Ventilatory Function in Relation to Mining Experience and Smoking in a Random Sample of Miners and Non-miners in a Witwatersrand Town¹

G. K. SLUIS-CREMER, L. G. WALTERS, and H. S. SICHEL

*From the Miners' Medical Bureau, the Pneumoconiosis Research Unit
and the Operational Research Bureau, Johannesburg*

The ventilatory capacity of a random sample of men over the age of 35 years in the town of Carletonville was estimated by the forced expiratory volume and the peak expiratory flow rate.

Five hundred and sixty-two persons were working or had worked in gold-mines and 265 had never worked in gold-mines.

No difference in ventilatory function was found between the miners and non-miners other than that due to the excess of chronic bronchitis in miners.

A description of the survey conducted in the town of Carletonville is given in the previous communication (Sluis-Cremer, Walters, and Sichel, 1967). The object was to determine whether chronic bronchitis occurred more frequently among a dust-exposed group of miners and ex-miners than in a non-mining group, both living in the same town where atmospheric pollution is virtually absent.

Both groups consisted of men over the age of 35 years. The sample was drawn from a population who are socio-economically homogeneous.

There were 562 persons in the dust-exposed group and 265 without dust exposure. Full details of the age, height, weight, smoking habit, and other characteristics of the two groups are described in detail in the previous paper. Suffice it to say that the dust-exposed group was slightly younger (average age 44.9 years compared to 46.5 years), slightly shorter (69.1 in., 175 cm.; and 69.5 in., 176 cm.), and slightly heavier (177.4 lb., 80 kg.; and 172.8 lb., 78 kg.). In addition, the dust-exposed group contained more smokers and fewer persons who had never smoked than the group without exposure to dust. The average amount smoked by present smokers in the two groups was, however, virtually identical.

The ventilatory function in the two groups was

estimated by the one-second forced expiratory volume (F.E.V._{1.0}) and the peak expiratory flow rate (P.E.F.R.). The purpose was to determine whether any differences existed between the dust-exposed and non-dust-exposed groups and, if such differences did exist, whether they could be ascribed to the increased prevalence of chronic bronchitis which has been shown in the dust-exposed group or whether there was a loss of ventilatory function not ascribable to chronic bronchitis.

Throughout this paper the term 'chronic bronchitis' is used in the sense of definition I, as given in the previous paper.

Methods

All the observations and measurements were made by the same field officer (a senior mine hygiene officer) who had been thoroughly trained in the use, care, and calibration of his instruments.

The instruments were housed in a Volkswagen Kombe converted into a mobile laboratory unit. Measurements were made with the subjects in the sitting position.

Forced Expiratory Volume The Poulton spirometer was used to measure the F.E.V._{1.0}. The instrument had been checked and calibrated in the laboratories of the Medical Research Council Pneumoconiosis Research Unit at Cardiff, South Wales. Mrs. McDermott of that Unit also provided two transistorized battery-operated timers which

¹This study was carried out under the auspices of the Pneumoconiosis Research Unit of the South African Council for Scientific and Industrial Research.

Received for publication April 29, 1966.

proved highly successful. All measurements could therefore be performed in the mobile unit.

Five measurements were made on each subject and the results are presented separately as the maximum value and as the mean of the last three readings.

The temperature of the water in the spirometer was recorded for every new subject, and appropriate corrections were made from a table prepared for the particular instrument. Figures were corrected to 37°C. saturated with water vapour (B.T.P.S.). The instrument was calibrated daily with the simple calibrating device described by McKerrrow, McDermott, and Gilson (1960).

Peak Expiratory Flow Rate The P.E.F.R. was measured by the Wright peak flowmeter. Two instruments were used which were calibrated against each other frequently. Five measurements were made on each subject and the results are expressed as the maximum reading and as the mean of readings 3, 4, and 5.

Results

Forced Expiratory Volume Table I shows the frequency distribution of the mean F.E.V._{1.0} for the four groups, dust-exposed with and without

chronic bronchitis and non-dust-exposed with and without chronic bronchitis.

The differences between the averages of the mean F.E.V._{1.0} readings for the dust-exposed and non-dust-exposed groups both with and without chronic bronchitis are not significant at the 5% level of probability.

On the other hand, when those persons with chronic bronchitis and those without are pooled in two groups, as in Table II, the average F.E.V._{1.0} of subjects with chronic bronchitis is 0.5 l. lower than that of the non-bronchitis group. This difference is highly significant ($P < 0.001$).

The same conclusion is reached if the observations are presented in terms of the maximal (of the last three readings) recorded for the F.E.V._{1.0} as shown in Table III.

Neither in the chronic bronchitis group nor in the group without bronchitis is there a difference significant at the 5% level of probability between the dust-exposed and non-dust-exposed groups.

Pooling the groups of persons with chronic bronchitis and persons free of bronchitis gives the results shown in Table IV.

Once again the average of the maximum F.E.V._{1.0} for the chronic bronchitis group is 0.5 l. lower and the difference is highly significant ($P < 0.001$).

