THE CAPACITY FOR PHYSICAL WORK OF WHITE MINERS IN SOUTH AFRICA*

PART III. THE MAXIMUM OXYGEN INTAKES OF NORMAL MINERS AND MINERS WITH CARDIORESPIRATORY DISEASES

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It is now generally accepted that the best measure of a man's capacity for work of an endurance nature is his maximum oxygen intake, because this value sets the limit to rate of work which can be carried out by an aerobic metabolism.[1-3] With increasing age men generally gain in weight and the maximum oxygen intake decreases, so that the maximum oxygen intake per kilogram of body-weight is markedly decreased.[4] In a recent paper on this subject[5] it was shown that the South African miner of Caucasian descent gains on the average approximately 10 kg. (22 lb.) in weight between the ages of 20 years and 50 years. No figures have been available up to the present on the changes in maximum oxygen intake with increase in age of the miner, so that it has not been possible to evaluate the influence, with advancing age, of the changes in weight and of maximum oxygen intake on the capacity for endurance work of the miner.

In order to fill this gap in our knowledge, measurements of maximum oxygen intake were made by an indirect method[6] on 815 miners who presented themselves for the benefit examination. These men were unevenly distributed over the ages 20 - 70 years, most being in the 40 - 60 years age-group. Most of these men were judged by the clinicians of the Miners' Medical Bureau to be either normal or suffering from mild chronic bronchitis. The numbers of men in these 2 categories were sufficient, in each of the 10-year age-intervals between 30 and 70, to make statistically valid comparisons of the mean maximum oxygen intakes and also to establish the effects of age on maximum oxygen intake. A small number of men in the older age-groups had cardiovascular disease (hypertension or ischaemia) or more severe bronchitis or silicosis, or combinations of 2 or more of these diseases, but the numbers of men in these categories in the various age-groups were too small to make valid statistical comparisons of the results.

The results presented in this paper, on the normal miners, may not be representative of the capacities for endurance work of the White miners in South Africa, because the men studied were a selected sample. Firstly, they are men who presented themselves for the benefit examination, i.e. they considered that they were suffering from some disability due to the inhalation of dust in the mines. Secondly, only those men were subjected to the exercise test who were considered by a medical officer of the Bureau to be fit enough to undergo the test. These reservations should be borne in mind when considering the results. Nevertheless, the study is of interest because of the light it throws on the capacities for endurance work of miners in different age-groups, with and without mild chronic bronchitis, who were still, in general, carrying out their duties underground in the mines.

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METHODS

The method of calculating the height to which the step-stool should be adjusted so that all the subjects, in spite

