

Note: A revised method of heat acclimatization

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INTRODUCTION

Climatic-room acclimatization was introduced in the gold-mining industry in 1965 and was rapidly adopted by all mines because it reduced the number of days required for heat acclimatization from 12 to 8. The method has been adequately described in previous papers^{1, 2} but, briefly, requires four hours of heat exposure per day while the work rate is progressively increased from 35 W on Day 1 to 70 W on Days 7 and 8. Several attempts to shorten this and other heat-acclimatization procedures to 7, 6, 5, or 4 days have not been very successful because of the high risk of heat stroke still present amongst men so acclimatized²⁻⁴. In an attempt to combine the best attributes of the British and South African systems of heat acclimatization, Turk and Thomas⁵ were able to acclimatize only 68,7 to 85 per cent of their subjects in 4 and 5 days respectively, and they used the severely criticized short (2 hours) exposure technique to acclimatize and to assess the degree of acclimatization attained².

A significant breakthrough in shorter and more effective acclimatization procedures was, however, achieved with the introduction of vitamin C (ascorbic acid) supplementation⁶. Unfortunately, the initial approach to the procedure for vitamin C supplementation, in which individual differences were taken into consideration, was not only complicated but also created opportunities for malpractices. It was therefore decided to use a basic 5-day procedure that would retain all the safety features of the established 8-day method. In this paper, the revised acclimatization procedure is described in detail, and the results obtained in applying it are discussed.

METHOD

The following alterations to the normal climatic room procedures^{1, 2}

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were introduced at an East Rand acclimatization centre.

Vitamin C Supplementation

Every labourer was given a 250 mg tablet of ascorbic acid on the one to three days prior to heat acclimatization and also daily during the acclimatization procedure. The best time to administer the tablets during the acclimatization procedure was found to be immediately after the man has been weighed and before he enters the chamber. The tablet is swallowed with 200 to 300 cm³ of water. This supplementation was entirely independent of any other supplementation regime that may have been in operation at the hostel, and was the responsibility of the acclimatization personnel. A check at the hostels indicated that no vitamin C supplementation was given during the period of this study. Tablets are the preferred means of administration as they facilitate easy control of intake and dosage.

Days Eliminated and Stepping Rates

The normal 8-day procedure suitable for wet-bulb (W.B.) environments of 30 to 32,8°C was reduced to 5 days, the old 5-day routine (29,0 to 29,9°C W.B.) was shortened to 4 days, and the 3-day routine (27,5 to 28,9°C W.B.) remained 3 days. The days eliminated from the previous stepping routine were 3,5 and 7. The stepping rates on days 1 and 2 were re-arranged so that no high rates (24 per minute) were performed during the last half-hour. The new rates of stepping are summarized in Table I.

The first four days were to be used for the old 5-day procedure and the first 3 for the 3-day procedure. At the centre concerned, only the normal 8-day procedure was employed.

Absentees

Men absent for up to two days during their acclimatization period were allowed, on return, to continue at the stage at which the procedure was interrupted, but three or more

days of absence required recommencement. Men who, after heat acclimatization, were absent from the underground environment because of illness, injury, or surface training procedures for different periods of time, were re-acclimatized according to the specifications given in Table II.

High-temperature Cases

Any man who developed high oral temperatures (38,4°C or above) on three consecutive days was required to recommence from Day 1. A medical checkup was required after five consecutive high temperatures.

Clear Days Required

The last two days in the climatic room had to be free from high temperatures. This rule protects the individual who is less heat-tolerant from unnecessary risk of heat stroke after heat acclimatization.

All the other recommendations about heat acclimatization procedures^{1, 2} remained in force.

Members of the Industrial Hygiene Division kept close contact with the acclimatization personnel at the mine and were consulted whenever necessary. The records of the first 860 men to be acclimatized were forwarded to the laboratory for analysis. The average fourth-hour oral temperature (D5) of this group compared with that of an eight-day group is reported below.