TABLE I

MEAN F.E.V._{1.0} IN DUST-EXPOSED AND NON-DUST-EXPOSED GROUPS WITH AND WITHOUT CHRONIC BRONCHITIS (DEFINITION I)

Mean F.E.V. _{1.0} (l.)	Chronic Bronchitis		No Bronchitis	
	Dust-exposed	No Exposure	Dust-exposed	No Exposure
0 -0.49	1 (0.5%)	—	—	—
0.50-0.99	3 (1.4%)	1 (1.9%)	3 (0.9%)	1 (0.5%)
1.00-1.49	9 (4.1%)	4 (7.7%)	3 (0.9%)	4 (1.9%)
1.50-1.99	22 (10.1%)	6 (11.5%)	11 (3.4%)	5 (2.4%)
2.00-2.49	32 (14.7%)	7 (13.5%)	17 (5.2%)	18 (8.5%)
2.50-2.99	54 (24.9%)	8 (15.4%)	65 (19.8%)	39 (18.5%)
3.00-3.49	54 (24.9%)	17 (32.7%)	87 (26.4%)	56 (26.5%)
3.50-3.99	27 (12.5%)	7 (13.5%)	86 (26.1%)	48 (22.7%)
4.00-4.49	9 (4.1%)	1 (1.9%)	35 (10.6%)	27 (12.8%)
4.50-4.99	3 (1.4%)	1 (1.9%)	17 (5.2%)	9 (4.3%)
5.00-5.49	3 (1.4%)	—	4 (1.2%)	4 (1.9%)
5.50-5.99	—	—	1 (0.3%)	—
Total	217 (100%)	52 (100%)	329 (100%)	211 (100%)
Refusals	4 —	—	12 —	2 —
Grand Total	221	52	341	213
Average (l.)	2.84	2.77	3.35	3.33
S.D. (l.)	0.84	0.85	0.77	0.79

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TABLE II

MEAN F.E.V._{1.0} IN THOSE WITH AND WITHOUT CHRONIC BRONCHITIS (DEFINITION I), DUST-EXPOSED AND NON-DUST-EXPOSED GROUPS COMBINED

Mean F.E.V. _{1.0} (l.)	Chronic Bronchitis	No Bronchitis
0 -0.49	1 (0.4%)	— —
0.50-0.99	4 (1.5%)	4 (0.7%)
1.00-1.49	13 (4.8%)	7 (1.3%)
1.50-1.99	28 (10.4%)	16 (3.0%)
2.00-2.49	39 (14.5%)	35 (6.5%)
2.50-2.99	62 (23.1%)	104 (19.2%)
3.00-3.49	71 (26.4%)	143 (26.5%)
3.50-3.99	34 (12.6%)	134 (24.8%)
4.00-4.49	10 (3.7%)	62 (11.5%)
4.50-4.99	4 (1.5%)	26 (4.8%)
5.00-5.49	3 (1.1%)	8 (1.5%)
5.50-5.99	— —	1 (0.2%)
Total	269 (100%)	540 (100%)
Refusals	4	14
Grand Total	273	554
Average (l.)	2.83	3.34
S.D. (l.)	0.84	0.78

TABLE IV

MAXIMUM F.E.V._{1.0} IN THOSE WITH AND WITHOUT CHRONIC BRONCHITIS (DEFINITION I), DUST-EXPOSED AND NON-DUST-EXPOSED GROUPS COMBINED

Max F.E.V. _{1.0} (l.)	Chronic Bronchitis	No Bronchitis
0 -0.49	1 (0.4%)	— —
0.50-0.99	4 (1.5%)	3 (0.5%)
1.00-1.49	10 (3.7%)	7 (1.3%)
1.50-1.99	22 (8.2%)	16 (3.0%)
2.00-2.49	40 (14.9%)	28 (5.2%)
2.50-2.99	60 (22.3%)	93 (17.2%)
3.00-3.49	70 (26.0%)	141 (26.1%)
3.50-3.99	41 (15.2%)	138 (25.5%)
4.00-4.49	13 (4.8%)	69 (12.8%)
4.50-4.99	5 (1.9%)	36 (6.7%)
5.00-5.49	3 (1.1%)	8 (1.5%)
5.50-5.99	— —	1 (0.2%)
Total	269 (100%)	540 (100%)
Refusals	4	14
Grand Total	273	554
Average (l.)	2.91	3.41
S.D. (l.)	0.84	0.78

TABLE III

MAXIMUM F.E.V._{1.0} IN DUST-EXPOSED AND NON-DUST-EXPOSED GROUPS WITH AND WITHOUT CHRONIC BRONCHITIS (DEFINITION I)

Maximum F.E.V. _{1.0} (l.)	Chronic Bronchitis		No Bronchitis	
	Dust-exposed	No Exposure	Dust-exposed	No Exposure
0 -0.49	1 (0.5%)	— —	— —	— —
0.50-0.99	3 (1.4%)	1 (1.9%)	2 (0.6%)	1 (0.5%)
1.00-1.49	6 (2.7%)	4 (7.7%)	3 (0.9%)	4 (1.9%)
1.50-1.99	18 (8.3%)	4 (7.7%)	11 (3.3%)	5 (2.3%)
2.00-2.49	31 (14.3%)	9 (17.3%)	12 (3.6%)	16 (7.6%)
2.50-2.99	54 (24.9%)	6 (11.6%)	57 (17.3%)	36 (17.1%)
3.00-3.49	51 (23.5%)	19 (36.5%)	87 (26.5%)	54 (25.6%)
3.50-3.99	35 (16.1%)	6 (11.6%)	88 (26.8%)	50 (23.7%)
4.00-4.49	11 (5.1%)	2 (3.8%)	43 (13.1%)	26 (12.3%)
4.50-4.99	4 (1.8%)	1 (1.9%)	21 (6.4%)	15 (7.1%)
5.00-5.49	3 (1.4%)	— —	4 (1.2%)	4 (1.9%)
5.50-5.99	— —	— —	1 (0.3%)	— —
Total	217 (100%)	52 (100%)	329 (100%)	211 (100%)
Refusals	4	—	12	2
Grand Total	221	52	341	213
Average (l.)	2.94	2.82	3.43	3.38
S.D. (l.)	0.84	0.85	0.76	0.81

TABLE V
MEAN P.E.F.R. IN DUST-EXPOSED AND NON-DUST-EXPOSED GROUPS WITH AND WITHOUT CHRONIC BRONCHITIS
(DEFINITION I)