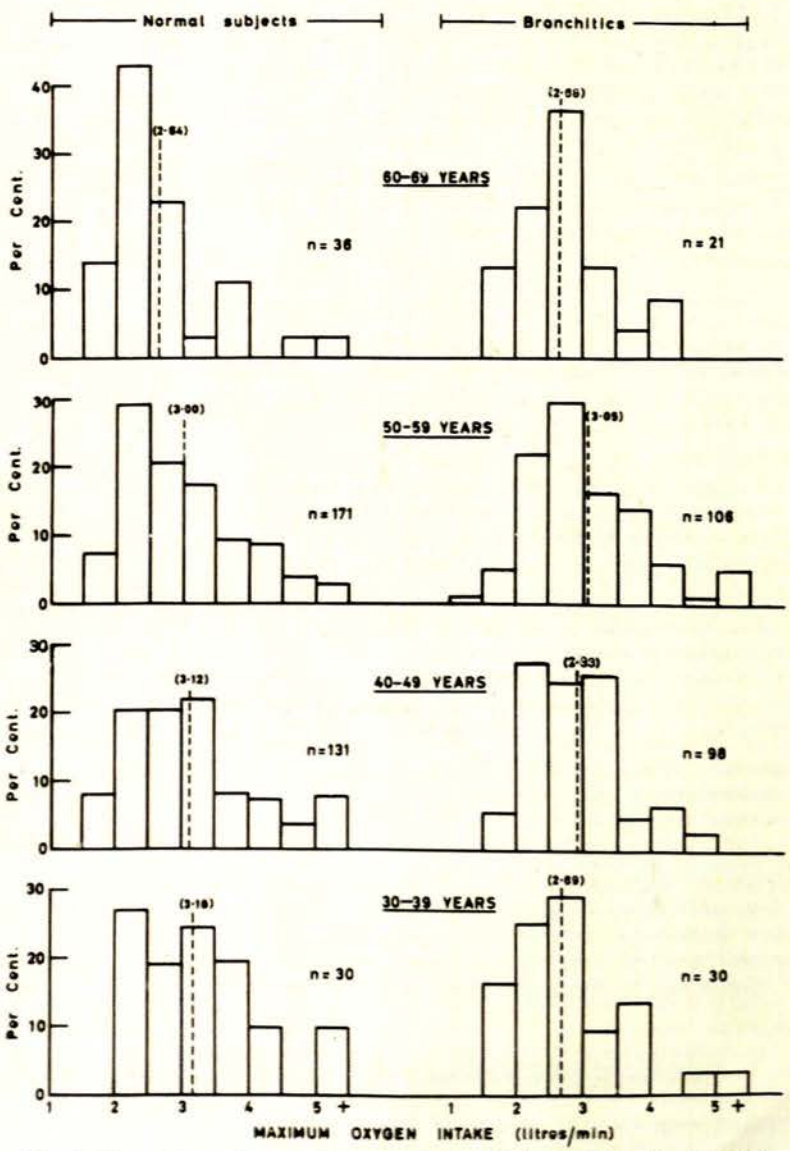

Fig. 1. Percentage of normal men and chronic bronchitics, in different age-groups, in various intervals of maximum oxygen intake.

of large differences in body-weight, worked at the same 3 rates of work (150, 250 and 350 kg.-m./min.), and the method of determining the rates of oxygen consumption of the experimental subjects at these 3 rates of work were described in an earlier paper.[7]

Heart rates were measured by means of a 'Metritel' system. This consists of 2 silver ECG electrodes attached to the chest in the region of the heart, and connected to a miniaturized radiotransmitter. The signal generated from the heart as it beats is picked up by means of a radio-receiver and recorded on an ECG machine. The heart rates used in this study were those recorded between the 9th and 10th minutes of stepping on and off the stool.

We have, therefore, on each subject heart rates and oxygen consumptions measured at each of the 3 rates of work. Maximum oxygen intakes were determined on each of the subjects by plotting the heart rates against oxygen consumptions from the 3 rates of work. A straight line was fitted by eye to the 3 plots, and was extrapolated to a heart rate of 180 beats/min. The oxygen consumption equivalent to the heart rate of 180 beats/min. on the fitted straight line, has been shown by this laboratory[8] to be a good estimate of the individual's maximum oxygen intake. Fitting a straight line by eye was also shown in a recent publication from this laboratory to give as good an estimate of the maximum oxygen intake as fitting a line by least squares. Some criticism might be made of the use of a maximum heart rate of 180 beats/min. in men of different ages. Recent data on 80 White males, in the age-group 18 - 20 years, gave a mean maximum heart rate of 187 beats/min. The fact that this mean is lower than Astrand's mean maximum of 195 beats/min. is due to the effect of altitude, Johannesburg being 5,745 feet above sea-level. The maximum heart rate falls with age,[4] so that the use of a maximum heart rate of 180 beats/min. for all the age-groups would probably cause an underestimate of the maximum oxygen consumption in the 30 - 39 years age-group and an overestimate in the 60 - 69 years age-group. The differences in maximum oxygen intakes in these 2 age-groups from the 'true' maximum oxygen intakes would, however, be very small.

RESULTS

The sample of men in the 20 - 29 year age-group was too small for statistical analysis and results are given on age-groups 30 - 39, 40 - 49, 50 - 59, and 60 - 69 years only.

