RESPIRATORY FUNCTION OF WITWATERSRAND GOLD-MINERS
A COMPARISON BETWEEN RADIOLOGICALLY NORMAL MINERS
AND CONTROL NON-MINING SUBJECTS

BY

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The diagnosis of pneumoconiosis during life depends upon an industrial history and radiological examination (Carpenter, Cochrane, Gilson, and Higgins, 1956). However, many miners complain of dyspnoea but have no radiological changes at all. This has led to the supposition that long exposure to industrial dust hazards may lead to pulmonary disability which is not typical pneumoconiosis (Carpenter, and others, 1956; Pemberton, 1956). This disability might be due to a forme fruste of pneumoconiosis or something different, such as chronic bronchitis and emphysema (Pemberton, 1956). It is obviously important in the first place to establish whether, in the mining population as a whole, there is any impairment of pulmonary function which is unassociated with radiological disease. A method of investigating this hypothesis is to compare the pulmonary function of a random selection of radiologically normal miners with a control group of equivalent age, physique, and socio-economic status. This paper describes such a study.

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Material and Methods

An annual examination at the Pneumoconiosis Bureau, Johannesburg (including clinical and radiological examination) is compulsory for all working miners, for all retired miners who wish to retain the right to mine, and for those who have left the industry and are in receipt of compensation until such time as their compensation reaches the maximum level. Thus, examination of the Bureau records makes it possible to compile a fairly complete list of miners (present and past) in any one radiological category. The names of 30 gold-miners or ex-miners were selected at random from the records of all men examined at the Bureau during the period December, 1955, to May, 1956, and these men were recalled for testing.

The only criteria for selection were a history of at least seven years' underground service (Table 1) and a chest radiograph within normal limits. The radiographs were read independently by at least two observers. As all miners are radiographed routinely every six months, comparison with previous radiographs and their readings was subsequently made in every case in order to detect the earliest signs of silicosis. No doubtful cases were included. Ten men in each age group, 31 to 40, 41 to 50, and 51 to 60 years, were thus chosen.

The control group consisted of 30 working artisans

<table>
<thead>
<tr>
<th>TABLE 1</th>
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<tr>
<td>PHYSICAL CHARACTERISTICS OF SUBJECTS STUDIED AND INCIDENCE OF CHRONIC BRONCHITIS, EMPHYSEMA, AND BRONCHIAL SPASM (PEMBERTON, 1956)</td>
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<tr>
<td>Group</td>
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<td>31–40 Years</td>
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<td>41–50 Years</td>
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<td>51–60 Years</td>
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from a railway workshop (population 700 men). They were asked to volunteer and then put into one of the three age groups to match the miners. The only criteria for rejection were a full age group, a history of exposure to silica dust, or any radiological abnormality of the chest. It was our impression that they were comparable as regards their socio-economic status and their physical activity at their respective occupations. The mean age, height, weight, and body surface area of each group is recorded in Table 1.

In all subjects a careful industrial and clinical history was obtained with particular emphasis on respiratory symptoms. Dyspnoea was graded on the scale suggested by Fletcher (1952). A clinical examination was made and radiological, electrocardiographic, and haematological examinations were carried out in each case. Lung function testing was performed using the methods previously described by Becklake, du Preez, and Lutz (1958), whose paper contains the results on the same 20 miners aged 41 to 60 years as are herein reported. Values are tabulated for comparison in Tables 2 and 3.

All lung volumes and ventilatory capacity values are corrected to B.T.P.S. The difference between the mean value for any one test in the miners and that for the control group was tested for significance using Student’s t test.

Results

Tables 2 and 3 report the mean and standard deviation of each test in each group of 10 men. Values for residual volume and functional residual capacity are similar. Vital capacity is slightly greater in miners in two age groups. The miners in these groups have consequently a slightly greater total lung capacity of which a slightly smaller percentage is taken up by the R.V. or F.R.C. respectively.

Tests of mixing efficiency and arterial oxygen saturation (oximetry) reveal no significant differences. The values for ventilation equivalent on effort suggest that there was a tendency for miners to have a greater ventilatory response to exercise, but this was significant at the 5% level in the 41 to 50-year-old age group only, and no significant differences were noted in the Hugh-Jones test. However, it is possibly related to the fact that the miners spend a number of hours each working day at a considerable depth below the surface where the oxygen tension is higher (altitude of Johannesburg 5,760 feet above sea level). The miners might, therefore, be less well adapted to altitude (Stickney and Van Liere, 1953) than the railway workers, but no detailed investigation on this problem has yet been attempted here.

Though the mean values for maximum voluntary ventilation suggest that the rate of fall with age is higher in the miners than the railway workers, there is no significant difference in the two regressions of M.V.V. on age, owing to the wide variation of individual values. Maximum mid-expiratory flow rates, while almost identical in the two younger age groups, are significantly different in the oldest group at the 5% level. Possible technical errors were eliminated when the railway workers aged 51 to 60 years were re-tested, and the same low result for the maximum mid-expiratory flow rate was obtained.