Mean P.E.F.R. (l./min.)	Chronic Bronchitis		No Bronchitis	
	Dust-exposed	No Exposure	Dust-exposed	No Exposure
50- 99	1 (0.5%)	—	—	1 (0.5%)
100-194	1 (0.5%)	1 (1.9%)	4 (1.2%)	1 (0.5%)
150-199	3 (1.4%)	4 (7.7%)	2 (0.6%)	—
200-249	9 (4.1%)	2 (3.8%)	1 (0.3%)	2 (0.9%)
250-299	8 (3.7%)	3 (5.8%)	3 (0.9%)	3 (1.4%)
300-349	17 (7.8%)	3 (5.8%)	7 (2.1%)	5 (2.4%)
350-399	25 (11.4%)	4 (7.7%)	15 (4.4%)	7 (3.3%)
400-449	41 (18.8%)	11 (21.1%)	28 (8.2%)	12 (5.7%)
450-499	40 (18.3%)	3 (5.8%)	76 (22.4%)	47 (22.2%)
500-549	45 (20.6%)	11 (21.1%)	81 (23.9%)	53 (25.0%)
550-599	18 (8.2%)	7 (13.5%)	68 (20.1%)	41 (19.3%)
600-649	8 (3.7%)	3 (5.8%)	35 (10.3%)	27 (12.7%)
650-699	1 (0.5%)	—	14 (4.1%)	9 (4.2%)
700-749	—	—	5 (1.5%)	3 (1.4%)
750-799	1 (0.5%)	—	—	1 (0.5%)
Total	218 (100%)	52 (100%)	339 (100%)	212 (100%)
Refusals	3	—	2	1
Grand Total	221	52	341	213
Average (l./min.)	443.1	429.3	513.9	520.5
S.D. (l./min.)	107.6	133.6	96.9	98.2

Peak Expiratory Flow Rate Table V shows the mean P.E.F.R. for the four groups of persons with and without chronic bronchitis in the dust-exposed and non-dust-exposed groups.

The averages of the mean P.E.F.R.s for the dust-exposed and non-dust-exposed groups are not significantly different from each other at the 5% level of probability.

The combination of those with chronic bronchitis and those without is shown in Table VI.

The chronic bronchitis group has an average mean P.E.F.R. 76 l./min. lower than that of the group free of bronchitis. This difference is highly significant ($P < 0.001$).

Similarly, the maximum values for the P.E.F.R. showed no significant differences at the 5% level between dust-exposed and non-dust-exposed persons among those with or without bronchitis.

The averages and standard deviations are shown in Table VII.

Similarly, when the values for the dust-exposed and non-dust-exposed groups are pooled for the chronic bronchitis and non-bronchitis groups, the chronic bronchitis group shows an average P.E.F.R.

74 l./min. lower than that of the non-bronchitis group (Table VIII). This difference is highly significant ($P < 0.001$).

The mean F.E.V._{1.0} was correlated with the phlegm grade for the dust-exposed and non-dust-exposed persons in both the chronic bronchitis and non-bronchitis groups. This is shown in Table IX.

This should provide an indication of any differences in the degree of severity of ventilatory impairment between chronic bronchitic miners and non-miners.

The phlegm grades were derived from the questionnaire (see this journal, p. 5) in the following manner. Only subjects who admitted to bringing up phlegm on most days for as much as three months each year (question 10) were included in grades I or II. For grade I, either question 6 or 8 was answered in the affirmative in addition to question 10.

Question 6 reads 'Do you usually bring up any phlegm from your chest first thing in the morning in the winter (on getting up)?'

Question 8 reads 'Do you bring up any phlegm from your chest during the day or at night in the winter?'

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TABLE VI

MEAN P.E.F.R. IN THOSE WITH AND WITHOUT CHRONIC BRONCHITIS (DEFINITION I), DUST-EXPOSED AND NON-DUST-EXPOSED GROUPS COMBINED

Mean P.E.F.R. (l./min.)	Chronic Bronchitis	No Bronchitis
50-99	I (0.4%)	I (0.2%)
100-149	2 (0.7%)	5 (0.9%)
150-199	7 (2.6%)	2 (0.4%)
200-249	II (4.1%)	3 (0.5%)
250-299	II (4.1%)	6 (1.1%)
300-349	20 (7.4%)	12 (2.2%)
350-399	29 (10.7%)	22 (4.0%)
400-449	52 (19.3%)	40 (7.3%)
450-499	43 (15.9%)	123 (22.3%)
500-549	56 (20.7%)	134 (24.3%)
550-599	25 (9.2%)	109 (19.8%)
600-649	II (4.1%)	62 (11.2%)
650-699	I (0.4%)	23 (4.2%)
700-749	—	8 (1.4%)
750-799	I (0.4%)	I (0.2%)
Total	270 (100%)	551 (100%)
Refusals	3	3
Grand Total ..	273	554
Average (l./min.) ..	440.4	516.4
S.D. (l./min.) ..	112.9	97.4

TABLE VII

AVERAGE MAXIMUM P.E.F.R. IN DUST-EXPOSED AND NON-DUST-EXPOSED GROUPS WITH AND WITHOUT CHRONIC BRONCHITIS (DEFINITION I)

	Average Max. P.E.F.R. (l./min.)	S.D.
Chronic bronchitis		
Dust-exposed	456.2	106.5
Non-dust-exposed ..	438.9	131.1
No bronchitis		
Dust-exposed	524.4	97.3
Non-dust-exposed ..	531.4	100.6

TABLE VIII

AVERAGE MAXIMUM P.E.F.R. IN THOSE WITH AND WITHOUT CHRONIC BRONCHITIS (DEFINITION I), DUST-EXPOSED AND NON-DUST-EXPOSED GROUPS COMBINED

	Average Max. P.E.F.R. (l./min.)	S.D.
Chronic bronchitis ..	452.8	111.6
No bronchitis	527.0	98.6

For grade II, both questions 6 and 8 were answered in the affirmative in addition to question 10.

