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Studies of the Maximum Capacity of Men for Physical Effort

Part III.

The effects on the maximum oxygen intake of young males of a regime of regular exercise and an adequate diet

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Introduction

The Bantu in their homelands have a diet which is low in animal protein and in fat content; and also in some areas, in total calories. They rarely do regular physical work. When they are recruited to the gold mines, however, this pattern changes. They work for 6 days a week at a moderate rate of work [4]. They are presented with an excellent and well-balanced diet of 4,000 cal/man/day and 136 gr of protein, of which 65 gr are from animal sources [2]. As a result of this new dietary and work regime the average gain in weight of the Bantu labourer is 2.7 kg in the first month of his contract. This increase is statistically significant [7]. There is also an associated and significant increase in the average maximum oxygen intake from 2.32 to 2.79 l/min over this period [7]. After the first month there are no further significant changes in either of these measurements. From these results it can be concluded that both the nutritional state and the capacity for physical work of an endurance nature of the Bantu recruit to the gold mines are improved during his service on the mines.

The young Caucasian in South Africa has a very different nutritional and exercise background. Generally diet is high in animal protein and in fat content. These two features characterise the diet of Western affluent societies. The cult of physical sports in the Caucasians' schools ensures that most high-school boys have some form of regular exercise. During their military training these favourable circumstances are continued. The recruits enjoy a well-balanced diet and undergo regular physical training.

In view of the differences between the young Caucasian and Bantu in their nutritional and exercise backgrounds it is of interest to compare

the influence on their maximum oxygen intakes and gross body weights of a period of military training in the case of the Caucasians and of service on the mines in the case of the Bantu. To this end the body weights and maximum oxygen intakes of 20 new recruits are compared with those of 20 recruits after 6 months of military training. These results are examined in the context of the information already published on the effects of service in the gold mines on the measurements of Bantu recruits.

Methods

Intermittent treadmill test

The subjects arrived at the working place approximately 2 to 3 h after a light breakfast. Heights and weights were measured with the subjects dressed in light running shorts only.

Each subject rested on a stretcher for a minimum of 20 min. Resting pulse rates were recorded.

A short explanation of the experiment was then given by the scientist supervising the experiment. Each subject was allowed to walk and run on the treadmill for a short period to warm up and to accustom himself to this form of exercise.

An Edwards' rubber face mask was fitted to each subject about 5 to 10 min before the first work load was attempted. RA and LA cardiographic leads, with RL as the earth, were secured to the subject's chest by means of a rubber belt at the fifth intercostal space.

Each subject was tested at three work loads which could be completed without undue stress. These work loads occupied 7 min each and were chosen so that the subject's heart rate did not exceed 150 beats/min after 6 min of work.

Most groups of untrained subjects tested in the past have had an average maximum oxygen intake of about 48 ml/kg/min [2]. Each subject's weight in kilograms was multiplied by 48, therefore, in order to determine what his oxygen consumption at maximal effort, was likely to be in litres per minute.

The results obtained from the three sub-maximum work rates were used to plot oxygen consumption in litres per minute against work rate. The line joining these three points was then extrapolated to the point corresponding to the subject's estimated maximum oxygen intake (in litres per minute). Three or more runs of 3 min each were then carried out. The first of these three runs was one that would require an oxygen consumption equivalent to the subject's maximum capacity, provided that his oxygen consumption was approximately 48 ml/kg/min. From the graph mentioned above the speed in question was read off against oxygen consumption. By measuring the subject's heart rate and plotting the heart rate on the graph, after each work rate, it was possible to choose three runs which required a maximum effort from the subject in question, whatever his capacity.

The final graph obtained for each subject included the results of at least three sub-maximum and three maximum runs. The extrapolated line tends towards its asymptote as the individual nears his maximum oxygen intake. The maximum oxygen intake was taken to be the mean of three points on the asymptote, on condition that these three oxygen intakes did not vary from each other by more than 0.15 l/min.

Expired air was collected from the 5th to the 7th min in the case of sub-maximum runs and from the 2nd to the 3rd min in the case of maximum runs.

Resting intervals between efforts were determined by the time taken for the pulse rate to return to normal after exercise.

Results

The effect of 6 months of service on body weights

The ages, heights and weights of the 20 new recruits and 20 men after 6 months of service, together with the standard deviations about the means, are given in Table 1.

