

A comparison of the effectiveness of five-, seven-, eight-, and nine-day acclimatization procedures

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SYNOPSIS

Groups of up to twelve new recruits to the industry were subjected to climatic room acclimatization for either five, seven, eight or nine days prior to being tested for the degree to which they had been acclimatized. These tests were done at 32,2°C (wet bulb) at a wind velocity of about 0,4 m/sec and the men worked for four hours at a rate of 215,6 kg m/min on one day and at a rate of 431,2 kg m/min on the second day. The results indicated that there is no significant difference between the degrees of acclimatization obtained by the eight- and nine-day procedures which confirms the conclusions drawn in a previous report¹. The eight-day procedure can thus be claimed to be perfectly adequate and safe. Decreasing the period of exposure to five or seven days would however, not be justified because of the significant differences in physiological responses that were observed on both test days between men acclimatized for these periods and those acclimatized for nine days. It is concluded that it would be unsafe to employ these shorter periods of acclimatization when underground environmental temperatures at which the men are to work, exceed 31°C (wet bulb).

INTRODUCTION

In an internal report to the Chamber of Mines it was concluded that ' . . . although better acclimatization is achieved by the nine-day procedure, it would be quite safe to reduce the period of heat exposure in climatic rooms to eight days'. A period of exposure to heat of eight days is therefore commonly used by all mines where the wet bulb temperatures of underground working areas exceed 31°C³. A five-day procedure is employed by mines in which the wet bulb temperatures are 31°C and below. The use of these procedures has been fairly successful as was revealed in a recent survey of the heat stroke cases which occurred during the period 1965 (the first year in which climatic room acclimatization was employed) to 1969¹.

In spite of the considerable savings associated with the introduction of climatic room acclimatization³, mine managements requested the Laboratory to investigate the possibility of reducing the acclimatization period still further. In the previous study on this issue³ only the eight- and nine-day procedures were compared and the subjects used for this comparison were the ordinary 'run of the mill' recruits to the industry. Only 30 per cent of the men were new recruits. No statistically significant differences between the degrees of acclimatization achieved by the eight- and nine-day procedures were detected and the question arises therefore whether differences would be detected between the extent of acclimatization achieved by five-, six-, seven-, and nine-day procedures. This paper contains the details of, and the conclusions drawn from, a study in which such a comparison was made. The study was made on new recruits to the industry.

METHOD

Groups of nine to 12 new recruits to the industry were subjected to acclimatization in a climatic room for 5, 7, 8 or 9 days at a temperature of 31,7°C (wet bulb). The official acclimatization procedure¹ was changed slightly in order to provide the men with the best possible combination of work load and heat to permit them to become fully acclimatized. The standard day used were the following:

5 day procedure: Days 1, 3, 4, 5, 7

7 day procedure: Days 1, 3, 4, 5, 6, 7, 8

9 day procedure: Days 1, 2, 3, 4, 5, 6, 7, 8, 8

On the completion of the acclimatization period the men underwent two step tests on successive days, one at 215,6 kilogram meters per minute (35 Watts) and the other at 431,2 kilogram meters per minute (70 W), at 32,2°C wet bulb and 34°C dry bulb temperature. The tests occupied four hours each day and at the end of each hour various measurements were made. In the analysis described in this paper, only heart rate and rectal temperature were used. On both test days those men whose rectal temperatures rose to 40°C were withdrawn from the test.

ANALYSIS OF RESULTS

In Table I the average heart rates of the subjects at rest and at the end of each hour of test day 1 are shown for the four groups.

TABLE I
TEST DAY 1: AVERAGE HEART RATES

Hour	5-day	7-day	8-day	9-day
Rest	72,9	70,7	65,1	71,3
1	121,3	126,9	122,4	118,4
2	128,0	133,8	125,3	120,4
3	134,0	134,9	131,8	122,6
4	137,8	140,4	134,2	124,7

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One-way analysis of variance showed that from the second hour onwards there were differences, which are significant at the 5 per cent level, between the averages of the four groups. In the second hour 120,4 is significantly lower than 133,8. In the third hour 122,6 is significantly lower than both 134,9 and 134,0. In the fourth hour 124,7 is significantly lower than both 140,4 and 137,8.

By using the nine-day acclimatized heart rate and body temperature averages as indicating 100 per cent acclimatization and previous figures for unacclimatized men as representing no acclimatization, the extent of the acclimatization achieved by each of the other procedures has been estimated. The extent of acclimatization calculated on the basis of average heart rates on test day 1 are shown in Table II.

TABLE II

TEST DAY 1: EXTENT OF ACCLIMATIZATION BASED ON AVERAGE HEART RATES

Hour	5-day	7-day	8-day
1	86%	59%	81%
2	74%	53%	83%
3	75%	73%	80%
4	70%	64%	78%

In Tables III and IV are shown the average heart rates for the first two hours of test day 2, and the extent of acclimatization based on them. Only the values for the first two hours could be compared because 22 per cent of the subjects from both the five- and seven-day groups had to be withdrawn before the third hour measurements could be made as they had developed body temperatures exceeding 40,0°C. All the subjects from the eight- and nine-day groups completed at least three hours of the severe test.

TABLE III

TEST DAY 2: AVERAGE HEART RATE

Hour	5-day	7-day	8-day	9-day
Rest	68,2	67,3	71,1	70,2
1	164,0	157,8	155,7	150,4
2	165,6	158,9	159,1	155,3

One-way analyses of variance showed that there were differences for the first hour which were significant at the 5 per cent level. Heart rates of 150,4 and 155,7 are both significantly lower than 164,0, and for the second hour 155,3 is significantly lower than 165,6.