Differences between the means of the F.E.V._{1.0}s for persons reporting phlegm grade II in the dust-exposed and non-dust-exposed groups exist for both bronchitics and non-bronchitics. Among the former the F.E.V._{1.0} was 0.35 l. higher in the dust-exposed group, and among non-bronchitics it was 0.76 l. lower in the dust-exposed group. These differences are, however, not significant at the 5% level of probability.

There is no significant difference between the means of the F.E.V._{1.0}s for the dust-exposed and non-dust-exposed groups without bronchitis and without complaint of phlegm (grade 0 phlegm).

The presence of 10 persons claiming grade I phlegm and four with grade II phlegm among the group free of bronchitis may be considered as something of an anomaly. These are persons who claim to produce phlegm on most days for as much as three months each year but deny they cough to that degree; they are, therefore, according to definition treated as non-bronchitics. Their average F.E.V._{1.0}s are not important because of the few persons involved.

Similar results are shown in Table X which were obtained by correlating the P.E.F.R. with the phlegm grade in the same way.

Among the dust-exposed with phlegm grade II the mean P.E.F.R. is 56.1 l./min. higher for the bronchitics and 100 l./min. lower for the non-bronchitics than in the corresponding non-dusty groups. Neither these differences nor the smaller differences for phlegm grade I are statistically significant.

No significant difference exists between the dust-exposed and non-dust-exposed persons who deny any phlegm (515.1 l./min. and 521.2 l./min. respectively).

Tables IX and X show important differences in both F.E.V._{1.0} and P.E.F.R., between grade 0, grade I, and grade II phlegm classes for both the dust-exposed and non-dust-exposed groups.

In the dust-exposed group, the F.E.V._{1.0} for grade 0 phlegm is 3.35 l., for grade I 3.08 l., and for grade II 2.59 litres. The difference between the F.E.V._{1.0} for grade 0 and grade I phlegm is significant at the 1% and that between grade I and grade II at 0.001% levels of significance. In the non-dust-exposed group the figures are 3.33 l., 2.99 l., and 2.24 l. respectively. In this case the difference between grade 0 and grade I phlegm is significant at the 1% level and that between grade I phlegm and grade II phlegm at the 5% level of significance.

Similar results are shown in Table X giving the

TABLE IX
MEAN F.E.V._{1.0} CORRELATED WITH PHLEGM GRADE IN THOSE WITH AND WITHOUT CHRONIC BRONCHITIS
(DEFINITION I)

Mean F.E.V. _{1.0} (l.)	Chronic Bronchitis						No Bronchitis					
	Dust-exposed			No Exposure			Dust-exposed			No Exposure		
Phlegm grade ..	0	1	2	0	1	2	0	1	2	0	1	2
0 -0.49	—	—	1	—	—	—	—	—	—	—	—	—
0.50-0.99	—	1	2	—	—	1	2	1	—	1	—	—
1.00-1.49	—	1	8	—	—	4	3	—	—	4	—	—
1.50-1.99	—	6	16	—	3	3	10	—	1	5	—	—
2.00-2.49	—	13	19	—	6	1	17	—	—	18	—	—
2.50-2.99	—	29	25	—	7	1	63	1	1	38	1	1
3.00-3.49	—	33	21	—	15	2	86	1	—	54	1	1
3.50-3.99	—	18	9	—	4	3	83	3	—	48	—	—
4.00-4.49	—	5	4	—	1	—	33	2	—	27	—	—
4.50-4.99	—	2	1	—	1	—	16	1	—	9	—	—
5.00-5.49	—	3	—	—	—	—	4	—	—	4	—	—
5.50-5.99	—	—	—	—	—	—	1	—	—	—	—	—
Total	—	111	106	—	37	15	318	9	2	208	1	2
Refusals	—	1	3	—	—	—	12	—	—	2	—	—
Grand Total ..	—	112	109	—	37	15	330	9	2	210	1	2
Average (l.) ..	—	3.08	2.59	—	2.99	2.24	3.35	3.47	2.24	3.33	3.24	3.00
S.D. (l.)	—	0.77	0.81	—	0.66	1.06	0.76	1.16	0.21	0.79	—	0.35

relation between P.E.F.R. and phlegm grade for the four groups.

The P.E.F.R. in the dust-exposed group is 515.1 l./min. in the grade 0, 476.3 l./min. in the grade I, and 408.6 l./min. in the grade II phlegm classes. The difference in P.E.F.R. between the grade 0 and grade I phlegm groups is significant at the 1% level and that between grade I and grade II at the 0.001% level. Similarly, in the non-dust-exposed group the figures are 521.2 l./min., 455.6 l./min., and 364.5 l./min. respectively. The difference between the grade 0 and grade I groups is significant at the 0.01% level whereas that between the grade I and grade II groups is almost significant at the 5% level.

F.E.V._{1.0}, Age, and Dyspnoea Grade In the following tables breathlessness is presented in five grades according to the answers to the following questions in the questionnaire:

Are you ever troubled by shortness of breath when hurrying on the level or walking up a slight hill? (I4a)

Do you get short of breath walking with other

people at an ordinary pace on the level? (I4b)

Do you stop for breath when walking at your own pace on the level? (I4c)

Are you short of breath on washing or dressing? (I4d)

Grade 1 = No to I4a to d

Grade 2 = Yes to I4a; no to b to d

Grade 3 = Yes to I4a and b; no to c and d

Grade 4 = Yes to I4a to c; no to d

Grade 5 = Yes to I4a to d.

Tables XI, XII, and XIII show this relationship for the three age groups, 35-44, 45-54, and 55 and over.

In general there is a negative association between the F.E.V._{1.0} and grade of dyspnoea.

It will be noted, however, that the dust-exposed group, particularly the chronic bronchitics, show a higher proportion of grades 4 and 5 dyspnoea than do the non-dust-exposed group, and that grades 4 and 5 dyspnoea occur more frequently with higher F.E.V._{1.0}s in the dust-exposed group.

