AND EX-MINERS AGED 55–64, IN THE THREE AREAS WITHOUT P.M.F., BY CATEGORY OF SIMPLE PNEUMOCONIOSIS

Area	Type of Categorization	Category of Simple Pneumoconiosis										
		0		1		2		3		Total 1, 2, 3		Total 0, 1, 2, 3
		Average I.M.B.C.	No.	Average I.M.B.C.	No.	Average I.M.B.C.	No.	Average I.M.B.C.	No.	Average I.M.B.C.	No.	No. of Cases
Rhondda Fach, 1954 (1) ..	Old ..	68·5	47	—	—	—	—	77·1	46	—	—	—
Rhondda Fach, 1954 (2) ..	Old ..	75·1	19	89·9	9	65·3	7	40·0	1	76·8	17	36
	Randomized	79·2	20	68·4	7	70·9	8	—	—	69·7	15	35
Rhondda Fach, 1958 (3) ..	Old ..	77·1	25	72·4	24	82·1	15	92·0	1	76·5	40	65
	Randomized	79·2	27	71·4	18	79·8	19	79·4	7	76·3	44	71
Leigh, 1954 ..	Old ..	76·6	64	91·2	5	84·5	6	81·3	6	85·4	17	81
	Randomized	77·0	49	71·1	17	85·8	6	94·5	8	80·0	31	80
Staveley, 1957	Old ..	86·8	96	82·9	27	93·6	22	82·5	4	87·3	53	149
	Randomized	86·2	107	92·9	19	90·3	14	92·0	5	91·8	38	145
Total	Old ..											331
	Randomized											331

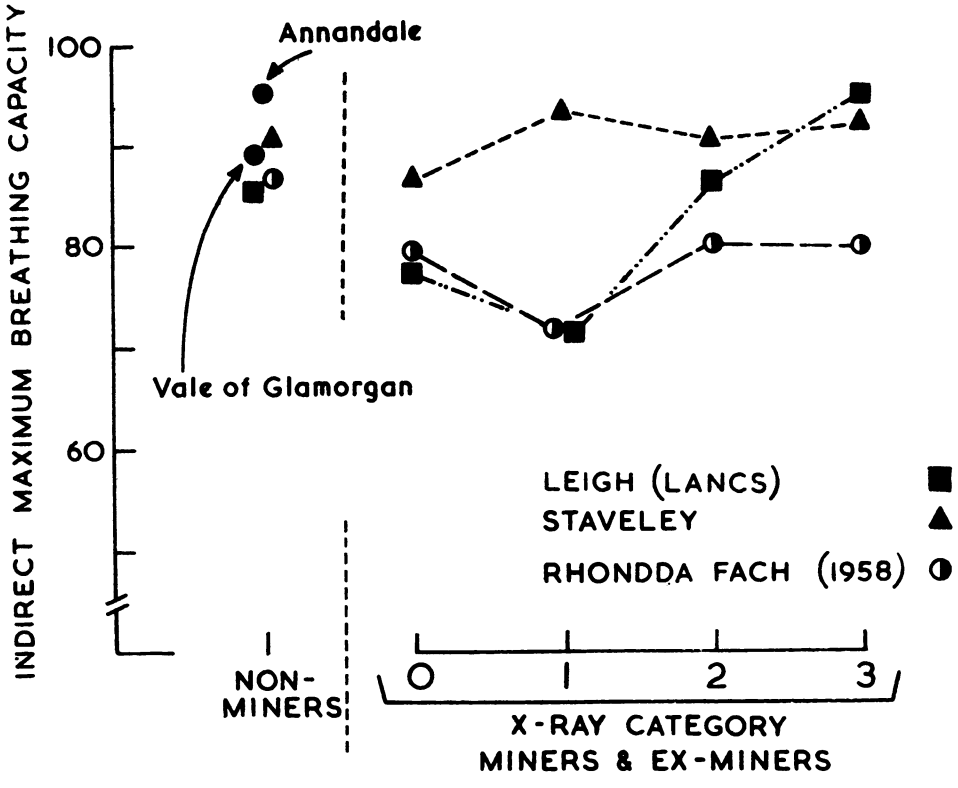

FIG. 1.—The relationship between the average indirect maximum breathing capacity and the *x*-ray category of pneumoconiosis in random samples of males aged 55–64 in various areas.

series. It must, however, be remembered that there is an alternative explanation. Pneumoconiosis is mainly a condition of face workers, and selective factors affect both the taking up of face work and the length of time men stay on the coal face. It seems possible that only the fittest people survive on the coal face long enough to reach Category 3. It may therefore be that although the average ventilatory capacities of the various categories are the same, the loss of potential ventilatory capacity may be greater in those with the higher categories.