Maximum Oxygen Intakes in Litres/Min.

In Table I are given, in 10-year class intervals, the numbers of men in each sample, the mean body-weights, the mean maximum oxygen intakes, and the standard deviations of the various means, of the benefit examinee normal miners and of the miners with mild chronic bronchitis.

TABLE I. MAXIMUM OXYGEN INTAKE IN LITRES/MIN. OF NORMAL MINERS AND BRONCHITICS

	Normal miners			*Miners with chronic bronchitis*		
Age-group	*No.*	*Wt.(kg.)*	*Max. VO_2*	*No.*	*Wt.(kg.)*	*Max. VO_2*
30–39	42	79·3 (12·6)	3·18 (0·89)	30	76·4 (13·4)	2·69 (0·69)
40–49	151	80·7 (11·1)	3·12 (0·96)	98	82·0 (12·3)	2·93 (0·71)
50–59	171	82·1 (11·8)	3·00 (0·87)	106	81·2 (12·4)	3·05 (0·90)
60–69	36	79·4 (11·6)	2·64 (0·80)	21	80·6 (14·1)	2·68 (0·74)

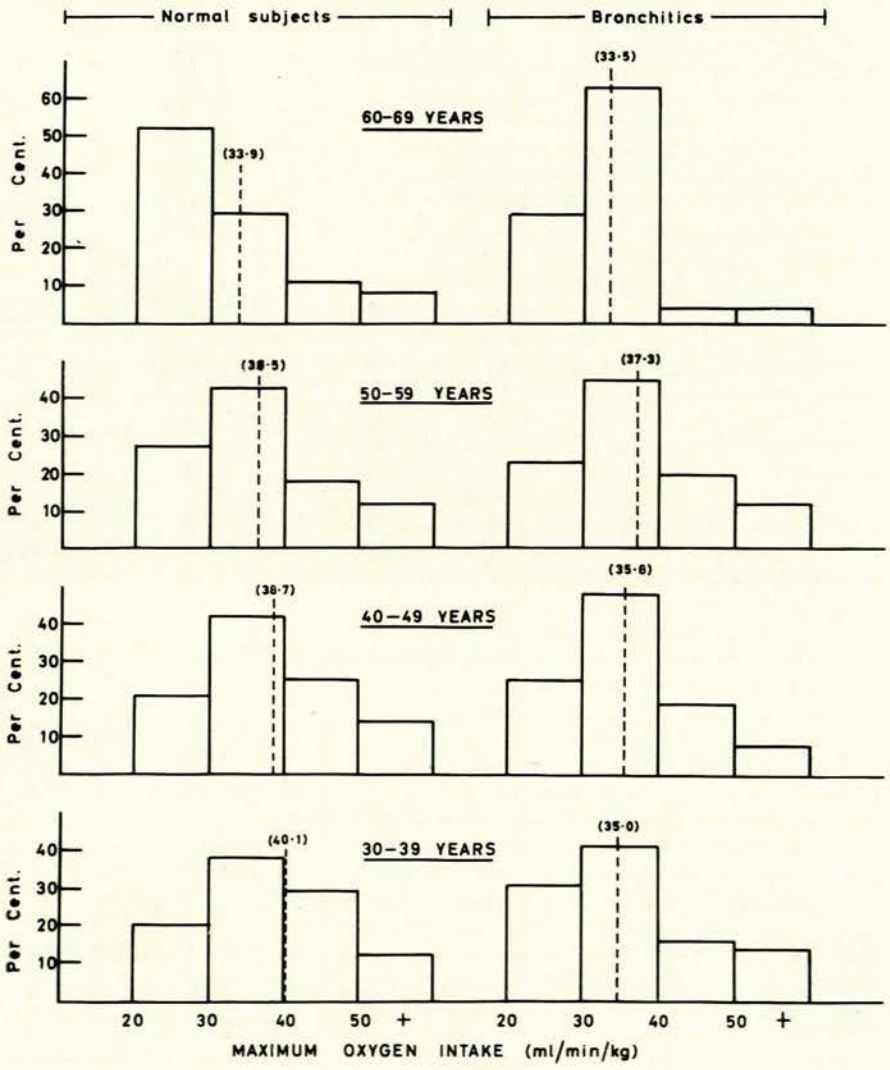

Fig. 2. Percentage of normal men and mild bronchitics, in different age-groups, at various intervals of maximum oxygen intake.