P.E.F.R., Age, and Dyspnoea Grade A similar situation was found when the P.E.F.R. was

TABLE X

MEAN P.E.F.R. CORRELATED WITH PHLEGM GRADE IN THOSE WITH AND WITHOUT CHRONIC BRONCHITIS

Mean P.E.F.R. (l./min.)	Chronic Bronchitis						No Bronchitis					
	Dust-exposed			No Exposure			Dust-exposed			No Exposure		
Phlegm Grade ..	0	1	2	0	1	2	0	1	2	0	1	2
50-99	—	—	1	—	—	—	—	—	—	1	—	—
100-149	—	—	1	—	—	1	4	—	—	1	—	—
150-199	—	—	3	—	—	4	2	—	—	—	—	—
200-249	—	3	6	—	1	1	1	—	—	2	—	—
250-299	—	2	6	—	1	2	3	—	—	3	—	—
300-349	—	5	12	—	3	—	7	—	—	5	—	—
350-399	—	9	16	—	4	—	13	—	2	7	—	—
400-449	—	22	19	—	10	1	27	1	—	11	—	1
450-499	—	18	22	—	3	—	71	5	—	46	1	—
500-549	—	33	12	—	9	2	80	1	—	52	—	1
550-599	—	12	6	—	5	2	67	1	—	41	—	—
600-649	—	5	3	—	1	2	34	1	—	27	—	—
650-699	—	1	—	—	—	—	14	—	—	9	—	—
700-749	—	—	—	—	—	—	5	—	—	3	—	—
750-799	—	1	—	—	—	—	—	—	—	1	—	—
Total	—	111	107	—	37	15	328	9	2	209	1	2
Refusals	—	1	2	—	—	—	2	—	—	1	—	—
Grand Total ..	—	112	109	—	37	15	330	9	2	210	1	2
Average (l./min.) ..	—	476.3	408.6	—	455.6	364.5	515.1	502.3	374.5	521.2	474.5	474.5
S.D. (l./min.) ..	—	92.8	111.4	—	92.7	191.4	97.5	59.9	—	98.7	—	70.7

correlated with the dyspnoea grade for the several age groups (Table XIV).

In general there is a negative correlation between P.E.F.R. and dyspnoea grade.

Discussion

Ventilatory Function in Relation to Dust Exposure The results for the mean F.E.V._{1.0}, maximum F.E.V._{1.0}, mean P.E.F.R., and maximum P.E.F.R. (Tables I, III, V, and VII) show quite clearly that there is no significant difference in ventilatory capacity between miners and ex-miners on the one hand and non-miners on the other.

The differences between the dust-exposed and non-dust-exposed groups are very small: F.E.V._{1.0} in chronic bronchitics 2.84 l. for the dust-exposed and 2.77 l. for the non-dust-exposed, and in the non-bronchitics 3.35 l. and 3.33 l. respectively. The differences are of a similar order for the other tests.

On the other hand, with all four tests important differences in ventilatory function are demonstrated between chronic bronchitics and non-bronchitics as

pooled groups (Tables II, IV, VI, and VIII).

This is also true for both dust-exposed and non-dust-exposed groups considered separately. Table I shows that dust-exposed non-bronchitics have a mean F.E.V._{1.0} of 3.35 l. as against 2.84 l. for dust-exposed chronic bronchitics, while for the non-dust-exposed group the figures are 3.33 l. and 2.77 l. respectively.

The same trends are found in the figures for the maximum F.E.V._{1.0}. In the dust-exposed groups the maximum F.E.V._{1.0} is 3.43 l. in the non-bronchitics compared with 2.94 l. in the bronchitics, and in those without dust exposure 3.38 l. compared with 2.82 l. respectively (Table III).

The same differences are found in the mean P.E.F.R. (Table V), the dust-exposed group without bronchitis exceeding those with bronchitis (513.9 l./min. compared with 443.1 l./min.). In the non-dust-exposed group the corresponding figures are 520.5 l./min. and 429.3 l./min. The figures for maximum P.E.F.R. give a virtually identical picture.

Dust exposure appears to have no effect on ventilatory function over and above the role it may

TABLE XI
MEAN F.E.V._{1.0} CORRELATED WITH DYSPNOEA GRADE, AGE 35-44 YEARS

Mean F.E.V. _{1.0} (l.)	Chronic Bronchitis												
	Dust-exposed						No Exposure						
	Dyspnoea Grade	1	2	3	4	5	Total	1	2	3	4	5	Total
0 -0.49	—	—	—	—	—	—	—	—	—	—	—	—	—
0.50-0.99	—	—	—	—	—	1	1	—	—	—	—	—	—
1.00-1.49	—	1	—	—	—	—	1	—	—	—	—	—	—
1.50-1.99	—	3	5	—	—	1	9	—	—	—	—	—	—
2.00-2.49	2	4	5	1	—	—	12	—	1	—	—	—	1
2.50-2.99	3	11	13	3	2	—	32	—	1	1	—	—	2
3.00-3.49	3	16	9	3	3	—	34	5	2	—	—	—	7
3.50-3.99	7	13	—	—	—	—	20	2	3	1	—	1	7
4.00-4.49	4	2	—	1	—	—	7	1	—	—	—	—	1
4.50-4.99	1	2	—	—	—	—	3	1	—	—	—	—	1
5.00-5.49	1	1	—	—	—	—	2	—	—	—	—	—	—
5.50-5.99	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	21	53	32	8	7	—	121	9	7	2	—	1	19
Refusals	—	1	—	—	—	—	1	—	—	—	—	—	—
Grand Total ..	21	54	32	8	7	—	122	9	7	2	—	1	19
Average (l.)	3.60	3.20	2.65	3.06	2.53	—	3.08	3.63	3.24	3.24	—	3.74	3.46