The problem of whether those with or without pneumoconiosis were the more disabled is best assessed by comparing the first and last columns in Table I. In our first Rhondda surveys and at Leigh we found that those without pneumoconiosis were the more disabled (Carpenter and others, 1956). In Staveley this effect was scarcely present, and when we repeated the survey in the Rhondda in 1958 we again were unable to show this effect in the same age group and the same population as that in which we demonstrated it before. We have some difficulty in explaining the findings. One possible explanation is that the difference was due to the time of year when the surveys were carried out—the first survey was done in early spring and the second in summer. On the whole, there is little to support this. Another possible explanation is that in the first survey we happened to be studying different though overlapping cohorts, one of which had been particularly severely affected by illness or migration in the early part of their lives. The difference in the average values of the I.M.B.Cs of those in Category 0 in 1954 (1) and 1958 (3) does not quite reach statistical significance at the 5 per cent. level, and can perhaps be explained by the inevitable sampling error. For the moment all we can say is that the evidence for any decrease in ventilatory function, specifically industrial in origin, amongst those without pneumoconiosis is not as strong as we had previously considered it to be.

The next question concerns the differences between the areas (Table II, overleaf). There is no significant difference between the areas in the average values of the I.M.B.C. for those not exposed to dust, except between Annandale and Leigh ($0{\cdot}05 < P < 0{\cdot}03$).

TABLE II

AVERAGE INDIRECT MAXIMUM BREATHING CAPACITIES OF MEN AGED 55-64, IN AGRICULTURAL AREAS AND OF THOSE NOT EXPOSED TO DUST, AND OF MINERS AND EX-MINERS WITHOUT PROGRESSIVE MASSIVE FIBROSIS IN THE THREE AREAS (RANDOMIZED READINGS)

Area	Not Exposed to Dust	Pure Miners and Ex-miners
Annandale	94·8 (91)	
Vale of Glamorgan..	89·0 (86)	
Rhondda Fach, 1958..	86·6 (85)	77·4 (71)
Leigh, Lancs.	84·9 (49)	78·2 (80)
Staveley	90·1 (81)	87·7 (145)

( ) Number in group.

This is possibly due to the atmospheric pollution for which Leigh is well known. Amongst the miners and ex-miners, the values for Leigh and the Rhondda Fach are significantly lower than those for Staveley ($P<0·01$), but they are not significantly different from each other. When the miners and ex-miners are compared with the non-miners in the same area, the only significant difference is found in the Rhondda Fach ($0·01<P<0·02$). A further point is worth making here. We referred earlier to some possible inter-area biases which we had attempted to avoid. In the case of the comparison between Staveley and the 1958 Rhondda Fach survey, it is possible to exclude bias as far as is humanly possible. Both surveys were carried out at the same time of year, and the physiological tests were carried out entirely by one of us (I.T.T.H.) in the Rhondda Fach in 1958, and the same man also carried out the tests on half (a randomized half) of the population examined at Staveley, so if we use in addition the randomized *x*-ray readings there appears to be no possibility of bias. The results are shown in Table III and the difference between Staveley and the Rhondda miners and ex-miners is significant ($P<0·01$).

TABLE III

COMPARISON BETWEEN THOSE MEN SEEN BY I.T.T.H. AT STAVELEY AND IN THE RHONDDA, AGED 55–64 IN 1958, USING THE RANDOMIZED X-RAY READINGS

Area	Average I.M.B.C.					
	Not Exposed to Dust	X-Ray Category of Pure Miners and Ex-Miners				
		0	1	2	3	Total
Rhondda Fach,.. 1958 .. .	86·6 (85)	79·2 (27)	71·4 (18)	79·8 (19)	79·4 (7)	77·4 (71)
Staveley	88·6 (42)	86·5 (51)	96·7 (10)	92·9 (7)	104·0 (1)	88·8 (69)

( ) Number in group.

The existence of such regional differences is surprising, and it is clear that we must approach the problem of possible explanations rather cautiously. The areas differ in very many ways, and the main problem will be to decide which, if any, of these differences is significant and relevant.

Considering first the anthropometric differences (summarized in Table IV), there are variations in both stem height and weight between the different areas.