The interpretation of this observation is, however, uncertain when it is seen that in the same age group there is a tendency for the miners to have a lower maximum voluntary ventilation, lower compliance, higher non-elastic expiratory resistance, and a lower maximal expiratory pressure. In the age group 31 to 40 years also, the miners have a significantly higher expiratory resistance, but not in the 41 to 50 group.

It thus appears that in a few tests only was there a significant difference between the mining and control groups and where such differences were present they were not consistent in all age groups. In a previous study, using identical testing techniques (Becklake, and others, 1958), it has been shown that by the technique of discriminant analysis a cumulative test score could be derived by which it was possible to separate miners with radiological changes of silicosis from those without, in spite of the fact that no individual test was capable of producing such separation. However, the application of this technique to the present data completely failed to show any significant difference between the miners and the control group. Also, when the results for V.C., R.V., T.L.C., F.R.C., and M.V.V. were expressed as a percentage of the predicted values* no significant differences were detected.

Finally, using Pemberton’s (1956) criteria † both miners and railway workers were placed in one of his four diagnostic groups for chronic bronchitis, emphysema, and bronchial spasm (Table 1). No significant difference in the incidence of these illnesses in miners and non-miners was found.

Discussion

There are few published reports of a comparison between radiologically normal miners and control groups composed of men who have never been exposed to the dust hazard. Craw (1947), in a comparison of non-miners and haematite miners, found no significant differences in the results for an exercise test and lung volumes between miners with normal radiographs, those with “reticulation”, and the controls. Vokac (1950) found a reduction of M.B.C. but not of V.C. in non-silicotic miners when com-

*Based on a study of 44 normal males and 50 normal females resident on the Witwatersrand at an altitude of ± 6,000 feet. (Goldman and Becklake, to be published.)

†Substituting the M.M.F. for the timed vital capacity used by Pemberton.
pared with a control group of normal non-miners. Gilson, Hugh-Jones, Oldham, and Meade (1955) compared coal-miners selected purely on the basis of age and radiographic appearance with men applying for work at an employment agency. The latter were asked to volunteer for lung function tests, and were excluded only if they had had mining experience, or were physically handicapped, or had

detectable abnormality on examination by the usual clinical methods. Their study included the application of a wide range of lung function tests. The only test in which important differences were noted between non-miners and miners was the maximum voluntary ventilation, and this was reflected in higher values for the dyspnoeic index in the mining group than in the non-mining control group.

Table 2
RESULTS OF LUNG VOLUME STUDIES, MIXING, AND EXERCISE VENTILATION

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<td>31-40 Years</td>
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<tr>
<td>Railway workers</td>
<td>4.068</td>
<td>1.448</td>
<td>6.526</td>
<td>3.117</td>
<td>23.50</td>
<td>49.20</td>
<td>5.595</td>
<td>5.67</td>
<td>2.48</td>
<td>11.78</td>
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<td>Miners</td>
<td>5.202</td>
<td>1.562</td>
<td>6.764</td>
<td>3.218</td>
<td>23.20</td>
<td>45.10</td>
<td>5.370</td>
<td>5.95</td>
<td>3.03</td>
<td>12.54</td>
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<td>41-50 Years</td>
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<tr>
<td>Railway workers</td>
<td>4.775</td>
<td>1.973</td>
<td>6.738</td>
<td>3.666</td>
<td>29.40</td>
<td>54.10</td>
<td>3.158</td>
<td>6.08</td>
<td>2.35*</td>
<td>11.30</td>
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<td>Miners</td>
<td>4.831</td>
<td>1.928</td>
<td>6.759</td>
<td>3.513</td>
<td>28.20</td>
<td>51.60</td>
<td>3.330</td>
<td>5.23</td>
<td>2.99</td>
<td>11.93</td>
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<td>51-60 Years</td>
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<tr>
<td>Railway workers</td>
<td>4.373</td>
<td>2.157</td>
<td>6.540</td>
<td>3.634</td>
<td>33.10</td>
<td>55.70</td>
<td>3.526</td>
<td>5.86</td>
<td>2.81</td>
<td>11.24</td>
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<tr>
<td>Miners</td>
<td>4.036</td>
<td>0.309</td>
<td>6.060</td>
<td>3.18</td>
<td>5.70</td>
<td>0.439</td>
<td>1.17</td>
<td>0.56</td>
<td>0.56</td>
<td>5.89</td>
</tr>
</tbody>
</table>

*Differs from the value for non-workers at the 5% level using Student's t test.
†The sum of the maximal fall in arterial oxygen saturation on standard effort plus the maximal rise in arterial saturation on breathing pure oxygen. This figure is based on the assumption that all subjects became 100% saturated on breathing pure oxygen. Thus the sum of the recorded deviations from the resting value, resulting first from effort and then from oxygen breathing at rest, represents the total percentage fall from 100 produced by effort.
‡Ventilation equivalent at an exercise requiring one litre oxygen uptake per minute (in litres ventilated per 100 ml. oxygen uptake).