TABLE XII
MEAN F.E.V._{1.0} CORRELATED WITH DYSPNOEA GRADE, AGE 45-54 YEARS

Mean F.E.V. _{1.0} (l.)	Chronic Bronchitis												
	Dust-exposed						No Exposure						
	Dyspnoea Grade	1	2	3	4	5	Total	1	2	3	4	5	Total
0 -0.49	—	—	—	—	—	—	—	—	—	—	—	—	—
0.50-0.99	—	—	1	—	—	1	—	—	—	—	—	—	—
1.00-1.49	—	—	1	—	3	4	—	—	1	—	1	2	—
1.50-1.99	1	2	4	—	3	10	1	1	1	—	1	4	—
2.00-2.49	1	2	4	1	4	12	2	3	—	—	—	5	—
2.50-2.99	3	4	6	3	3	19	3	—	—	1	—	4	—
3.00-3.49	6	4	5	2	1	18	2	5	—	—	—	7	—
3.50-3.99	1	2	3	—	1	7	—	—	—	—	—	—	—
4.00-4.49	1	—	—	—	—	1	—	—	—	—	—	—	—
4.50-4.99	—	—	—	—	—	—	—	—	—	—	—	—	—
5.00-5.49	—	1	—	—	—	1	—	—	—	—	—	—	—
5.50-5.99	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	13	15	24	6	15	73	8	9	2	1	2	22	—
Refusals	—	—	1	—	1	2	—	—	—	—	—	—	—
Grand Total ..	13	15	25	6	16	75	8	9	2	1	2	22	—
Average (l.)	3.05	2.98	2.58	2.83	2.21	2.69	2.64	2.74	1.5	2.74	1.5	2.47	—

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TABLE XI *continued*

Mean F.E.V. _{1.0} (l.)	No Bronchitis											
	Dust-exposed						No Exposure					
Dyspnoea Grade	1	2	3	4	5	Total	1	2	3	4	5	Total
0 -0.49	—	—	—	—	—	—	—	—	—	—	—	—
0.50-0.99	—	—	—	—	1	1	—	—	—	—	—	—
1.00-1.49	—	—	—	—	—	—	—	—	—	—	—	—
1.50-1.99	1	—	—	—	—	1	—	—	1	—	—	1
2.00-2.49	2	1	—	—	—	3	1	1	1	—	—	3
2.50-2.99	12	8	2	1	—	23	6	3	1	—	—	10
3.00-3.49	26	18	5	2	1	52	21	7	—	—	—	28
3.50-3.99	33	22	4	—	1	60	26	7	1	—	—	34
4.00-4.49	19	8	1	—	1	29	20	4	—	—	—	24
4.50-4.99	10	2	1	—	—	13	5	2	—	—	—	7
5.00-5.49	2	1	—	—	—	3	3	—	—	—	—	3
5.50-5.99	1	—	—	—	—	1	—	—	—	—	—	—
Total	106	60	13	3	4	186	82	24	4	—	—	110
Refusals	—	1	1	2	—	4	—	—	—	—	—	—
Grand Total ..	106	61	14	5	4	190	82	24	4	—	—	110
Average (l.)	3.69	3.56	3.51	3.08	3.00	3.61	3.76	3.58	2.62	—	—	3.68

TABLE XII *continued*

Mean F.E.V. _{1.0} (l.)	No Bronchitis											
	Dust-exposed						No Exposure					
Dyspnoea Grade	1	2	3	4	5	Total	1	2	3	4	5	Total
0 -0.49	—	—	—	—	—	—	—	—	—	—	—	—
0.50-0.99	—	1	—	—	—	1	—	—	—	—	—	—
1.00-1.49	—	—	—	1	—	1	—	—	—	—	—	—
1.50-1.99	—	1	4	—	—	5	1	—	—	—	—	1
2.00-2.49	—	5	1	1	2	9	2	5	2	—	1	10
2.50-2.99	10	14	10	—	2	36	11	8	1	—	1	21
3.00-3.49	13	10	4	2	—	29	15	6	3	—	—	24
3.50-3.99	13	8	4	—	—	24	6	1	2	—	1	10
4.00-4.49	2	3	—	—	—	5	2	1	—	—	—	3
4.50-4.99	2	2	—	—	—	4	1	1	—	—	—	2
5.00-5.49	—	1	—	—	—	1	1	—	—	—	—	1
5.50-5.99	—	—	—	—	—	—	—	—	—	—	—	—
Total	39	45	23	4	4	115	39	22	8	—	3	72
Refusals	3	3	—	—	—	6	—	—	—	—	—	—
Grand Total ..	42	48	23	4	4	121	39	22	8	—	3	72
Average (l.)	3.40	3.16	2.81	2.50	2.50	3.12	3.23	2.97	3.06	—	2.91	3.12

TABLE XIII
MEAN F.E.V._{1.0} CORRELATED WITH DYSPNOEA GRADE, AGE 55 AND OVER

Mean F.E.V. _{1.0} (l.)	Chronic Bronchitis											
	Dust-exposed						No Exposure					
	I	2	3	4	5	Total	I	2	3	4	5	Total
Dyspnoea Grade												
0 -0.50	—	—	—	—	1	1	—	—	—	—	—	—
0.50-0.99	—	—	1	—	—	1	—	—	—	—	1	1
1.00-1.49	—	1	1	1	1	4	—	—	—	1	1	2
1.50-1.99	—	—	—	2	1	3	1	—	1	—	—	2
2.00-2.49	2	2	1	1	2	8	—	1	—	—	—	1
2.50-2.99	—	1	2	—	—	3	1	1	—	—	—	2
3.00-3.49	—	1	1	—	—	2	2	—	1	—	—	3
3.50-3.99	—	—	—	—	—	—	—	—	—	—	—	—
4.00-4.49	—	1	—	—	—	1	—	—	—	—	—	—
4.50-4.99	—	—	—	—	—	—	—	—	—	—	—	—
5.00-5.49	—	—	—	—	—	—	—	—	—	—	—	—
5.50-5.99	—	—	—	—	—	—	—	—	—	—	—	—
Total	2	6	6	4	5	23	4	2	2	1	2	11
Refusals	—	—	—	—	1	1	—	—	—	—	—	—
Grand Total ..	2	6	6	4	6	24	4	2	2	1	2	11
Average (l.) ..	2.24	2.66	2.16	1.74	1.50	2.08	2.74	2.5	2.5	1.24	1.00	2.20