TABLE IV

MEASUREMENTS OF STEM HEIGHT AND WEIGHT OF MINERS AND EX-MINERS AGED 55–64 WITHOUT PROGRESSIVE MASSIVE FIBROSIS IN THE THREE AREAS BY CATEGORY OF SIMPLE PNEUMOCONIOSIS (RANDOMIZED READINGS)

Area	Stem Height (in.)		Weight (lb.)	
	Category 0	Categories 1, 2, 3	Category 0	Categories 1, 2, 3
Rhondda Fach,.. 1958	34·4 (27)	34·2 (44)	144·9 (27)	137·4 (44)
Leigh, Lancs. ..	34·2 (49)	34·0 (31)	152·1 (49)	144·5 (31)
Staveley	35·7 (107)	34·7 (38)	152·7 (107)	152·4 (38)

The former, however, is small and is unlikely to account for the difference (1 in. of stem height = 6·8 litres per minute I.M.B.C.: Carpenter and others, 1956). The differences in weight are more striking but are operating in the wrong direction (Gilson and Hugh-Jones, 1955). A possible explanation is the higher prevalence of bronchitis in the Rhondda Fach compared with the other areas. Table V (opposite) gives a comparison of the smoking habits of the same groups. The percentage of non-smokers is somewhat higher at Staveley but the percentage of heavy smokers is also higher there.

Table VI (opposite) summarizes the differences as regards the prevalence of pneumoconiosis, together with the average time spent by the miners and ex-miners at the coal face and underground. The prevalence of pneumoconiosis is very much higher in the Rhondda than in Leigh, and in Leigh than in Staveley. This in itself is probably unimportant from our present point of view, as our results have been standardized for *x*-ray category, but the higher prevalence of P.M.F. in the Rhondda and Leigh may be important. If P.M.F. tends to develop in miners who before onset have a high I.M.B.C., the exclusion of these men would decrease the average I.M.B.C. of the remainder, *i.e.* areas with a high prevalence of P.M.F. (*e.g.* the Rhondda), would have low average I.M.B.C. among those with simple pneumoconiosis. This

TABLE V

SMOKING HABITS OF MINERS AND EX-MINERS AGED 55–64 IN THE THREE AREAS, WITHOUT PROGRESSIVE MASSIVE FIBROSIS (USING RANDOMIZED READINGS)

Area	Smoking Habits	Non-Smokers	Cigarettes (per day)				Ex Smokers	Total
			1–4	5–14	15–24	25+		
Rhondda Fach	No.	2	4	41	12	2	10	71
	Per cent.	2·8	5·6	57·7	16·9	2·8	14·1	99·9
Staveley	No.	19	11	52	38	10	15	145
	Per cent.	13·1	7·6	35·9	26·2	6·9	10·3	100·0
Leigh	No.	3	2	41	20	7	7	80
	Per cent.	3·8	2·5	51·3	25·0	8·8	8·8	100·2

TABLE VI

VARIOUS CHARACTERISTICS OF THE MINERS AND EX-MINERS, AGED 55–64. IN THE THREE AREAS (RANDOMIZED READINGS)

Area	No. of Miners	Simple Pneumoconiosis		Progressive Massive Fibrosis		Average No. of Years at Coal Face
		No.	Per cent.	No.	Per cent.	
Rhondda Fach, 1958	92	44	47·8	21	22·8	12·0
Leigh, Lancs. ..	85	31	36·5	5	5·9	12·6
Staveley ..	145	38	26·2	0	0	12·5

TABLE VII

THE RELATIONSHIP BETWEEN X-RAY CATEGORY OF PNEUMOCONIOSIS AND THE AVERAGE NUMBER OF YEARS SPENT ON THE COAL FACE AMONGST MINERS AND EX-MINERS IN THE THREE AREAS (RANDOMIZED READINGS)

Category	Rhondda Fach		Leigh		Staveley	
	No. of Miners	Average Years at Coal Face	No. of Miners	Average Years at Coal Face	No. of Miners	Average Years at Coal Face
0	27	7·0	49	10·1	107	10·0
1	18	10·9	17	10·8	19	18·5
2	19	13·3	6	13·7	14	19·1
All Category 2 including P.M.F.	26	13·2	9	21·0	—	—
3	7	15·8	8	25·5	5	25·2
All Category 3 including P.M.F. and U.R.	21	18·7	10	21·0	—	—
Total ..	92		85		145	

explanation of the regional differences in disability seems improbable, and is contradicted by the observation that the average I.M.B.C. of those with the earliest signs of P.M.F. in this age group is identical with that of miners with simple pneumoconiosis. The regional differences in the prevalence of P.M.F. are of course interesting in themselves, but are hardly relevant here. They have been discussed by McCallum and Browne (1955).

The similarity in the average values for the time spent at the coal face is probably due to several factors balancing out, *e.g.* the fact that Welsh miners go on to the coal face earlier has been balanced by the greater unemployment in Wales. It does, however, suggest that the Rhondda Fach collieries may have been, on average, dustier than the others, or that the Staveley dust is less easily retained or less radio-opaque (Rivers, Wise, King, and Nagelschmidt, 1960). This point is brought out rather more clearly in Table VII, in which the average number of years at the coal face is related to the *x*-ray categories of simple pneumoconiosis. The values for Leigh are somewhat erratic (probably for the reasons already mentioned), but in general there seems to be a steady gradient from the Rhondda Fach to Staveley. If one then assumes that dust retention is related to the product of dust concentration and duration of exposure, one can hazard the suggestion that the average dust concentration on the coal faces in the Rhondda Fach has been on average about 50 per cent. higher than at Staveley.

