

The responses of men weighing less than 50 kg to the standard climatic room acclimatization procedure

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SYNOPSIS

A group of 23 underweight men weighing less than 50 kg were subjected to an acclimatization procedure in which the work rate was gradually increased from 35 Watts on the first day to 70 Watts on the eighth day. Excessively high body temperatures and heart rates were observed on these subjects throughout the acclimatization period and on their performance they must be rated as heat-intolerant. It can be concluded that such underweight men should not be subjected to acclimatization at such high work rates and that they should not be allocated to tasks involving these rates in a hot environment. The fact that their body surface areas are inadequate to enable them to get rid of the internal heat produced during strenuous work plus their low work capacities are the major reasons for their inability to tolerate heat.

INTRODUCTION

When the optimum work rate for the effective acclimatization of the underground labour force in climatic rooms was set, the energy expenditure of the different mining tasks had to be taken into consideration¹. It would have been very dangerous to acclimatize a man at a low rate of work and then expect him to do hard work in heat. For this reason the work rate during the final days of the acclimatization procedure was set at 70 W or 1.4 litres of oxygen/min, that is, a work rate with energy requirements equivalent to that of shovelling rock², the hardest of the underground tasks. The work used in the climatic room procedure is to have men step on and off benches at 24 times per minute. This type of work is used because the work rate can be standardised accurately and the space requirements per man are small. The work rate of 70 W is obtained by adjusting the height of the bench according to the man's body weight, the lower his weight the higher the stepping height will be.

It is well known in physiological literature that for a man to do sustained work such as pushing a mine car requiring an oxygen intake of 1.25 litres/min he must have a maximum oxygen intake of at least twice this value i.e. more than 2.5 litres/min³. Studies at Human Sciences Laboratory⁴ have shown that there is a significant correlation between maximum oxygen intake and body weight. Heavier men have higher maximum oxygen intakes and vice-versa. Only 11 per cent of the Bantu recruits weighing less than 50 kg have maximum oxygen intakes of more than 2.5 litres/min⁴.

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On theoretical grounds men of less than 50 kg should not be subjected to the usual climatic room procedure. Firstly, when they work at an oxygen intake of 1.4 litres/min most of these men would be working at more than 50 per cent of maximum oxygen intake and would be in anaerobic metabolism. In these circumstances men are less mechanically efficient than when they are working on aerobic metabolism and for the same rate of external work they produce more 'waste heat' than heavier men and may therefore suffer an excessive body temperature rise. Secondly, men of less than 50 kg have been shown to have too small a surface area for them to lose the waste heat of stepping in the climatic room at 70 watts. They may therefore on this count also suffer excessive rises in body temperature. On these two grounds it seemed unlikely that it would be possible to acclimatise adequately most men of less than 50 kg in weight.

In order to test this hypothesis, which is of great practical importance to mines, a sample of new Bantu recruits to the mines, all of whom weighed less than 50 kg, were studied while being acclimatized by the standard climatic room procedure.

METHOD

Volunteer test subjects were selected from amongst Bantu men under the weight of 50 kg.

The maximum oxygen intake capacity of each subject was measured using both the step test and treadmill technique⁵. Thereafter the men were subjected to a heat acclimatization (eight day) procedure¹. To bring their work rates up to the required levels of 35 and 70 W the stepping heights had to be increased above those

TABLE I
PHYSICAL CHARACTERISTICS

Subject	Age	Height	Weight (1st Day)	Weight (8th Day)	Treadmill Max. Cap.	Body Surface area m ²
1	29	148,6	47,00	48,45	1,8492	1,61
2	39	154,6	45,70	47,35	1,5939	1,65
3	51	152,2	44,80	45,00	1,6814	1,59
4	45	160,4	46,10	47,55	1,7573	1,71
5	27	152,6	44,35	44,65	1,7626	1,60
6	47	155,3	46,30	47,00	1,9209	1,65
7	25	152,8	46,35	46,85	2,0083	1,64
8	49	151,2	40,10	39,50	1,4527	1,51
9	25	150,8	47,50	48,35	1,9474	1,64
10	21	154,9	46,60	47,35	2,1437	1,65
11	19	161,7	48,15	47,45	2,0990	1,67
12	19	151,2	44,15	43,45	1,9556	1,58
12	18	152,4	44,95	45,00	1,9993	1,54
14	25	154,5	46,60	47,45	2,4701	1,64
15	23	158,8	47,45	48,65	2,0238	1,71
16	23	160,8	50,30	51,05	2,2112	1,77
17	22	166,9	49,90	50,10	2,0570	1,79
18	18	154,2	45,05	45,40	2,1048	1,58
19	20	149,2	47,20	47,10	2,3612	1,64
20	22	154,4	45,80	45,50	2,1174	1,61
21	21	159,6	45,70	46,80	2,1322	1,67
22	21	156,8	47,20	48,80	2,4327	1,68
23	22	156,2	47,20	47,55	2,2898	1,69