TABLE XIV
MEAN P.E.F.R. CORRELATED WITH DYSPNOEA GRADE

Dyspnoea Grade	Chronic Bronchitis											
	Dust-exposed						No Exposure					
	I	2	3	4	5	Total	I	2	3	4	5	Total
Age Group 35-44												
Total	21	53	32	8	7	121	9	7	2	—	1	19
Refusals	—	1	—	—	—	1	—	—	—	—	—	—
Grand Total ..	21	54	32	8	7	122	9	7	2	—	1	19
Average P.E.F.R. (l./min.) ..	508	435	413	443	417	464	497	510	525	—	525	506
Age Group 45-54												
Total	13	15	25	6	15	74	8	9	2	1	2	22
Refusals	—	—	—	—	1	1	—	—	—	—	—	—
Grand Total ..	13	15	25	6	16	75	8	9	2	1	2	22
Average P.E.F.R. (l./min.) ..	482	455	410	415	358	426	481	430	200	425	200	406
Age Group 55 and Over												
Total	2	6	6	4	5	23	4	2	2	1	2	11
Refusals	—	—	—	—	1	1	—	—	—	—	—	—
Grand Total ..	2	6	6	4	6	24	4	2	2	1	2	11
Average P.E.F.R. (l./min.) ..	450	457	366	375	305	335	450	400	325	175	175	343

TABLE XIII continued

Mean F.E.V. _{1.0} (l.)	No Bronchitis											
	Dust-exposed						No Exposure					
Dyspnoea Grade	1	2	3	4	5	Total	1	2	3	4	5	Total
0 -0.50	—	—	—	—	—	—	—	—	—	—	—	—
0.50-0.99	—	—	1	—	—	1	—	1	—	—	—	1
1.00-1.49	1	—	1	—	—	2	—	2	1	—	1	4
1.50-1.99	1	2	1	—	1	5	2	1	—	—	—	3
2.00-2.49	—	1	3	—	1	5	—	3	2	—	—	5
2.50-2.99	1	2	—	1	2	6	8	—	—	—	—	8
3.00-3.49	3	1	2	—	—	6	2	2	—	—	—	4
3.50-3.99	1	—	1	—	—	2	2	1	1	—	—	4
4.00-4.49	1	—	—	—	—	1	—	—	—	—	—	—
4.50-4.99	—	—	—	—	—	—	—	—	—	—	—	—
5.00-5.49	—	—	—	—	—	—	—	—	—	—	—	—
5.50-5.99	—	—	—	—	—	—	—	—	—	—	—	—
Total	8	6	9	1	4	28	14	10	4	—	1	29
Refusals	1	—	—	—	1	2	1	1	—	—	—	2
Grand Total ..	9	6	9	1	5	30	15	11	4	—	1	31
Average (l.) ..	2.93	2.41	2.30	2.74	2.37	2.53	2.82	2.20	2.37	—	1.24	—

TABLE XIV continued

Dyspnoea Grade	No Bronchitis											
	Dust-exposed						No Exposure					
	1	2	3	4	5	Total	1	2	3	4	5	Total
Age Group 35-44												
Total	106	61	14	5	4	190	82	24	4	—	—	110
Refusals	—	—	—	—	—	—	—	—	—	—	—	—
Grand Total ..	106	61	14	5	4	190	82	24	4	—	—	110
Average P.E.F.R. (l./min.) ..	536	536	517	434	562	534	555	554	512	—	—	553
Age Group 45-54												
Total	41	48	23	4	4	120	39	22	8	—	3	72
Refusals	1	—	—	—	—	1	—	—	—	—	—	—
Grand Total ..	42	48	23	4	4	121	39	22	8	—	3	72
Average P.E.F.R. (l./min.) ..	537	516	459	362	420	505	516	504	500	—	475	475
Age Group 55 and Over												
Total	9	6	9	1	4	29	14	11	4	—	1	30
Refusals	—	—	—	—	1	1	1	—	—	—	—	1
Grand Total ..	9	6	9	1	5	30	15	11	4	—	1	31
Average P.E.F.R. (l./min.) ..	475	425	391	375	375	421	485	375	400	—	325	428

play in causing chronic bronchitis in miners (Sluis-Cremer *et al.*, 1967).

This conclusion is strongly supported by the findings when the mean F.E.V._{1.0} and P.E.F.R. are plotted against phlegm grade. No significant differences appear between the dust-exposed and non-dust-exposed groups for grade 0, grade I, or grade II phlegm.

On the other hand, increasing severity of chronic bronchitis as reflected in phlegm grade is associated with a fall in both mean F.E.V._{1.0} and mean P.E.F.R. (Tables IX and X).

Ventilatory Function in Relation to Dyspnoea Grade When F.E.V._{1.0} and P.E.F.R. are plotted against dyspnoea grade in the four groups (chronic bronchitis, dust-exposed and non-dust-exposed and non-bronchitic dust-exposed and non-dust-exposed) standardizing for age, there is a negative correlation with dyspnoea grade but an important anomaly appears (Tables XI, XII, XIII, and XIV).

In all age groups there appear to be more persons suffering from grades 4 and 5 dyspnoea among miners than non-miners irrespective of whether they have chronic bronchitis or not. For instance in the 35-44 year age group (Table XI) 15 out of 121 (12.4%) reported grade 4 or 5 dyspnoea among the dust-exposed bronchitics, and seven out of 186 (2.8%) among the dust-exposed non-bronchitics, whereas only one out of 19 (5.3%) non-dust-exposed chronic bronchitics and none out of 110 non-dust-exposed non-bronchitics reported these degrees of dyspnoea.