Turning now to the problem of bronchitis. Throughout all these surveys the diagnosis of bronchitis has been based on the questionnaire (p. 2), and the same arbitrary level for diagnosis has been used, *i.e.* "persistent sputum and at least one bronchitic illness during the past 3 years" (Higgins and others, 1959). Table VIII (overleaf) shows the overall prevalence of bronchitis and the lack of obvious relationship between bronchitis and *x*-ray category, although the numbers are, of course, small. This is very possibly due to the fact that bronchitics may leave the coal face early before they have had time to progress to the higher categories, but we are unable to find any evidence here connecting bronchitis with dust retention. There are

TABLE VIII

PREVALENCE OF "BRONCHITIS" IN RELATION TO X-RAY CATEGORY OF SIMPLE PNEUMOCONIOSIS AMONGST MINERS AND EX-MINERS, AGED 55–64, IN THE THREE AREAS (EXCLUDING P.M.F.) (RANDOMIZED READINGS)

Area	X-ray Category of Simple Pneumoconiosis														
	0			1			2			3			Total		
	No. of Miners	Cases of Bronchitis	Per cent.	No. of Miners	Cases of Bronchitis	Per cent.	No. of Miners	Cases of Bronchitis	Per cent.	No. of Miners	Cases of Bronchitis	Per cent.	No. of Miners	Cases of Bronchitis	Per cent.
Rhonnda Fach, 1958	27	10	37·0	18	5	27·8	19	4	21·1	7	1	14·3	71	20	28·2
Leigh, Lancs ...	49	12	24·5	17	6	35·3	6	—	—	8	1	12·5	80	19	23·8
Staveley	107	23	21·5	19	1	5·3	14	3	21·4	5	3	60·0	145	30	20·7

other reasons for being cautious about blaming bronchitis for the regional differences. In a previous paper (Carpenter and others, 1956) we showed that when the bronchitics were excluded from the Rhondda and Leigh populations the differences remained. Similarly, exclusion of the Staveley bronchitics makes very little difference. The high prevalence of bronchitis amongst miners' wives in the Rhondda Fach (Higgins and Cochrane, 1961) also suggests that there are non-industrial causes for the high prevalence of bronchitis there.

Another approach to this problem is that suggested by Kadlec and Vyskocil (1950). They called attention to the fact that there was a relationship between ventilatory capacity and the number of years men had been exposed to dust. They found this effect chiefly in workers over 45, but in all *x*-ray category groups. Similar effects have been reported by Carstens, Brinkmann, Lange, Meisterernst, and Schlicht (1958) and by Worth, Valentin, Gasthaus, Hoffmann, and Venrath (1955). Table IX summarizes our results from this point of view. This effect appears somewhat irregularly in our material; considering all four categories (0, 1, 2, and 3), it is present and gradual at Staveley, but not apparent at Leigh, while in the Rhondda Fach there appears to be a marked drop after one year in mining, and thereafter a plateau. The effect is apparent to some degree in all the groups of Category 0, but not at Leigh or Staveley amongst groups of Category 1, 2, and 3. Possibly the extent to which we have confirmed the work of the other workers is better demonstrated in Table X.

TABLE X

RELATIONSHIP BETWEEN I.M.B.C. IN MEN AGED 55–64 IN THREE AREAS AND THE NUMBER OF YEARS SPENT ON THE COAL FACE (EXCLUDING CASES OF P.M.F.) (RANDOMIZED READINGS) (AS IN TABLE IX)

Area	Non-Miners	Miners and Ex-Miners		
		Number of Years on Coal-getting Shift		
		<1	<10	>10
Rhondda Fach,.. 1958	86·6	89·9	78·8	75·8
Leigh, Lancs. ..	84·9	79·9	80·8	75·7
Staveley	90·1	94·0	92·7	83·5

TABLE IX

RELATIONSHIP BETWEEN THE AVERAGE I.M.B.C. OF MINERS AND EX-MINERS, AGED 55–64, IN THREE AREAS AND THE NUMBER OF YEARS SPENT ON THE COALFACE (EXCLUDING CASES OF P.M.F.) (RANDOMIZED READINGS)