Table 1. *Physical characteristics of the subjects*

	Age Mean	Height Mean	Weight Mean
Raw Recruits	18 yrs. ± 0.73	69.75 ins. ± 2.13 ins.	148 lbs 8 ozs. ± 17 lbs
Trained Recruits	19 yrs. ± 0.84	68.25 ins. ± 2.39 ins.	147 lbs 3 ozs. ± 14 lbs

From this Table it is clear that the new recruits are younger, but their heights and weights are not significantly different. The young Caucasian does not gain weight during the first 6 months of his military service.

The effect of 6 months of service on the maximum oxygen intakes

The mean maximum oxygen intakes, in l/min and ml/min/kg, of the new recruits and the men with 6 months of service are given in Table 2.

Table 2. *Maximum oxygen intakes and heart rates*

	Maximum Oxygen Intake l/min Mean	Maximum oxygen Intake/kg ml/kg/min Mean
Raw Recruits	3.05 ± 0.415	45.0 ± 4.26
Trained Recruits	3.10 ± 0.337	46.3 ± 3.85

A student "t" test for differences between the groups in maximum oxygen intakes yielded a value of 0.4856 with 19 degrees of freedom. These means are therefore not significantly different at the 5% level.

Distributions of the maximum oxygen intakes in the two groups

The distributions of the maximum oxygen intakes of the new recruits and of the men with 6 months of service are shown in Fig. 1.

This shows that 20% of the new recruits have maximum oxygen intake values which are below 2.5 l/min, whereas none of the men with 6 months of service have such low values. 45% of the new recruits and 40% of the men with six months of service have values which are below 3.0 l/min. None of the two groups of men have maximum oxygen intake values which are above 4.0 l/min.

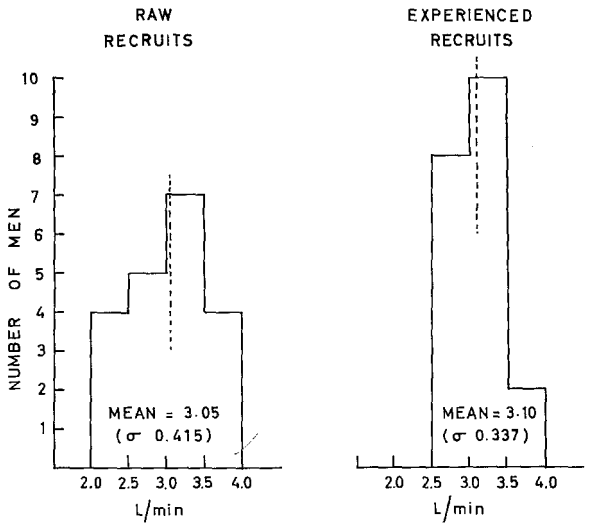

Fig. 1. Distribution of maximum oxygen intakes

Discussion

The effect of the Bantu's diet in his homeland is evident in both the low mean value for the percentage body fat (calculated from skinfold thicknesses) and in the small variance about the mean, compared with

Table 3

	Mean % body fat	Standard Deviation	Extreme Values
Caucasians	13.7	8.34	34%
Bantu	4.2	1.00	7%

the values for young, active Caucasians [6]. A comparison is made in Table 3.

When the young male Bantu is recruited to the mine he engages in regular physical work at a moderate rate and eats an excellent and balanced diet. In consequence, there is a gain of 2.7 kg in weight in the first month and an increase in skinfold thickness [3]. Maximum oxygen intake values are also increased. It can be inferred that the increase in maximum oxygen intake is not solely due to the gain in weight, because when the maximum oxygen intakes are expressed per kilogram of gross body weight, the value on recruitment is 42.1 ml/min/kg, and this increases to 49.0 ml/min/kg after the first month. This indicates that the men are more "fit" for prolonged physical effort after the month of regular work at a moderate rate and the excellent compound diet. There is support for this idea in the change in the correlation coefficient between maximum oxygen intake and gross body weight of these men. It increases from

0.53 at the first examination to 0.63 after the period of a month. From these correlations it can be argued that on recruitment 27% (i.e. the correlation coefficient squared) of the variations between individuals in maximum oxygen intake is accounted for by differences in gross body weight. After one month of service 42% of the differences can be accounted for by body weight differences. This indicates that after the month of service, factors which influence maximum oxygen intakes, (other than body weight) play a smaller role in the differences between individuals in this measurement.