appropriate for heavier men. Oral and rectal temperatures were recorded, and on the first acclimatization day only those subjects who developed rectal temperatures of 40°C or above were rested. This was done for purposes of comparison, but for the rest of the acclimatization period the standard procedures in the climatic room procedure were used for the management of high temperature cases. Special attention was given to the drinking of water and each subject consumed at least 200 ml every half-hour.

On completion of the eight-day acclimatization period the subjects were again tested for maximum oxygen intake and their body surface areas were measured in the photodermoplanimeter.

RESULTS

The physical characteristics, maximum oxygen intakes, as determined by the treadmill procedure, and the body surface area of the 23 subjects are given in Table I. The average given age of the subjects was 27 years (range 18 to 49 years), the average height 155,2 cm, the average body weight 46,3 kg (with a range of 40 to 50 kg), and the average calculated body surface area 1,43 m². On the average the subjects gained 0,4 kg in body weight over the eight-day period but five of them lost weight. The biggest weight gain was 1,6 kg and the maximum weight loss was 0,7 kg. On the eighth day of acclimatization, body weight varied from 39,5 kg to 50,8 kg with an average value of 46,7 kg. Only the value of maximum oxygen intake at the start of the experiment is given in Table I for each subject because there was no significant change in this value over the eight-day period. The average value for the group was 2,02 l/min. Not one of these men had a maximum oxygen intake above 2,5 litres/min and the value for 43 per cent was below 2,0 litres/min.

On day 1 every one of the 23 men developed an oral temperature of 38,4°C or above. Nine of the 23 men developed oral temperatures of 39,5°C or above and an even more serious case was No 19 whose oral temperature rose from 38,8 to 40,7°C in the course of the last hour. With only 3 exceptions all the men developed oral temperatures of 38,4°C or above on every one of the eight days of the acclimatization process and even on day 8 there were four cases of oral temperatures of 39,5°C or above.

TABLE II
RECTAL TEMPERATURE RESPONSES ON THE FIRST AND LAST DAYS OF ACCLIMATIZATION

Subject No	Rectal Temperature per Half-Hour							Subject No	Rectal Temperature per Half-Hour							
	R	2	4	5	6	7	8		R	2	3	4	5	6	7	8
1	36,9	38,1	38,3		38,5		39,6	1	36,4	38,1		39,0	37,4	38,0		39,3
2	37,4	38,8	39,1	37,7	37,9		39,4	2	36,2	38,2		38,9	37,6	38,2		39,1
3	37,0	38,5	39,2	38,1	38,5		40,2	3	36,1	38,4		39,3	37,6	38,2		39,8
4	36,9	38,4	38,8		38,9	39,1	37,9	4	36,2	38,4		38,9	38,1	38,2		39,2
5	36,6	38,4	39,4	39,9	40,3	39,3	38,8	5	36,2	38,7		40,3	38,8	38,0		40,7
6	36,8	38,5	38,7		39,1		40,2	6	36,7	38,7		39,1	39,0	37,6		39,4
7	36,7	38,5	39,2		39,7	40,1	38,9	7	37,6	39,3	39,2	38,1	38,2	38,7	39,4	39,2
8	37,1	39,2	40,2	39,0	37,8	38,2	39,6	8	36,7	39,1	37,9	38,8	38,2	38,9	38,4	38,1
9	37,3	39,2	39,6	39,6	39,7	39,8	40,7	9	36,3	39,1	37,9	38,8	38,2	38,9	37,6	39,1
10	37,1	39,1	39,7	40,1	39,4	38,6	38,1	10	37,2	39,3	38,1	39,0	38,2	37,9	37,9	38,8
11	37,4	38,8	39,2		39,9	40,2	38,6	11	36,8	38,7		39,6	37,9	39,1	38,1	39,0
12	37,2	38,8	39,1		39,2	39,4	40,2	12	36,7	38,3		39,2		40,3	39,2	38,1
13	37,6	38,9	39,2		39,6	39,6	40,2	13	36,8	38,8	38,0	38,6	39,4	38,4		39,8
14	36,6	38,8	40,0	38,8	38,1		40,3	14	36,8	39,1	37,7	38,6	37,8	38,9	38,1	39,2
15	37,8	39,0	39,1		39,3		39,8	15	36,8	39,0	37,9	38,9		40,2	38,7	38,2
16	37,4	38,4	39,0		39,2		40,1	16	37,4	38,6	39,2	38,4	37,6	38,4	39,3	38,6
17	37,1	38,6	39,2		39,7	39,7	40,4	17	36,8	38,9	39,2	38,4		40,0	38,8	37,9
18	37,1	38,3	38,4		38,7		40,0	18	36,8	38,3		38,7		39,1	37,8	38,4
19	36,9	38,7	39,2		39,4		41,3	19	36,3	38,9	39,2	38,1		39,2	38,5	38,9
20	36,9	38,3	38,8		38,8		40,3	20	36,2	38,8	39,0	37,7		39,5	37,7	38,8
21	36,7	38,3	38,7		39,0		40,4	21	36,5	39,4	38,1	38,7		40,4	38,9	38,1
22	37,0	38,4	38,8		38,8		40,0	22	36,4	38,4		38,6		39,2	39,3	38,4
23	37,2	38,6	38,7		38,9		39,8	23	36,7	38,1		38,1		38,0		38,9