Area	Category	No. of Years on Coal-getting Shift								Total
		<1		1–9		10–19		20+		
		No. of Miners	Average I.M.B.C.	No. of Miners	Average I.M.B.C.	No. of Miners	Average I.M.B.C.	No. of Miners	Average I.M.B.C.	
Rhondda Fach, 1958	0	5	92·4	15	79·5	5	58·4	2	95·5	27
	1, 2, 3	4	86·8	14	70·9	16	82·8	10	69·3	44
	0, 1, 2, 3	9	89·9	29	75·4	21	77·0	12	73·7	71
Leigh, Lancs. ..	0	19	81·2	8	81·6	11	79·7	11	63·6	49
	1, 2, 3	10	77·5	1	102·0	8	83·1	12	78·2	31
	0, 1, 2, 3	29	79·9	9	83·9	19	81·2	23	71·2	80
Staveley ..	0	38	93·4	20	86·8	27	81·4	22	79·0	107
	1, 2, 3	2	105·5	5	106·4	12	89·2	19	88·2	38
	0, 1, 2, 3	40	94·0	25	90·7	39	83·8	41	83·2	145

TABLE XI

PREVALENCE OF "BRONCHITIS" IN RELATION TO YEARS SPENT ON THE COALFACE AMONGST MINERS AND EX-MINERS, AGED 55–64, IN THE THREE AREAS (EXCLUDING P.M.F.) (RANDOMIZED READINGS)

Area	Years at the Coal Face														
	1			1–9			10–12			20+			Total		
	No. of Miners	Cases of Bronchitis	Per cent.	No. of Miners	Cases of Bronchitis	Per cent.	No. of Miners	Cases of Bronchitis	Per cent.	No. of Miners	Cases of Bronchitis	Per cent.	No. of Miners	Cases of Bronchitis	Per cent.
Rhondda Fach, 1958	9	1	11·1	29	10	34·5	21	6	28·6	12	3	25·0	71	20	28·2
Leigh, Lancs. ..	29	7	24·1	9	2	22·2	19	5	26·3	23	5	21·7	80	19	23·8
Staveley ..	40	9	22·5	25	3	12·0	39	10	25·6	41	8	19·5	145	30	20·7

There are several reasons why our results should differ from those of Kadlec and Vyskocil (1950), Worth and others (1955), and Carstens and others (1958). In general our material is less selected but much smaller numerically, and Kadlec used a different index of pulmonary ventilation. It does, however, appear to be an important finding which merits further attention.

Table XI shows the relationship of bronchitis to years at the coal face, but unfortunately from the point of view of any simple hypothesis there is very little sign of any relationship, although here again self-selection may be concealing the effect.

Another possibility is that differences in atmospheric pollution may be important. Leigh is visually the most polluted area, then Staveley, and then the Rhondda. The actual measurements available (D.S.I.R., 1959) are open to the criticism that they are not made in positions designed to give a representative value for the area in question, but the values for "SO_2" support the visual ranking order. Atmospheric pollution is therefore unlikely to be the cause of the differences, though it is of course possible that we do not yet know which constituent of the atmosphere to measure.

Yet another possibility is differential emigration. If more people left one area than another and they were on the average healthier than those remaining, such differences might well occur. The crude figures for the changes in size of the three cohorts involved can be obtained more or less directly from the Registrar General's Census returns. This is to say the figures for Leigh were obtained directly; for the Rhondda Fach we have used the figures for the Rhondda Urban District (now the Rhondda Borough) which includes both the Rhondda Fawr and the Rhondda Fach. Staveley was more complicated as it was involved in the Local Authority reorganization in the 1930s, when Staveley Urban District was formed from the Parish of Staveley and most of the Parish of Duckmanton. For the period before the reorganization we have combined the males of these two parishes and applied to them the age distribution of Chesterfield Rural District. After the reorganization we have used the required male age group of Staveley Urban District plus the number of men estimated to be in that age group in the remains of the Parish of Duckmanton, calculated from applying the Chesterfield Rural District age distribution to the total males there. This method, though inelegant, seemed likely to achieve comparability with the others. The results are shown in Table XII, and in Fig. 2 (overleaf), in which the number in each population aged 15–24 in 1911 represents 100 per cent. and the number in the same cohort at subsequent censuses is expressed as a percentage of that in 1911. This is not, of course, a study of a true cohort, since the size of each age group represents the balance between emigration and death on the one hand and immigration on the other, as compared with the size of the previous age groups at the previous census.

TABLE XII

PERCENTAGE DECLINE IN SIZE OF COHORTS IN VARIOUS AREAS

Area	Subjects	Age of Cohort (yrs)				
		15–24	25–34	35–44	45–54	55–64
Staveley	No.	1,368	1,066	1,286		950
	Per cent.	100	77·9	94·0		69·4
England and Wales (thousands)	No.	3,158	2,621	2,512	No Census	2,028
	Per cent.	100	83·0	79·5		64·2
Leigh Borough	No.	4,417	3,610	3,112		2,451
	Per cent.	100	81·7	70·0		55·5
Rhondda Urban District	No.	16,104	12,764	9,781		6,721
	Per cent.	100	79·3	60·7		41·7
Census Year		1911	1921	1931	1941	1951