Tests were made to determine whether the differences between the means of normals and bronchitics are significant. In the age-group 30 - 39 years the means were significantly different from each other at the 5% level, namely 3·18 litres/min. was significantly higher than 2·69 litres/min. In all other cases the means of the 2 groups did not differ significantly at the 5% level.

Tests were also made to determine whether age has an effect on maximum oxygen intake. The only differences that were significant at the 5% level were seen in the age-group 60 - 69 years, where 2·64 litres/min. was significantly lower than the means for the age-groups 30 - 39, 40 - 49 and 50 - 59 years.

Among the bronchitics none of the differences between means was significant at the 5% level.

The distributions of the sample of normal miners and miners with mild chronic bronchitis in the various age-groups, in different class intervals of maximum oxygen intake, are given as percentages in Fig. 1. The first point to note is that in both the normal miners and the miners with mild chronic bronchitis there is in the 30 - 39 year age-group a skewness in the distributions towards the right and higher values; that in the age-groups 40 - 49 and 50 - 59 years the distributions are more even; and that in the 60 - 69 year age-group a high proportion of the sample of normal miners has a maximum oxygen intake below 2·5 litres/min. The second point illustrated by Fig. 1 is the change with advancing age in the percentage of the various samples with maximum oxygen intakes below 2·5 litres/min. The percentages below 2·5 litres/min. in the various age-groups are given in Table II. Table II emphasizes the fact that in the normal miner there is an increase in the percentage of the sample with maximum oxygen intakes below 2·5 litres/min. with advancing age, but a similar trend is not seen in the miners with mild chronic bronchitis.

TABLE II. PERCENTAGE IN SAMPLES WITH MAXIMUM OXYGEN INTAKES BELOW 2·5 LITRES/MIN.

Age-group	*Normal miners*	*Miners with bronchitis*
30–39	27%	40%
40–49	29%	34%
50–59	37%	28%
60–69	57%	36%

The Relationship between Maximum Oxygen Intake and Gross Body-Weight

Correlation coefficients were calculated between maximum oxygen intakes and body-weights for the samples in the various age-groups, and the results are given in Table III. This shows that the correlations are significant at the 1% level in the samples of miners with mild chronic bronchitis and the normal miners in the age-groups 40 - 49 and 50 - 59 years. The correlations in the other age-groups are either significant at only a low level or are not significant. However, it is probable that if the sample sizes had been larger in the age-group 30 - 39 years, the correlations would also have been significant at a high level of confidence.

TABLE III. CORRELATIONS BETWEEN MAXIMUM OXYGEN INTAKE AND BODY-WEIGHT

	Normal miners			*Miners with chronic bronchitis*		
Age-group	*No.*	*'r'*	*Sign. level*	*No.*	*'r'*	*Sign. level*
30–39	42	0·24	10%	30	0·20	—
40–49	151	0·36	1%	98	0·40	1%
50–59	171	0·29	1%	106	0·35	1%
60–69	36	0·08	—	21	0·26	—

Maximum Oxygen Intakes in ml./min./kg.

In view of the highly significant correlations between maximum oxygen intakes and body-weights in some of the samples, it is more valid to compare samples with different mean weights in terms of their mean maximum oxygen intakes per kilogram of gross body-weight. This has been done in Table IV.