Table 3
RESULTS OF WORK OF BREATHING STUDIES

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<td>31-40 Years</td>
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<tr>
<td>Railway workers</td>
<td>169.9</td>
<td>5.58</td>
<td>0.183</td>
<td>2.601</td>
<td>18.4</td>
<td>-0.022</td>
<td>3.650</td>
<td>99.0</td>
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<tr>
<td>Miners</td>
<td>268</td>
<td>0.86</td>
<td>0.031</td>
<td>0.21</td>
<td>6.9</td>
<td>0.020</td>
<td>2.195</td>
<td>15.1</td>
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<tr>
<td>41-50 Years</td>
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<tr>
<td>Railway workers</td>
<td>166.4</td>
<td>3.13</td>
<td>0.190</td>
<td>3.23</td>
<td>15.3</td>
<td>-0.022</td>
<td>4.460</td>
<td>82.0</td>
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<tr>
<td>Miners</td>
<td>278</td>
<td>1.55</td>
<td>0.050</td>
<td>0.80</td>
<td>5.5</td>
<td>0.024</td>
<td>1.794</td>
<td>22.7</td>
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<tr>
<td>51-60 Years</td>
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</tr>
<tr>
<td>Railway workers</td>
<td>147.4</td>
<td>3.12</td>
<td>0.023</td>
<td>3.12</td>
<td>19.9</td>
<td>-0.015</td>
<td>3.550</td>
<td>99.0</td>
</tr>
<tr>
<td>Miners</td>
<td>33.5</td>
<td>1.06</td>
<td>0.052</td>
<td>0.89</td>
<td>4.7</td>
<td>0.044</td>
<td>0.989</td>
<td>15.0</td>
</tr>
</tbody>
</table>

*Terminology recommended by Gandevia and Hugh-Jones (1957).
†Differs from the value for non-workers at the 5% level using Student's t test.
RESPIRATORY FUNCTION OF WITWATERSRAND GOLD-MINERS

Pemberton (1956), in a largely clinical study, compared a group of coal-miners with two groups of industrial workers. He found chronic bronchitis, emphysema, and bronchial spasm commoner in miners than in the industrial workers, and amongst the former its incidence was unrelated to the presence of pneumoconiosis. Expressed differently, miners with a normal chest radiograph were found to have a higher incidence of these respiratory illnesses than non-miners and evidence was presented suggesting that this was occupational in origin. Our results are not in agreement but it is not unreasonable to expect that a certain concentration of coal dust inhaled by his subjects might produce different results from the relatively low concentration of silica dust inhaled by the Witwatersrand gold-miner.

From Table 1 the interesting fact emerges that there is only six and a half years’ difference in the length of underground service between the miners aged 31 to 40 and those aged 51 to 60 years. This suggests the possibility that the disabled miners with longer underground service may have left the industry, but, as pointed out earlier in this paper, such miners would still present themselves for examination at the Pneumoconiosis Bureau and would be included in our sample. It is, perhaps, more likely that men with longer service would show some radiographic changes which would have automatically excluded them from this survey.

Although in two age groups the non-elastic expiratory resistance is significantly higher in the miners, if all the tests are considered together it appears that no obvious difference had been disclosed between miners and controls in this study. However, it cannot be concluded that mining causes no disability other than that associated with radiologically evident silicosis. The test battery employed here, though fairly comprehensive, cannot be said to have tested all aspects of lung function nor was the series examined large enough to exclude the possibility that mining causes disability in a small percentage of more susceptible individuals.

Short of an effective random sample of the whole population of a geographically defined area, unfortunately seldom practicable, the procedure was chosen of testing as controls a population of similar age, physique, and socio-economic status engaged in an occupation involving a similar degree of physical activity but known not to have been exposed to silica dust. However, as soon as the control group is selected by calling for volunteers it ceases to be fully representative (Pemberton, 1956; Schilling, 1957), nor can it be certain that the railway workers themselves do not suffer from a higher incidence of respiratory disease than the general population due to the nature of their employment. This difficulty is partially answered by the fact that the mean values for vital capacity, residual volume, total lung capacity, functional residual capacity, and maximum voluntary ventilation in both miners and railwaymen fall within the predicted normal limits using the prediction formulae of Goldman and Becklake (to be published).

It is concluded that comparison of radiologically normal miners and railway workers by the methods used in this study has failed to demonstrate conclusive clinical or physiological evidence of an increased incidence of chest disability in the former.

Summary

Lung function studies were made in a random sample of the Witwatersrand gold-miners and examiners with normal chest radiographs in the ages 31 to 60 and compared with an age-matched group of volunteers from railway workshops. Ten subjects in each 10-year age group were studied. The incidence of chronic bronchitis, emphysema, and bronchial spasm was assessed using criteria suggested by Pemberton.

No conclusive evidence, clinical or physiological, of an increased respiratory disability among the mining group was obtained, although the average maximum breathing capacity was lower in the miners over the age of 40, but the differences were not statistically significant.

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References

Goldman, H. I., and Becklake, M. R. To be published.
Respiratory Function of Witwatersrand 
Gold-miners: A Comparison between 
Radiologically Normal Miners and 
Control Non-mining Subjects. 
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