As an assessment of the time-saving value of the new procedure, the acclimatization data for June and July 1975 were compared with those for September with respect to the number of days required for acclimatization. Finally, to answer the question whether acclimatization by the modified procedure is retained, groups of 20 men were withdrawn from underground 1, 2, 3, and 4 weeks after completing the revised acclimatization procedure, and were brought to the laboratory, where they were subjected to the normal heat stress test used to assess degree of heat acclimatization⁷. For purposes of comparison,

TABLE I
STEPPING RATES DURING ACCLIMATIZATION

Day of acclimatization	Number of steps/min for each half-hour of work (stepping periods in minutes)							
	0-30	31-60	61-90	91-120	121-150	151-180	181-210	211-240
1	12	12	12	12	12	12	24	12
2	12	12	24	12	24	12	24	12
3	12	24	12	24	12	24	24	24
4	12	24	24	24	24	24	24	24
5	24	24	24	24	24	24	24	24

TABLE II
ACCLIMATIZATION REQUIREMENTS FOR ABSENTEES

Maximum temperature of working area °C W.B.	Period of absence from work d	Days to be spent in climatic chamber
29,9	1 to 7	Re-acclimatization not required
	8 to 14 15 to 21 22 or more	Days 3 and 4 Days 2, 3, and 4 Days 1 to 4
33,0	1 to 7	Re-acclimatization not required
	8 to 14 15 to 21 22 or more	Days 3, 4, and 5 Days 2, 3, 4, and 5 Days 1 to 5

TABLE III

A CLIMATIC ROOM DATA — 8-DAY ACCLIMATIZATION PERIOD FOR THE MONTHS OF JUNE AND JULY 1975

No. of days		8	9	10	11	12	13	14	15+	Totals
June	Men	879	70	36	13	18	18	10	31	1075
1975	Shifts	7032	630	360	143	216	234	140	538	9293
July	Men	640	71	36	27	11	19	25	31	860
1975	Shifts	5120	639	360	297	132	247	350	485	7630
Total	Men	1519	141	72	40	29	37	35	62	1935 16923
Percentages		78,5	7,3	3,7	2,1	1,5	1,9	1,8	3,2	

B 5-DAY ACCLIMATIZATION PERIOD (VIT. C) FOR SEPTEMBER

No. of days	5	6	7	8	9	Totals
No. of men	1228	48	25	45	16	1362
No. of shifts	6140	288	175	360	176	7139
Percentages	90,16	3,52	1,8	3,3	1,17	

TABLE IV
FOURTH-HOUR ORAL TEMPERATURES

Basic acclimatization	Supplementation	Mean °C	Standard deviation	n
5 days	250 mg of ascorbic acid	37,66	0,2466	860
8 days	Placebo	37,77	0,2602	99

a group that had just completed their rapid acclimatization was similarly tested before going underground.

RESULTS

As there was some confusion at the mine about the correct procedure during the first two weeks after the introduction of the shorter method, only the results obtained during September 1975 are considered. During that month, a total of 1362 men were acclimatized by the revised method, and the periods required for the acclimatization of all the men are summarized in Table III, together with the data for June and July 1975.

Table IV compares the fourth-hour oral temperatures of the first 860 men on their last day of acclimatization on the basic five-day (vitamin C supplementation) procedure with those of 99 subjects acclimatized on the normal eight-day procedure. An *F*-test was used to compare the variances in fourth-hour oral temperatures obtained from the two groups, and the Students's *t*-test was used to compare the mean fourth-hour oral temperatures.

No significant differences could be shown to exist between the two different periods of acclimatization with respect to variance in fourth-hour oral temperature at the 5 per cent level of significance:

$$F=1,114; V_1=98; V_2=859.$$

However, the two periods of acclimatization could be shown to differ significantly with respect to mean fourth-hour oral temperature on their respective last days of acclimatization at the 0,1 per cent level of significance:

$$t=3,9273; df=957.$$

The average physiological responses of the groups withdrawn from underground or brought from the climatic centre and tested at the laboratory at an environmental temperature of 32,2°C W.B. (33,9°C dry bulb) and working at 35W are given in Table V.

The results in Table V must be compared with the average responses of 18 highly acclimatized and 22 unacclimatized men used previously on the same test to determine the effectiveness of acclimatization pro-