For the 45-54 year age group the figures are 21 out of 73 (28.8%) and three out of 22 (13.6%) for chronic bronchitics dust- and non-dust-exposed respectively, and eight out of 115 (7%) and three out of 72 (4.2%) for the non-bronchitic dust- and non-dust-exposed respectively.

For the group 55 and over, the figures are nine out of 23 (39.6%) and three out of 11 (27.2%) for the chronic bronchitics dust- and non-dust-exposed, and five out of 28 (17.9%) and one out of 29 (3.4%) for the non-bronchitic group.

These findings are at variance with the demonstration that there is no significant difference between the mean F.E.V._{1.0} and P.E.F.R. among chronic bronchitic dust-exposed and non-dust-exposed groups or among non-bronchitic dust-exposed and non-dust-exposed groups.

As the dyspnoea grade is a personal subjective assessment this unexpected finding could be due to bias among miners and ex-miners. Good reasons for such bias to render 'high' answers to questions on dyspnoea exist for miners. There is acute, even

excessive awareness among them as a community of the potentially harmful effects of breathing silica dust. This is partly induced at home (many of today's miners had a miner among their older relatives), partly by regular questioning on respiratory symptoms at the compulsory annual periodical examination, and partly by a desire for compensation.

That bias is in fact the reason for this anomaly is supported by a close study of Tables XI, XII, and XIII. It will be noted that the dust-exposed groups have high grades of dyspnoea relative to the ventilatory capacity. Thus in the age group 35-44, grades 4 or 5 dyspnoea are found associated with an F.E.V._{1.0} of 2.0 l. or over in 19 of 307 men in the dust-exposed group and only once in 129 men in the non-dust-exposed group.

Similarly, in the age group 45-54, grades 4 or 5 dyspnoea occur in the same F.E.V._{1.0} range 22 times in 188 miners but in only four of 94 non-miners. In the age group 55 years and over, the corresponding figures are seven of 51 miners and none of 40 non-miners. A similar picture is found in the relation of the P.E.F.R. to the dyspnoea grade.

The possibility that some parameter of lung function not measured by the F.E.V._{1.0} or P.E.F.R. is affected by dust exposure cannot be entirely ruled out but appears unlikely as the predominant clinical and physiological aberrations in silicotics are those of airway obstruction.

Relationship between the Tests Applied A striking similarity between the mean F.E.V._{1.0} and the maximum F.E.V._{1.0} becomes apparent on comparing Tables I and III and Tables II and IV. This also applies to the standard deviations and the percentage distributions of the volume categories.

The same close agreement in mean flow rate is noted for the mean and maximum P.E.F.R. when Tables V and VII and VI and VIII are compared.

It seems clear that in fact no advantage accrues by calculating both parameters in a study of this kind and that it matters little which is chosen.

The close agreement of these results probably also testifies to the consistency with which the field officer carried out these tests and to the degree of co-operation in performing them which was obtained from this population.

In this population the trend of the results in the different groups is identical for both the F.E.V._{1.0} and the P.E.F.R.

International Comparisons Table XV shows the indirect M.B.C. in the 55-64 year age group or a similar age group as reported from various surveys in other countries. The South African figures are

TABLE XV
MEAN INDIRECT M.B.C. IN VARIOUS SURVEYS

Country	Rural (R) or Urban (U)	Occupational Group	Sample	Indirect M.B.C. (l./min.)	Age Group (yrs.)
Denmark ..	(R) Bornholm (Olsen and Gilson, 1960)	No dust exposure	156	106	55-64
Scotland ..	(R) Annandale (Higgins and Cochran, 1958)	No dust exposure	87	95	55-64
Wales ..	(R) Vale of Glamorgan (Higgins and Cochran, 1958)	No dust exposure	86	89	55-64
England ..	(U) Leigh (Higgins, Oldham, Cochrane, and Gilson, 1956)	Non-miners	84	85	55-64
		Miners category O	101	76	55-64
		Simple C.W.P.	21	85	55-64
England ..	(U) Staveley (Higgins, Cochrane, Gilson, and Wood, 1959)	Non-miners	81	90	55-64
		Miners category O	96	87	55-64
		Simple C.W.P.	53	87	55-64
Wales ..	Rhondda Fach (Carpenter, Cochrane, Gilson, and Higgins, 1956)	Non-miners	86	87	55-64
		Miners category O	25	77	55-64
		Simple C.W.P.	40	77	55-64
U.S.A. ..	(U) Chicago (Sharp, Paul, Lepper, McKean, and Saxton, 1965)	Non-miners	1641	105	45-54
U.S.A. ..	(U) Jersey City (Gocke and Duffy, 1962)	Non-miners	428	99	40-59
England ..	(U) London (Holland, Reid, Seltser, and Stone, 1965)	Post-Office van drivers	137	68	56-59
England ..	(R) Peterborough, Norwich, and Gloucester (Holland <i>et al.</i> , 1965)	Post-Office van drivers	157	78	50-59
U.S.A. ..	(U) Washington, D.C., Baltimore, and Westchester, N.Y. (Holland <i>et al.</i> , 1965)	Outside telephone workers	229	87	50-59
South Africa ..	(U) Carletonville (This study)	Non-miners	40	84	55 and over
		Miners category O	51	82	55 and over
		Simple silicosis	27	94	Average 49.5

C.W.P. = coalworkers' pneumoconiosis.

comparable to those found elsewhere. The somewhat high figure for the group with simple silicosis is in part attributable to the fact that they are a younger age group.

We gladly acknowledge the outstanding manner in which Mr. C. S. Rautenbach, the field officer for this survey, acquitted himself of his task.

We appreciate the advice and assistance given by Dr. J. C. Gilson at various times before and during the survey.

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