The figures demonstrate that there have been large differences between the three areas in the rate of decline of the cohort measured in this way, and

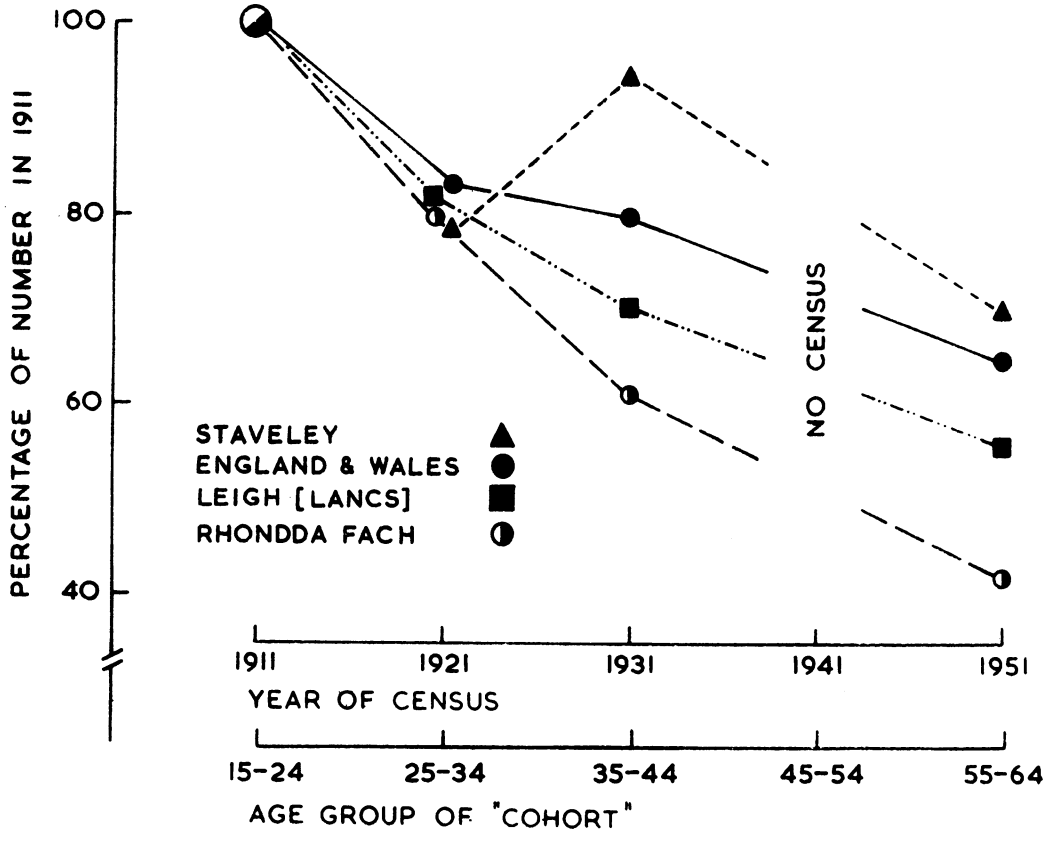

FIG. 2.—The percentage change in male "cohorts" (born 1887–1896) in three mining areas and in England and Wales.

further that the ranking of the areas is the same as that found in the surveys. This appears promising, but deficiencies in the data must be pointed out. These figures relate to all the males in that particular cohort and tell us nothing directly about the miners and ex-miners. In areas like the Rhondda the possible error is probably small because the miners and ex-miners represent such a high proportion of the male population, but in areas like Staveley where they represent under 50 per cent. in the 55 to 64 age group the possible error, when applying these figures to the mining community, may be large. It is, however, probable that in all three areas the figures are an under-estimate of the rate of decline of the mining cohort. In the late 1920s and 1930s unemployment was much higher in mining than in the lighter non-dusty industries and migration was probably higher too. In the case of the Rhondda Fach there is probably another factor causing the percentage of migrants to be an under-estimate. Local opinion is unanimous that a higher percentage of miners left the Rhondda Fach than the Rhondda Fawr, and although it is difficult to get quantitative evidence for this it seems reasonable to suggest that only

30 per cent. of the mining cohort remained in the Rhondda Fach compared with the 40 per cent. in the Rhondda Urban District. There has therefore been great scope for the various types of selection to have taken place.