TABLE IV

TEST DAY 2: EXTENT OF ACCLIMATIZATION BASED ON AVERAGE HEART RATES

Hour	5-day	7-day	8-day
1	61%	79%	85%
2	65%	88%	87%

In Tables V, VI, VII, and VIII the corresponding figures based on rectal temperature are shown.

TABLE V

TEST DAY 1: AVERAGE RECTAL TEMPERATURE

Hour	5-day	7-day	8-day	9-day
Rest	36,8	36,6	36,5	36,8
1	37,4	37,5	37,4	37,5
2	38,1	38,0	38,0	37,8
3	38,2	38,2	38,1	37,9
4	38,4	38,5	38,2	38,0

Although the average rectal temperature for the nine-day group was lower than the averages for the other groups in the third and fourth hours, the differences were not significant at the 5 per cent level.

TABLE VI

TEST DAY 1: EXTENT OF ACCLIMATIZATION BASED ON AVERAGE RECTAL TEMPERATURE

Hour	5-day	7-day	8-day
1	100%	100%	100%
2	64%	73%	100%
3	65%	75%	83%
4	70%	61%	83%

Although it is stated above that the differences between corresponding averages in Table V are not significant, Table VI shows estimates of 'extent of acclimatization' which differ from 100 per cent. This may be explained by saying that the indications are that the different acclimatization procedures produce different average rectal temperatures but that it is not possible to state, with 95 per cent confidence, that this is, in fact, so.

TABLE VII

TEST DAY 2: AVERAGE RECTAL TEMPERATURES

Hour	5-day	7-day	8-day	9-day
Rest	36,7	36,6	36,8	36,7
1	38,9	38,4	38,3	38,2
2	39,4	39,3	39,1	38,7

The one-way analyses of variance show that there are significant differences for both the first and second hours. In the first hour 38,2, 38,3 and 38,4 are all three significantly lower than 38,9. In the second hour 38,7 is significantly lower than both 39,3 and 39,4.

TABLE VIII

TEST DAY 2: EXTENT OF ACCLIMATIZATION BASED ON AVERAGE RECTAL TEMPERATURE

Hour	5-day	7-day	8-day
1	61%	85%	91%
2	59%	68%	79%

DISCUSSION

The previously reported finding of a lack of significant differences between the degrees of acclimatization produced by the eight- and nine-day procedures³ has been confirmed by the results of the present study. It must, however, again be conceded that the nine-day acclimatization procedure produces a better result than the eight-day procedure. This is shown clearly in Tables II, IV, VI and VIII in which the percentage acclimatization attained demonstrates the short-comings of the different methods tested. If heart rate is used as the criterion of extent of acclimatization then the eight day procedure produces only about 80 and 86 per cent of the effect achieved by the nine-day procedure when the subject does moderate and hard work in heat respectively. When judged by rectal temperature response, the eight-day procedure produces on the average 91 and 85 per cent of the extent of acclimatization produced by the nine-day procedure for moderate and hard rates of work, respectively. Provided that all those men who are heat-intolerant (that is, those who develop oral temperatures of 38,0 °C or above on five consecutive days) are eliminated and that no man is transferred from the acclimatization centre unless he has had two consecutive 'clear' days as regards body temperature, the extent of acclimatization achieved by the eight-day procedures should be more than adequate to safeguard labourers against the possibility of heat stroke when they are required to work in environments of 31 to 33 °C (Wet bulb).

If there is any doubt regarding the adequacy of the eight-day acclimatization procedure for adapting men to work at environmental wet bulb temperatures higher than 31 °C then the seven- and five-day procedures must be ruled out entirely. Significant differences were detected between the heart rate and rectal temperature responses during the five- and seven-day procedures. Heart rate response is an indication of physiological strain and in Table I it is shown clearly that even for a moderate rate of work in heat the men in the five- and seven-day groups had significantly higher heart rates than those men in the nine-day group.

The degree of acclimatization produced by the shorter periods of acclimatization (Tables II, IV, VI and VIII) hardly exceeds 75 per cent. The fact that first-hour values obtained on both test days indicated only very small differences between the physiological responses

of the various groups was referred to before³, and it was emphasised that a two-hour heat stress test must be regarded as inadequate to determine the true extent of heat acclimatization. Even a period of five days of acclimatization would result in an increase in mechanical efficiency, an improved circulatory system, better heat dissipation and, therefore, definite signs of heat adaptation during short periods of exposure to heat. Third- and fourth-hour values are, however, the determining factors and on the basis of percentage acclimatization achieved, the five- and seven-day acclimatization procedures must be regarded as being inadequate for proper acclimatization to the heat stress of working hard at a wet bulb temperature of 32,0 °C. It must, therefore, be concluded that it would be unsafe to employ these shorter periods of acclimatization for men required to work underground in environments in which the wet bulb temperature exceeds 31,0 °C.

Not only would these shorter periods produce inadequate acclimatization but the risk of heat stroke during the acclimatization period would also be too great. A large number of recruits to the gold mines are actually incapable of moderate to hard physical labour and time is required in which to build them up to normal nutritional and physical condition⁴. The increase in work rate from 215,6 kg m/min (35 W) to 431,2 kg m/min (70 W) during the shorter five-, six-, or seven-day procedures is too rapid and the men tend to develop excessively high body temperatures from the second day of the acclimatization procedure. On the third day, for instance, the oral temperature of one of these men increased from 37,7° to 39,5 °C (rectal 40,6 °C) in one hour. Ten instances of rectal temperatures of higher than 39,0 °C were observed in the five- and seven-day groups on the third day while none was recorded in the eight- and nine-day groups.

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