Intermittent exposures to heat, and the retention of heat acclimatization

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SYNOPSIS

Twenty-one heat acclimatized subjects were assessed for the degree of acclimatization attained with respect to heart rate, rectal temperature, and sweat rate during a standard four-hour heat-stress test. Thereafter, they were put on light duties in cool environments for four weeks, except for four hours of exposure to heat every seventh day. Their state of heat acclimatization was again assessed two days after the final week's exposure. Although heart rates and body temperatures showed significant increases over the initial values, no differences were observed in sweat rates and, in general, the subjects were rated as still adequately acclimatized to heat.

SAMEVATTING

Een-en-twintig hitte-geakklimatiseerde proefpersone is gedurende 'n standaard vier-uur hittespanningstoets ondersoek om die mate van akklimatisasie wat bereik is met betrekking tot polsslag, rektaaltemperatuur en sweetvermoë vas te stel. Daarna het hulle ligte werk in koel omgewings vir vier weke gedoen, behalwe vir 'n vier-uur blootstelling aan hitte elke sewende dag. Hulle mate van hitte-akklimatisasie is weereens bepaal twee dae na blootstelling gedurende die finale week. Hoewel polsslag en liggaamstemperatuur 'n beduidende toename bo aanvanklike waardes getoon het, kon geen verskil in sweetvermoë waargeneem word nie. Oor die algemeen kon die proefpersone as steeds voldoende geakklimatiseerd beskou word.

INTRODUCTION

Acclimatization to heat has been shown to be a rather temporary physiological state that can be lost rapidly[1, 2]. Wyndham and Jacobs[3], Williams *et al.*[4], and Adam *et al.*[5], state that significant losses occur within six to seven days, and most researchers agree that heat acclimatization is lost almost entirely if the subject is not exposed to heat for three to four weeks. Loss of acclimatization is a matter of great concern to the gold-mining industry, in particular in men who are brought up from underground for training periods of three to five weeks. At present, these men have to be re-acclimatized in full after their training has been completed. The argument has been put forward also that, apart from the obvious loss in productivity, these men lose some of the training concepts during the re-acclimatization period. Without re-acclimatization, however, they run the risk of developing heat stroke.

If it were at all possible to decrease the loss of acclimatization by intermittent exposures to heat, such an approach would save time, would eliminate any possible discontent, and would increase general productivity. The study reported here was an attempt to achieve this goal by exposing men to heat once every week during an absence of a month from underground work.

METHODS

Twenty-one subjects who had been absent from underground work for more than six months, and who had the physical characteristics given in Table I, were acclimatized to heat for eight days according to the accepted climatic-room acclimatization procedure[6]. On the day following this procedure, they were subjected to the standard heat-stress test, namely four hours of working at 35 W in an environment in which the wet-bulb temperature was 32,3 °C, the dry-bulb temperature 33,8 °C, and the wind velocity about 0,5 m/s (Test 1).

For the next four weeks, the subjects did general cleaning tasks in relatively cool environments (20 to 22 °C) in and around the laboratory, but were exposed every seventh day to the Day-8 routine of the climatic room acclimatization procedure (70 W, 31,7 °C WB, 33,3 °C DB, WV *ca* 0,5 m/s). Two days after their fourth exposure, they

TABLE I
PHYSICAL CHARACTERISTICS

Subject	Age y	Height cm	Initial weight kg	Work cap. category	Heart rate beat/min
A	25	169,9	68,40	A	108
B	46	167,2	74,70	B	124
C	22	175,4	65,15	B	124
D	23	179,3	71,45	A	96
E	27	162,3	60,70	A	104
F	23	170,1	61,55	A	104
G	43	166,0	55,40	A	112
H	21	165,6	65,85	A	110
I	39	170,8	66,25	A	114
J	23	164,6	60,20	A	110
K	20	162,4	55,00	A	110
L	25	166,8	57,10	B	124
M	29	166,8	62,05	A	100
N	26	176,8	69,20	A	112
O	23	162,8	56,40	A	114
P	27	167,8	61,05	B	124
Q	19	170,2	58,17	A	112
R	20	162,6	57,55	A	94
S	20	165,4	57,15	A	100
T	30	162,3	59,35	A	88
U	19	165,3	52,85	A	112

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were again subjected to the standard heat-stress test (Test 2). Student's *t*-tests were used to compare the results obtained.

RESULTS

The results of the two tests on the state of heat acclimatization of the subjects are given in Table II, together with Student's *t*-test calculations. Except for sweat rate, significant differences were found between the results obtained after acclimatization and those recorded after four weeks of intermittent exposure to heat. Heart rates increased by 9 to 17 beats per minute, and rectal temperatures were 0,3 to 0,5 °C higher after the four weeks of intermittent exposure.

To assess the true state of heat acclimatization of these subjects, their physiological responses during Tests 1 and 2 were compared with those obtained on unacclimatized and fully acclimatized men. A similar procedure was used in the development of a standard test for determining the effectiveness of heat-acclimatization procedures on the mines[7]. These comparisons are shown in Fig. 1.