Having established the probability of quantitative differences, the next step is to see whether the migration can have been selective from a qualitative point of view. Bradford Hill (1925) and Martin (1949) have already published work suggesting that migrants are healthier, taller, and heavier than non-migrants. There is also some unpublished evidence from the M.R.C.'s Obstetric Medicine Research Unit in Aberdeen suggesting that migrants are taller, have higher I.Q.s and, in the case of women, have a lower perinatal mortality rate (Illsley, 1960). We shall never discover how the migrants in the 1920s and 1930s from the Rhondda, Leigh, and Staveley differed from those they left behind. All we can do is to examine the situation at present, and some unpublished work is available at the Pneumoconiosis Research Unit, based on a follow-up of those *x*-rayed in 1950–51 (Cochrane, Cox, and Jarman, 1952); this strongly suggests that those who have left the valley since then were taller and heavier than those that remained. One should not, of course, imagine that all migrants were "up-and-coming go-getters". There were undoubtedly "drifters" as well. It is also probable that different types of migrant went to different areas. In the 1920s and 1930s the most vigorous tried their luck in London, Coventry, and Slough. The drifters probably moved to the same occupation in a neighbouring town. It seems clear that this, too, is a possible cause of the differences we have found, though its importance is hard to evaluate.

It is clearly impossible to be dogmatic about the causes of the regional differences. It is tempting to accept the evidence for a difference in dustiness at the coal face and assume this is the cause, but there is little evidence to connect bronchitis with dust retention, as seen in the *x*-ray, or to dust exposure. The effect described by Kadlec and Vyskocil (1950) may well be the key to the riddle, but as yet we know too little about it, while differential emigration may well have exaggerated the effects of the dust, if the bronchitics were less likely to migrate.

In discussing the regional differences we have assembled all the evidence available to help in deciding the final question whether miners and ex-miners would have had greater ventilatory capacities if they had never been coalminers. This is by far the most important question. It could be answered clearly by a long-term follow-up study of a male cohort which was randomly allocated, on leaving school, into coalmining and another occupation involving the same amount of hard work as coalmining for the same financial rewards. Both groups would stay in the same area in the same occupation throughout their working lives. Neither group would ever smoke. Clearly such a survey will never even be contemplated. The nearest to this that is practically possible and ethically desirable is a straightforward follow-up of school-leavers in mining areas, such as that started by Higgins and his colleagues (1956), but it will be many years before the results will be available. In the meantime, we must make the best possible use of cross-sectional studies as summarized in Table I, and the question resolves itself into deciding which of the three areas is least misleading.

Most people would agree that the Rhondda Fach, with its unique history of dusty mines and population loss, is likely to be unreliable. Similarly, one could argue that Staveley, with its odd history of immigration (Table XII), might give an over-optimistic picture. Three points can, however, be legitimately made against the latter view:

(1) The final figure for Staveley in 1951 is closer to the national average than Leigh.

(2) If it is argued that these Staveley miners would have had a higher average I.M.B.C. if they had not been exposed to coal dust, then we should find more evidence of the cause of the reduction in the form of respiratory symptoms. Higgins and others (1959), however, show that at Staveley the prevalence of respiratory symptoms amongst miners is little higher than amongst non-miners.

(3) If it is argued that the average I.M.B.C. of miners at Staveley is too high because of the influx of vigorous migrants, one can easily test the hypothesis by excluding the migrants. This actually causes the average I.M.B.C. to fall fractionally from 87·0 to 86·8.

(*b*) Progressive Massive Fibrosis

Owing to the general assumption that P.M.F. is a serious disease, there has understandably been more effort put into studying the disability of simple pneumoconiosis than that of P.M.F. No study of an entirely unselected sample has yet been published. The nearest approach was that of Gilson and Hugh-Jones (1955), who showed that as far as ventilatory capacity was concerned the early stage of P.M.F. was little different from that of simple pneumoconiosis. Other studies of P.M.F. as it occurred amongst working miners or amongst hospital patients are clearly unrepresentative.

We ourselves have only studied a few cases of P.M.F. where they occurred in random samples of