TABLE IV. MAXIMUM OXYGEN INTAKE IN ML./MIN./KG. OF NORMAL MINERS AND BRONCHITICS

	Normal miners		*Miners with chronic bronchitis*	
Age-group	*Max. VO_2*	*SD*	*Max. VO_2*	*SD*
30–39	40·1	11·26	35·0	9·08
40–49	38·7	10·93	35·8	8·69
50–59	36·5	10·64	37·3	11·04
60–69	33·3	10·07	33·2	8·07

Tests were made to determine whether the differences between the means per kilogram of body-weight of normal men and bronchitics are significant. The following means were significantly different at the 5% level:

Age 30 - 39 years: 40·1 ml./min./kg. was significantly higher than 35·0 ml./min./kg.

Age 40 - 49 years: 38·7 ml./min./kg. was significantly higher than 35·8 ml./min./kg.

In all other cases the means of the 2 groups were not significantly different.

Tests to determine whether age has an effect gave the following results at the 5% level of significance: In the age-group 60 - 69 years, 33·3 ml./min./kg. was significantly lower than the means for the age-groups 30 - 39 and 40 - 49 years but not for 50 - 59 years. Among the bronchitics none of the differences between the means was significant at the 5% level.

The distributions of the samples in different class intervals, of maximum oxygen intakes per kilogram of body-weight, are given as percentages in Fig. 2 for the various age-groups. These histograms show the increasing percentages of the samples with advancing age in the lower class intervals of maximum oxygen intake. Taking 30 ml./min./kg. as the 'cut-off' level, Table V gives the percentages which fall below this limit in the various age-groups. It will be noted that in the normal miners there is an increase with advancing age in the percentage of the samples

TABLE V. PERCENTAGE IN SAMPLES WITH MAXIMUM OXYGEN INTAKES BELOW 30 ML./MIN./KG.

Age-group	*Normal miners*	*Miners with mild bronchitis*
30–39	20%	31%
40–49	21%	25%
50–59	27%	23%
60–69	52%	29%

with maximum oxygen intakes below 30 ml./min./kg., but this is not the case in the miners with mild chronic bronchitis.

Maximum Oxygen Intakes of Samples with More Severe Bronchitis, Heart Diseases, Silicosis and Mixed Lesions

The size of the samples with more severe chronic bronchitis, heart diseases (hypertension and ischaemic heart disease), silicosis, and various combinations of these diseases was too small to make possible any statistical comparisons between the means of these samples and those given above. However, the mean maximum oxygen intakes of the various samples are given in Table VI, from

TABLE VI. MAXIMUM OXYGEN INTAKES IN LITRES/MIN. OF MINERS, NORMAL AND WITH VARIOUS DISEASES

Age-group	*Normal miners*	*Mild bronchitis*	*Cardiacs (hyp. & isch.)*	*Bronchitis plus*	*Silicosis*
30–39	3·2 (42)*	2·7 (30)	—	—	—
40–49	3·1 (151)	2·9 (98)	3·0 (18)	2·5 (18)	3·3 (18)
50–59	3·0 (171)	3·1 (107)	2·9 (23)	2·8 (29)	3·1 (15)
60–69	2·6 (35)	2·7 (21)	—	—	—

* Figures in brackets represent the numbers in sample.

which it can be said, tentatively, that silicosis *per se* does not have any effect on this measurement; that the effect of cardiac disease, in the state seen in these men, is small; and that cases of chronic bronchitis, with some other disease, have the lowest values.

DISCUSSION

Lange Andersen[9] has given measurements of maximum oxygen intakes of industrial workers and office workers in Norway in various age-groups. Apart from Lange Andersen's data there are very few references in the physiological literature on maximum oxygen intakes of industrial workers with which to compare the present results on miners in South Africa of Caucasian origin. Table VII compares Lange Andersen's with the present results.

It will be noted in Table VII that the South African miners are heavier than the Norwegian industrial and office workers in all 4 age-groups. The maximum oxygen intakes in litres/min. of the South African miners are similar to those of the Norwegians in the 30 - 39 year age-group, but expressed per kg. of body-weight they are lower, because of the greater weights of the South African miners. However, the maximum oxygen intakes of the South African miners do not fall off with advancing age, up to the age of 59 years, as rapidly as do those of the Norwegians. In the age-group 60 - 69 years there is a sharp fall in maximum oxygen intake in all 3 groups.