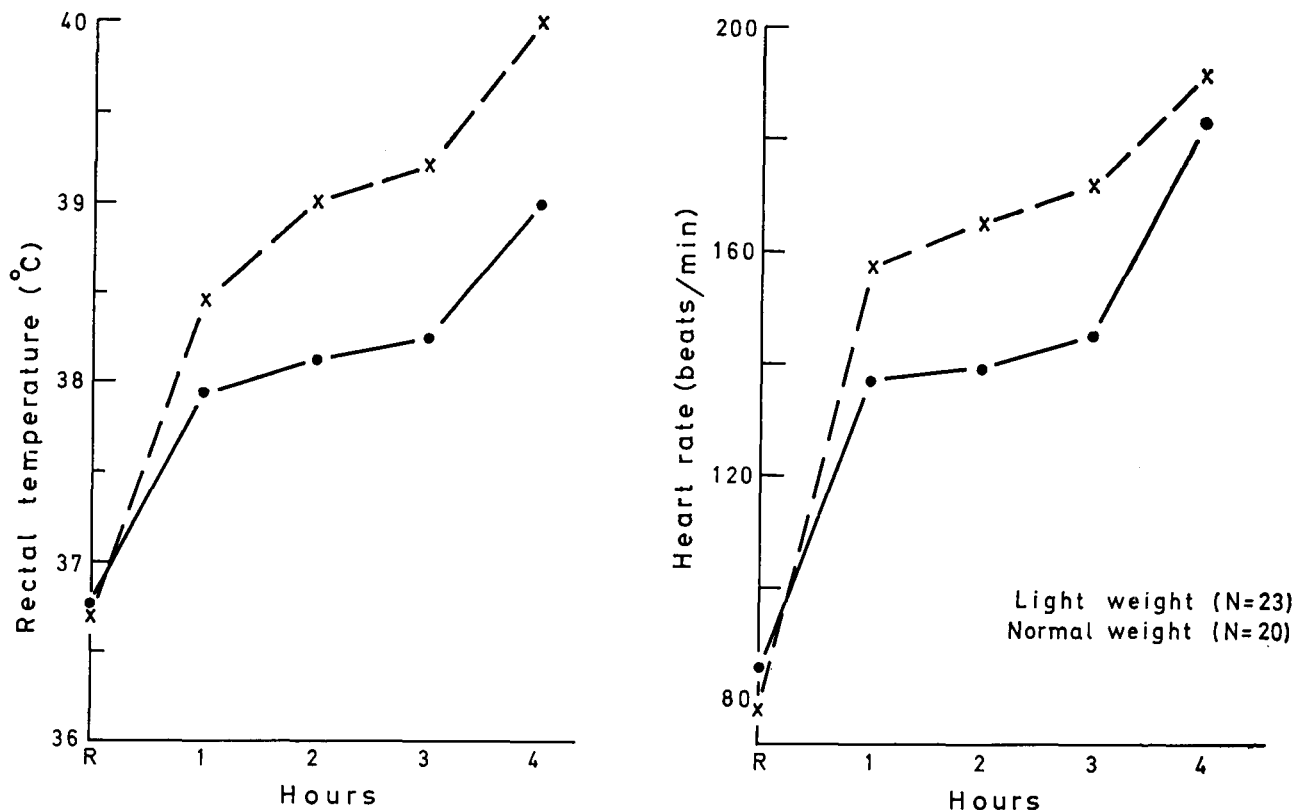


Fig 1—Physiological reactions of men of light and normal weight while performing work under identical conditions