However, even after a month of stabilising to the new dietary and work regime, 58% of the differences between individual Bantu in maximum oxygen intake is unaccounted for. This is surprising because BUSKIRK and TAYLOR [1] in their study of young U.S.A. army recruits found a correlation coefficient of 0.63 between maximum oxygen intake and gross body weight (i.e. 42% of the differences between individuals in this measurement could be accounted for by their differences in gross body weight). However, when they correlated maximum oxygen intake with fat-free mass (measured by densitometric methods) the correlation coefficient was 0.85 (i.e. 72% of the differences between individuals in maximum oxygen intake could be accounted for by variations between them in fat-free mass). The Bantu recruits, as shown in Table 3, have a very small percentage of body fat and the variations between them in this measurement is also very small. Their body compositions would therefore have been similar to the fat-free masses of BUSKIRK and TAYLOR's subjects. On these grounds a higher correlation between maximum oxygen intake and gross body weight would have been expected in the Bantu. The fact that this was not so can probably be attributed to the influence of other factors which are known to affect the maximum oxygen intake. These are the nutritional states and the degree of physical fitness of the subjects, and the type of infection and the extent to which they are infected with endemic diseases in their homelands. The subjects of these experiments came from tribes which are spread all over Southern Africa and they would undoubtedly have differed widely in these three factors.

The reactions of the young, active Caucasian to a uniform good diet and regular physical exercises during Army training is quite different to that of the Bantu. There is no significant change in body weight, or in maximum oxygen intake, or in the correlation coefficient between maximum oxygen intake and gross body weight. From the lack of change in these measurements, it can be deduced that either the recruits were in good nutritional state and were fit for endurance efforts or that the physical training programme was not effective. The first alternative appears to be the correct explanation. The mean maximum oxygen intake

of these recruits was 45 ml/min/kg. The study was made in Johannesburg at an altitude of 5,784 feet above sea-level. At this altitude the mean maximum oxygen intake is expected to be between 10 and 15% lower than at sea-level [5]. Making a correction of this order for the effect of altitude gives a mean maximum oxygen intake of 53 ml/min/kg for these young men. This compares well with ASTRAND's mean figure of 58.5 ml/min/kg for his young, very fit gymnasts. This suggestion is also supported by the very high correlation coefficients of 0.75 on recruitment and 0.78 after training between maximum oxygen intake and gross body weight. This means that about 60% of the variation in maximum oxygen intake between the individuals could be accounted for on the differences between them in gross body weights. The figure for BUSKIRK and TAYLOR's young U.S.A. army recruits was 42%. From this difference between the figure for South African recruits and U.S. Army recruits it can be inferred that either the young South African Caucasian has a smaller proportion of body fat than his American counterpart or that he is in a better state of physical training for prolonged physical effort. The young South African Caucasian is lighter than the young American recruit, 66.4 kg compared with 74.8 kg, and his percentage body fat is also less.

Even though no significant influence on the mean maximum oxygen intake was shown by the 6 months of Army training, there was nonetheless one positive effect. 20% of the new recruits had maximum oxygen intakes of less than 2.5 l/min but after 6 months of service no recruit had such low values. From this finding one might infer that the influence of the uniform diet and regular physical training is greater in the men who initially have low maximum oxygen intakes, either because they were relatively physically inactive or because they were still growing.

Summary

It is the normal pattern for the Bantu to gain about 2.7 kg in weight during the first month of his service on the mines. This is because the mines provide an excellent and well-balanced diet, which supplies 136 gm/man/day of protein, of which 65 g are from animal origin, and 4000 cal/man/day. This is very different from the diet they enjoy in the Bantu homelands, where they also rarely do regular physical work. On the mines they work for 6 days at a moderate rate of work. The regular work and good diet results in the Bantu gaining in weight and in an increase in his maximum oxygen intake from 2.32 to 2.79 l/min. Both these increases are significant.

The nutritional and exercise background of the young South African Caucasian is very much different. At home, in the school and during their military training these factors are well catered for.

While the Bantu gains in weight and increases his maximum oxygen intake, the young Caucasian does not gain either in weight or maximum oxygen intake during 6 months of his military training. By comparison, therefore, the young Caucasian in South Africa is in a good nutritional state and is fit for endurance effort, while the Bantu lacks both of these in his homelands, but rapidly gains in both during the first few months of his contract on the mines.

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