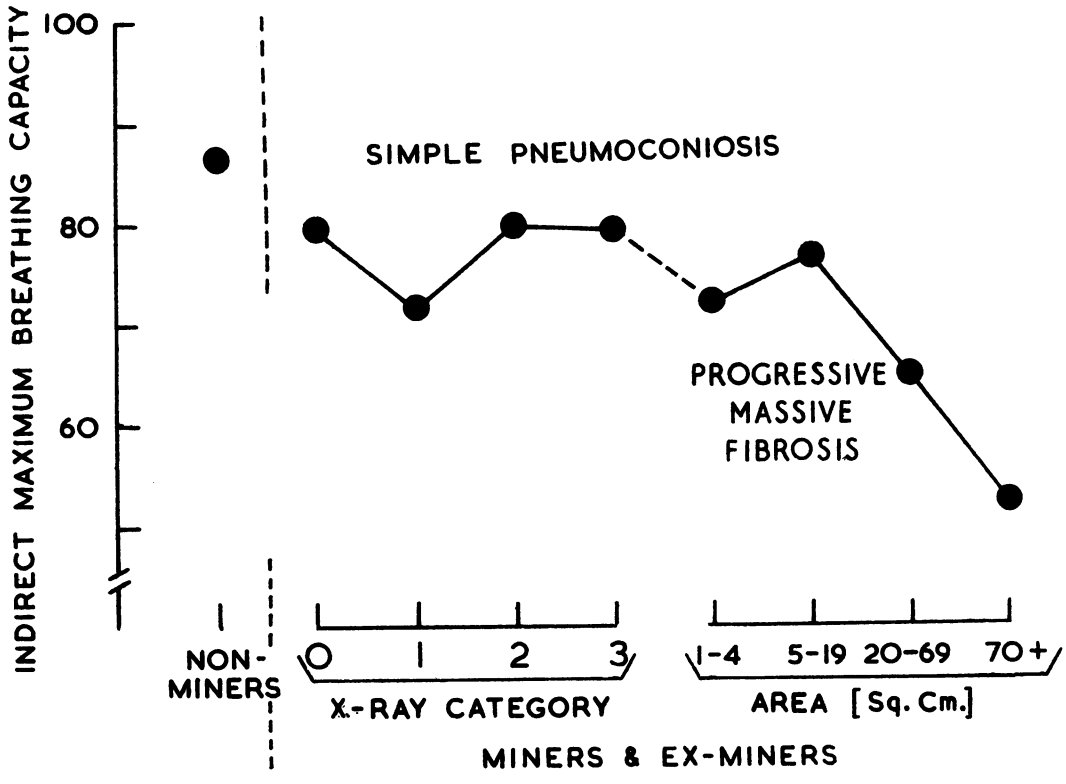

FIG. 3.—The relationship between the average indirect maximum breathing capacity and the *x*-ray category of pneumoconiosis in males aged 55–64 in the Rhondda Fach (random samples in 1958).

miners and ex-miners in the Rhondda Fach surveys of 1954 and 1958. The results are shown in Table XIII, and they are also shown diagrammatically in Fig. 3, together with the results of the 1958 survey for simple pneumoconiosis. The cases of P.M.F. have been classified according to the latest International Classification (International Labour Office, 1959), and also according to the area of the shadow.

TABLE XIII

AVERAGE VENTILATORY CAPACITIES OF MINERS AND EX-MINERS AGED 55–64 IN THE RHONDDA FACH WITH PROGRESSIVE MASSIVE FIBROSIS

Classification X-Ray Category	No. of Miners	Average Maximum Breathing Capacities	Classification Area (sq. cm.) of Shadow	No. of Miners	Average Maximum Breathing Capacities
A	20	74·0	1–4	4	72·3
B	10	66·8	5–19	19	76·7
C	10	61·3	20–69	10	64·8
Total	40	69·4	70+	7	52·4
			Total	40	69·4

The latter has been shown to be more sensitive as far as mortality is concerned than the former (Cochrane, Thomas, and Moore, 1961). The results show that the early stages of P.M.F. cause very little disability. Fig. 3 also shows what difficulties any selection hypothesis would have to face if one attempted to argue that the reduction in ventilatory capacity caused by pneumoconiosis was exactly balanced by the originally fitter men being self-selected to stay longer at the coal face, thus increasing their risk of developing pneumoconiosis.

CONCLUSIONS

Finally, the attempt must be made to answer the questions posed at the beginning.

(1) There appears to be no sound evidence at present to suggest an association of decreasing ventilatory function with increasing category of simple pneumoconiosis. It is still possible that some effect is concealed by selection, but it is unlikely.

The disabling effect of P.M.F. appears to be less than was previously thought. The disability does not seem to be appreciable until the area of the shadow on the radiograph exceeds 20 sq. cm.

(2) There appears to be less evidence than was previously thought for believing that those without pneumoconiosis are more disabled from the point of view of ventilatory function than those with simple pneumoconiosis.

(3) The existence of regional differences in the ventilatory function of miners and ex-miners seems to be established. There are probably several causes, among which the phenomena described by Kadlec and Vyskocil, bronchitis, and differential migration are probably important.

(4) There seems to be evidence for some decrease in ventilatory function in elderly miners, according to the length of time spent at the coal face. This effect appears to be unrelated to dust retention as seen in the radiograph, or to respiratory symptoms.

(5) The balance of the evidence is slightly in favour of elderly miners being slightly more disabled from the point of view of ventilatory function than they would have been if they had never become miners.

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APPENDIX

COMPARISON OF OLD AND NEW READINGS

		Old Reading					Total
		0	1	2	3	PMF	
New Reading	0	405	38	3	—	1	447
	1	43	45	19	—	2	109
	2	1	21	44	21	6	93
	3	—	—	9	100	10	119
	PMF	1	1	1	6	61	70
Total		450	105	76	127	80	838