TABLE V
MEAN RESPONSES OF GROUPS WITHDRAWN FROM UNDERGROUND

Days underground	Rectal temperature °C					Heart rate beat/min					Sweat rate ml/h				n
	R	1	2	3	4	R	1	2	3	4	1	2	3	4	
0 M SD	37,16 0,27	38,00 0,20	38,10 0,24	38,17 0,30	38,40 0,34	74 10,0	111 7,7	117 10,8	123 11,8	130 15,1	550 23	631 23	484 22	605 23	18
7 M SD	37,20 0,31	37,92 0,34	38,07 0,37	38,07 0,47	38,26 0,45	73 10,7	112 13,3	115 15,3	122 15,6	126 16,9	505 16	596 22	421 18	468 23	20
14 M SD	36,60 0,47	37,99 0,36	38,08 0,32	28,22 0,33	38,19 0,33	74 13,4	119 13,4	124 13,9	128 15,1	128 15,4	548 16	517 22	886 53	540 39	17
23 M SD	36,92 0,41	37,97 0,31	38,04 0,32	38,09 0,36	38,19 0,35	66 13,9	117 16,4	118 17,5	119 18,9	123 17,9	490 18	614 19	436 20	486 16	20
28 M SD	37,05 0,38	37,86 0,31	38,04 0,26	38,22 0,40	38,30 0,45	65 10,0	117 11,9	121 12,7	126 15,8	131 17,8	329 15	565 30	492 36	243 13	19

cedures on mines⁷. Student's *t*-tests indicate that all the values for rectal temperature, heart rate, and sweat rate obtained during heat exposure from the five different groups brought from the mine are significantly different from those of 22 unacclimatized men, and not significantly different from those of 18 fully acclimatized subjects. No difference could be shown to exist between the five groups, and their combined values also do not differ from those of highly acclimatized men. The average first-, second-, third-, and fourth-hour rectal temperatures of the combined group are as follows: 37,95°C, 38,07°C, 38,15°C, and 38,25°C. In Fig. 1 the acclimatized values of a vitamin C supplemented group are compared with those of fully acclimatized and unacclimatized men.

DISCUSSION

Irrespective of the contribution of vitamin C, the time-saving value of the new procedure cannot be contested. With the old procedure it took 16 923 shifts to acclimatize 1935 men, or about 8,75 days per man to gain full acclimatization, and only 78,5 per cent of them successfully completed the process within the stipulated 8 days. Some men spent as long as 15 to 18 days in the climatic room. The demoralizing effect of such a long stay in the climatic room must have been devastating, and must have been a contributing factor to the high rate of absenteeism recorded among men being acclimatized. It must be mentioned that the position at other mines is certainly no different from

that at the mine at which the work was undertaken, and in some it is certainly worse.

In the revised procedure, the average time to acclimatize a labourer is 5,2 days, and the average saving effected is therefore 3,5 days per man. In the mine at which the study was done, this means a saving of 4767 shifts for September. The percentage of men acclimatized within the stipulated 5 days was 90,2 per cent, and 98,8 per cent of the September group was acclimatized within 8 days.

The financial aspect of the number of shifts saved by the vitamin supplementation procedure is not assessed in this discussion, but this saving will be significant in several respects. Many climatic centres are at present operated round the clock. With the shorter method, the men will pass through the centres very much faster, and some acclimatization shifts may therefore be dropped. This would also relieve supervisors for other tasks.

The morale of the men being acclimatized has improved considerably; the number of cases sent to hospital has decreased, and complaints about sore legs are now seldom heard.

The comparison between vitamin C assisted acclimatization (5-day) and placebo acclimatized men (8-day) with respect to fourth-hour oral temperature on the final day indicates that the new procedure is safe and effective. The 860 subjects (5 days) attained a higher level of heat tolerance as assessed by fourth-hour oral temperature

response than the 99 men on the normal 8-day climatic room procedure (Table V). It should be noted that the work rate on the final day of the 5-day procedure is exactly the same as that on the final day of the 8-day procedure.

The test in the climatic room also indicates that the 5-day (vitamin C) procedure results in a very satisfactory state of heat acclimatization. The rectal temperatures and heart rates of the 18 men tested were not significantly different from those for highly acclimatized men (Fig. 1), but they were significantly different from those of unacclimatized men. In fact, the vitamin C group would have earned an A rating on the test originally used to determine the effectiveness of acclimatization procedures on mines⁷. This confirms the results previously reported⁶ that the mean fourth-hour rectal temperature on the last day (vitamin C) was 38,48°C, as against 38,66°C on the final day for men acclimatized for 8 days.