It has been postulated that regular physical work of moderate intensity delays the fall-off in maximum oxygen intake with advancing age.[10] This postulate is supported by the values reported by Lange Andersen[9] for lumberjacks. Their mean maximum oxygen intakes and those of the South African miners are given in Table VIII.

TABLE VIII. COMPARISON OF MAXIMUM OXYGEN INTAKES OF NORWEGIAN LUMBERJACKS AND S.A. MINERS

	Norwegian lumberjacks			*S.A. miners*		
Age-group	*Wt.(kg.)*	*Max. O_2 litres/min.*	*Max. O_2 ml./min./kg.*	*Wt.(kg.)*	*Max. O_2 litres/min.*	*Max. O_2 ml./min./kg.*
30–39	71·7	3·3	46	79·3	3·2	40
40–49	70·5	3·1	44	80·7	3·1	39
50–59	70·2	2·8	39	82·1	3·0	37

Table VIII shows that the Norwegian lumberjacks are also lighter than South African miners. The maximum oxygen intakes of the 2 groups, in the 3 age-groups, are closely similar but, because of the lighter weights of the Norwegian lumberjacks, the maximum oxygen intakes per kg. of the South African miners are lower. However, the fall in maximum oxygen intake with advancing age of the miners is even slower than that of the lumberjacks. This finding bears out the hypothesis that continuing with moderate physical activity into middle age, as in mining and lumberjacking, slows down the rate of decrease in maximum oxygen intake with advancing age.

These results, which were obtained as part of routine studies on benefit examinees, are closely similar to those reported recently by one of us (C.H.W.) in a research study of a selected sample of 59 miners in the age-groups 30 - 39 and 40 - 49 years.[11] The mean maximum oxygen intakes were 3·00 and 2·99 litres/min. or 37·9 and 38·5 ml./min./kg., respectively, in the selected miners in these 2 age-groups. The present results should also be compared with those obtained on a sample of 80 fit, young army recruits, aged 18 - 20 years.[12] The mean maximum oxygen intake of the army recruits was 3·15 litres/min. but, as their mean body-weight was only 66·4 kg., the mean maximum oxygen intake per kg. of body-weight was 47·2 ml./min./kg. This figure is considerably higher than that of the sample of miners in the age-group 30 - 39 years, even though the mean maximum oxygen intake of that group of miners, 3·20 litres/min., was closely similar to the figure of 3·15 litres/min. of the army recruits.

The significant correlation between maximum oxygen intakes and body-weights of the samples of the miners in the 40 - 49 and 50 - 59 year age-groups is in line with previous findings in this regard. In the group of 59 miners, referred to above, the correlation coefficient was 0·36 and in the sample of 80 fit, young army recruits it was 0·78. From these various correlation coefficients one can calculate the percentage of the variation between individuals in maximum oxygen intake, in the various samples, which can be accounted for by differences between them in body-

TABLE VII. COMPARISON OF MAXIMUM OXYGEN INTAKES OF MINERS AND INDUSTRIAL AND OFFICE WORKERS

	Norwegian office workers			*Norwegian industrial workers*			*South African miners*		
Age-group	*Wt.(kg.)*	*Max. O_2 litres/min.*	*Max. O_2 ml./min./kg.*	*Wt.(kg.)*	*Max. O_2 litres/min.*	*Max. O_2 ml./min./kg.*	*Wt.(kg.)*	*Max. O_2 litres/min.*	*Max. O_2 ml./min./kg.*
30–39	76·1	3·2	42	70·5	3·1	44	79·3	3·2	40
40–49	74·3	2·9	39	76·3	2·9	38	80·7	3·1	39
50–59	72·2	2·6	36	73·4	2·5	34	82·1	3·0	37
60–69	69·7	2·3	32	71·4	2·0	28	79·4	2·6	33

weight. This is done by means of the coefficient of determination ($r^2 \times 100$). In the present samples only about 10 - 15% of the variation between individuals in maximum oxygen intake can be accounted for by differences in body-weight. This figure is much lower than that of the fit, young army recruits in which about 60% of the variation between individuals in maximum oxygen intake can be accounted for by differences between the army recruits in body-weight. This finding suggests that the maximum oxygen intakes of the miners are affected more by other factors which are known to influence the maximum oxygen intake than is the case in the army recruits; such as cardiorespiratory diseases, physical fitness, nutrition (both over- and under-nutrition), and habitual physical activities.[13]