The serious risk of heat stroke to which these underweight men are exposed on the first day of climatic room acclimatisation is shown clearly in Table II in which the rectal temperatures are given. On day 1, 18 of the 23 men (about 80 per cent) developed rectal temperatures of 40°C or above and in case No 19 the rectal temperature rose from 39,4 to 41,3°C in the course of the last hour. Not only was there this serious risk of heat stroke on day 1 but most of these underweight men failed to acclimatise to heat in the normal way. This is shown by the observations that on Day 8 there were still five men who developed rectal temperatures of 40°C or above (18 per cent) and that every man at some time on Day 8 had a rectal temperature of 39,0°C or above.

That these underweight men are more heat intolerant than men of normal weight is shown, firstly, in Fig 1 in which the average rectal temperatures of the 23 underweight men are compared with the average rectal temperature of 20 Bantu of normal weight. Secondly, of even greater importance, is that on Day 8 not one man of normal weight developed a rectal temperature of 40,0°C but five of the 23 underweight men did so.

The fact that these men developed severe physiological strain during the acclimatization procedure can also be seen from their heart rate responses in Fig 1. On the average the heart rates on Day 1 were 20 beats/min higher than the average of a normal group. The highest heart rate ever recorded at the Human Sciences Laboratory, namely, 214 to 216 beats/min, was measured

on one of these subjects on the first day of acclimatization.

DISCUSSION

For underweight men to exercise at the required work rate of 70 W, those weighing between 45 and 48 kg have to step at a height of 40,6 cm and those weighing between 40,8 and 45,4 kg have to step at a height of 43,2 cm. These were the stepping heights used in this study. Lightweight men stepping at these heights appear to be at a disadvantage compared with their heavier compatriots but it must be appreciated that the energy requirement in stepping at these heights is the same as that required for shovelling rock at the usual production rates. Therefore lightweight men are at a similar disadvantage when they are put onto the task of shovelling rock, underground.

The results of this study show that men who weigh less than 50 kg are more heat intolerant than heavier men. From the first day of the acclimatization procedure these men developed excessively high body temperatures. Rectal temperatures of 40°C+ and oral temperatures of 39,5°C+ were not uncommon; one man developed a rectal temperature of 41,3°C at the end of the 4th hour on Day 1. Moreover during the 8 day period of acclimatization there were no fewer than 10 occasions on which rectal temperatures of 40,6°C or above were recorded. Temperature rises of this order can be dealt with in a research laboratory but they could be dangerous

in the hands of the lay supervisors in routine acclimatization. In the present acclimatization procedure an oral temperature of 38,4°C or above on 5 consecutive days qualifies a man to be classified as heat intolerant and to be delegated to work in cool areas. In this group of 23 lightweight men, 22 had five consecutive days of such oral temperatures and would therefore have been regarded as heat intolerant. Perhaps the best measure of the failure of these men to acclimatise is that all the men developed oral temperatures of 38,4°C or above on day 8 and had to be rested and no fewer than 11 had rectal temperatures of 39,4°C or above. This study shows conclusively that our hypothesis is correct. Men who weigh less than 50 kg cannot be acclimatized by means of the present climatic room procedure.

Heat tolerance of low work capacity men has previously been shown to be lower than that of high capacity individuals³. The maximum oxygen intakes of these lightweight men was 2,02 litres/min compared with 2,63 litres/min of ordinary recruits. Their mean surface areas was 1,43 m² compared with 1,76 m² of ordinary recruits. Which of these two factors, a low maximum oxygen intake or a small surface area, is the more important in the poor heat tolerance of the underweight men is not clear from this study and requires further investigation.

CONCLUSION

Men weighing less than 50 kg cannot be acclimatized by the present climatic room procedures because of the

frequency with which they run excessively high body temperatures during the procedure and the high proportion of excessive body temperatures even on the last day of acclimatization.

Reasoning to the effect that underweight men have been employed on such tasks in the past without ill effects probably indicates that their work levels were far below those which can be expected for men of normal weight in hot conditions. If underweight men are used in shovelling and tramping then the work rate must be reduced if they are not to be subjected to excessive danger of heat stroke.

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