Laboratory tests further indicate that men acclimatized by the vitamin-assisted procedure do not lose this acclimatization while working underground, even though no further vitamin supplementation is given (Table V). In fact, men even improve their state of heat acclimatization during the 1 to 3 weeks after the completion of the acclimatization process. This should, however, not be used as evidence that vitamin supplementation in the hostels is not necessary. The advice given by Visagie *et al.*⁸ that all Black labourers should be given a daily supplement of vitamin

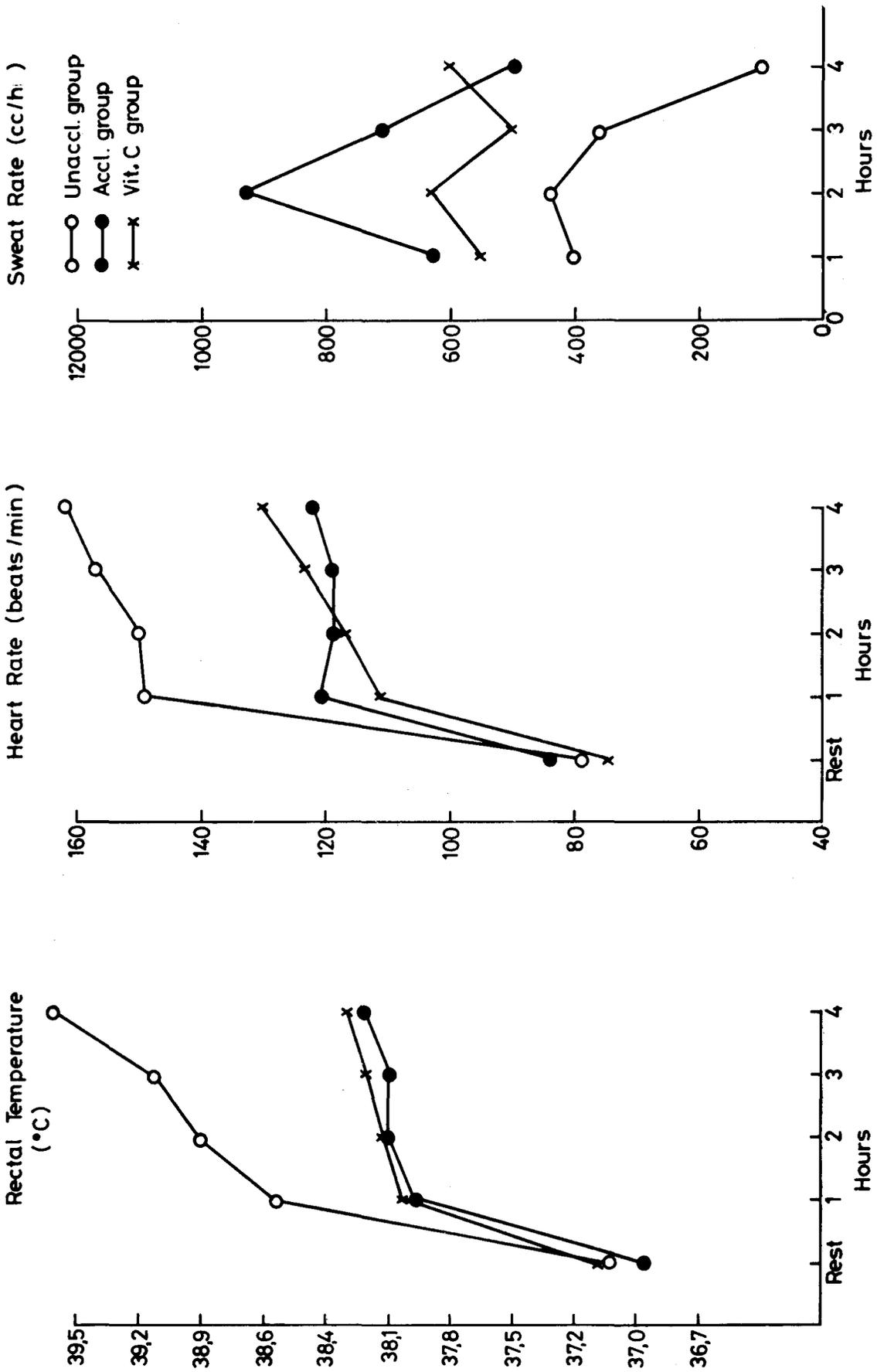


Fig. 1—Comparisons between unacclimatized, acclimatized, and vitamin-supplemented groups of men

C remains sound and is to be recommended.

CONCLUSION

The revised climatic room procedure has been proved to be safe, to be more economical in the number of shifts required for full acclimatization, and to be well-liked by those who have to undergo it. It is therefore recommended that the method should be introduced at all acclimatization centres.

ACKNOWLEDGEMENT

This study would not have been possible without the valuable assist-

ance of the E.R.P.M. management and staff. The contribution of other members of the Industrial Hygiene Division is also acknowledged.

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