These results on the normal miners show a decrease in maximum oxygen intake in the age-group 60 - 69 years. However, what has not been demonstrated previously is that the percentage of men in the samples who have a maximum oxygen intake of less than 30 ml./min./kg. (the minimum required for a moderate rate of work) also increases with advancing age. Table VIII shows that 20% of the sample in the age-group 30 - 39 years fell below this limit, i.e. one-fifth of the normal miners in that age-group. This may be compared with the figure of 12% in the 59 selected miners studied by this laboratory recently[11] and 0% of fit, young army recruits.[12] With advancing age this percentage increases, so that in the 50 - 59 year age-group 27% of the sample falls below this limit, and 52% in the 60 - 69 year age-group. The figures on the miners with mild chronic bronchitis do not show this trend. This may be because the medical officers allowed only the very fit men with mild chronic bronchitis in the older age-groups to take part in the exercise tests.

Effects of Mild Bronchitis and other Pathology

Comparison can be made on these results of the capacities for endurance work of normal miners and miners with mild chronic bronchitis. In the 2 younger age-groups the mean maximum oxygen intakes of the miners with mild chronic bronchitis are significantly lower than those of the normal miners, and there is also a higher percentage of the miners with chronic bronchitis with maximum oxygen intakes below 30 ml./min./kg., i.e. not capable of a moderate rate of work. Few miners in the age-groups 30 - 39 and 40 - 49 years with mild chronic bronchitis were regarded by the medical officers of the Bureau as not capable of carrying out the exercise test, so that the results on the normal miners and miners with mild chronic bronchitis, in these 2 age-groups, can be regarded as representative of the populations of miners in these age and fitness categories. The fact that similar differences were not seen between these 2 categories of miners in the 2 older age-groups is probably due to the fact that the medical officers of the Bureau allowed only very fit miners with mild chronic bronchitis in the age-grouns 50 - 59 and 60 - 69 years to carry out the fitness test. Hence the samples of miners with mild chronic bronchitis in these 2 age-groups cannot be regarded as representative of the populations of miners with these chest complaints. A similar difficulty exists in interpreting the results on the samples of miners with such diseases as more severe bronchitis, heart and circulatory diseases, silicosis and combinations of these diseases. Also the samples of miners with these diseases were too small to apply statistical analysis. The results indicate that silicosis *per se* does not reduce the mean maximum oxygen intake; that the heart and circulatory diseases seen in these samples (hypertension and ischaemic heart disease) do not reduce the mean maximum oxygen intake appreciably; and that if bronchitis is associated with some other disease, such as silicosis or a heart complaint, then the man's capacity for physical effort is markedly affected. However, these indications must be regarded as only very tentative until they are validated by results on larger samples of men.

Ability to Perform Normal Work in a Mine

These results should, however, also be considered in the context of the physical efforts required from the miners in the course of their everyday activities in the mines. For example, in this paper the figure of 30 ml./min./kg. is taken to be the minimum value of the maximum oxygen intake which a miner requires in order to carry out a moderate rate of work. It is argued that miners with values below this limit would not be physically capable of performing their normal duties in the mine. However, this limit of maximum oxygen intake must be regarded as entirely tentative at present. No studies have been carried out on the oxygen consumptions of White miners during the course of their normal duties, underground, in the mines. Such information is available for the Bantu from a study of a very large sample of Bantu mineworkers carrying out all the various tasks they are called upon to do in the mines.[14] This information cannot be applied to the White miners because, in the first place, the White miner is much heavier than the Bantu and body-weight very markedly affects the rates of oxygen consumption and, in the second place, the nature of the duties of the White miner is very different from that of the Bantu mineworker. It would appear, therefore, that in assessing the capacity of the White miner for physical effort of an endurance nature, a survey of the energy costs of his various physical activities in the mines is called for, similar to that carried out on the Bantu by the Human Sciences Laboratory[14] and on British coalminers by Garry *et al.*[15]

SUMMARY

Men generally gain weight with increasing age, and the maximum oxygen intake decreases; no figures are, however, available on the changes in maximum oxygen intake with increase in age. Measurements of maximum oxygen intake were made by an indirect method on 815 miners between the ages of 20 and 70 years, who were considered clinically to be either normal or suffering from cardiorespiratory diseases.

Heart rates and oxygen consumptions were measured on each of the subjects at 3 rates of work. Maximum oxygen intakes were determined by plotting the heart rates against the oxygen consumptions at the 3 rates of work for each individual, and extrapolating the line to a heart rate of 180 beats/min.

The maximum oxygen intake of the 60 - 69 years age-group was significantly different (5% level) from the means for the age-groups 30 - 39 years and 40 - 49 years, but not for the 50 - 59 years age-group. Among the bronchitics none of the differences between the means was significant at the 5% level. When expressed as maximum oxygen intake per kilogram of body-weight, there was a decided increase in the percentages of the samples with advancing age in the lower class intervals of maximum oxygen intake. This was not so in the case of the miners with mild chronic bronchitis.

These results are closely similar to those obtained on a selected sample of 59 different miners in the age-groups 30 - 39 and 40 - 49 years.

REFERENCES

1. Astrand, P. O. (1952): *Experimental Studies of Physical Working Capacity in Relation to Age and Sex*. Copenhagen: Munksgaard.
2. Taylor, H. L., Buskirk, E. R. and Henschel, A. (1955): J. Appl. Physiol., **8**, 73.
3. Wyndham, C. H., Strydom, N. B., Morrison, J. F., Peter, J. and Potgieter, Z. U. (1959): *Ibid.*, **14**, 927.
4. Astrand, I. (1960): Acta physiol. scand., **49**, suppl. 169, 1.
5. Wyndham, C. H. and Sluis-Cremer, G. K. (1968): S. Afr. Med. J., **42**, 280.
6. Maritz, J. S., Morrison, J. F., Peter, J., Strydom, N. B. and Wyndham, C. H. (1961): Ergonomics, **4**, 97.
7. Wyndham, C. H. and Sluis-Cremer, G. K. (1968): S. Afr. Med. J., **42**, 841.
8. Wyndham, C. H., Strydom, N. B., Leary, W. P. and Williams, C. G. (1966): Int. Z. angew. Physiol., **22**, 285.
9. Lange Andersen, K. and Evans, K., eds. (1966): *Physical Activities in Health and Disease*, pp. 163 - 174. Oslo: Universitatsforlaget.
10. Lange Andersen, K. and Hermansen, L. (1965): J. Appl. Physiol., **20**, 432.
11. Wyndham, C. H., Strydom, N. B., Williams, C. G. and Heyns, A. J. (1968): Journal of the Institute of Mining and Metallurgy (South Africa), **68**, 79.
12. Wyndham, C. H., Strydom, N. B. and Leary, W. P. (1966): Int. Z. angew. Physiol., **22**, 296.
13. Buskirk, E. R. and Taylor, H. L. (1957): J. Appl. Physiol., **11**, 72.
14. Morrison, J. F., Wyndham, C. H., Minnie, B. and Strydom, N. B. (1969): Journal of the Institute of Mining and Metallurgy (South Africa) (in the press).
15. Garry, R. C., Passmore, R., Warnock, G. M. and Durnin, J. V. G. A. (1955): Spec. Rep. Ser. Med. Res. Coun. (Lond.), No. 289.