In Table III, the mean fourth-hour heart rates and rectal temperatures of fully acclimatized and unacclimatized men are compared with those of the present group on their last exposure. Student's *t*-test analysis indicates that the mean rectal temperature of the experimental group was significantly higher than that of the fully acclimatized men (2 per cent level), but also significantly lower than that of the unacclimatized men (0,1 per cent level). The mean heart rate for the intermittently exposed subjects could not be shown to differ significantly from that of the fully acclimatized group at the 10 per cent level of significance. It could, however, be shown to be significantly lower than that of the unacclimatized group at the 0,1 per cent level.

DISCUSSION

Even with intermittent exposures once a week, a significant amount of heat acclimatization, as gauged by heart rates and rectal temperatures, was lost over a period of four weeks (Table II). Average hourly heart rates and rectal temperatures were all significantly higher during the final test than those during the test done immediately after acclimatization. If the average heart rate and body temperature observed during Test 1 is regarded as representing 100 per cent acclimatization, and if previous figures for unacclimatized men[7] are used as representing no acclimatization, the relative amount of heat acclimatization lost can be calculated. On average, these losses amount to about 25 per cent of the previously attained heat acclimatization. These losses are significantly less than those reported for *one* week by Williams *et al.*[4], who found losses of 50, 40, and 60 per cent per week respectively for heart rate, rectal temperature, and sweat rate.

In an attempt to assess the time at which the major losses in acclimatization occur, the observations obtained on the eighth day of the acclimatization procedure were tabulated with those for the weekly intermittent exposures. These results are given in Table IV, but it must be emphasized immediately that they are not comparable with the results obtained in the standard heat-stress test because the work rates and environmental temperatures were different. Inspection of the data in this table indicates that the major losses occurred within the first week of absence from heat. For example, the average fourth-hour heart rate increased from 146 to 165 beats per minute within the first week, with no further increase thereafter. The same position holds for all the other hours and also for rectal temperatures and sweat rates.

Retention of Acclimatization

Intermittent exposures certainly resulted in a marked retention of heat acclimatization in that no difference in total sweat rates was observed between Tests 1 and 2. This observation is most encouraging in the light of the finding[4] that the ability to produce increased amounts of sweat rapidly deteriorates with loss of acclimatization. If a change in sweat rate is regarded as a sensitive index of loss of acclimatization, the significant differences found in heart rates and rectal temperatures between the two assessment tests cannot be too serious. The high degree of acclimatization achieved before Test 1 may have influenced these results.

For a real assessment of the extent of heat acclimatization retained by the subjects after four weeks of intermittent exposure, comparisons would have to be made with the accepted standard physiological requirements for fully acclimatized

TABLE II
RESULTS AND STATISTICAL ANALYSIS

Parameter	Time	Test 1 $(\bar{x})$	Test 2 $(\bar{y})$	$\bar{x}-\bar{y}$	t	df	p
Heart rate (beat/min)	1	102,0	111,2	− 9,2	−3,658	20	0,005
	2	105,6	117,9	−12,3	−4,209	20	0,001
	3	108,8	123,0	−14,2	−5,098	20	0,001
	4	112,8	129,4	−16,6	−6,388	20	0,001
Rectal temperature (°C)	1	37,48	37,75	− 0,27	−5,500	20	0,001
	2	37,72	38,08	− 0,36	−5,915	20	0,001
	3	37,80	38,23	− 0,43	−5,857	20	0,001
	4	37,94	38,40	− 0,46	−6,549	20	0,001
Sweat rate (ml/4 h)	Total	1991,2	2027,9	−36,7	−0,347	20	0,70

TABLE III
COMPARATIVE DATA

Group	Parameter	Mean (4th h)	N
Fully acclimatized	Heart rate	122,33	18
	Rectal temp.	38,14	18
Intermittent exposure	Heart rate	129,43	21
	Rectal temp.	38,40	21
Unacclimatized	Heart rate	161,91	22
	Rectal temp.	39,54	18

TABLE IV
RESPONSES ON DAY 8 AND INTERMITTENT EXPOSURES

	Heart Rate, beat/min					Rectal Temperature, °C					Sweat Rate, ml/h				
	D8	1 wk	2 wk	3 wk	4 wk	D8	1 wk	2 wk	3 wk	4 wk	D8	1 wk	2 wk	3 wk	4 wk
Resting	65	69	72	71	73	36,6	36,9	37,0	37,0	36,9	—	—	—	—	—
1 h	135	146	150	151	152	38,1	38,3	38,6	38,6	38,5	962	813	840	886	899
2 h	139	155	157	156	158	38,5	38,7	38,9	38,9	38,9	1047	920	915	805	813
3 h	141	158	164	162	162	38,6	38,9	39,1	39,2	39,1	776	767	677	652	668
4 h	146	165	163	162	159	38,8	39,1	39,1	39,0	39,0	536	511	557	454	456

men. In Fig. 1, the results of this study are compared with those previously reported for 18 fully acclimatized and 22 unacclimatized subjects[7].

The marked differences in rectal temperatures and heart rates during Tests 1 and 2 are immediately noticeable. It is also obvious that the present group (Test 1) had significantly lower values (0,1 to 1,0 per cent level) than those recorded for the standard acclimatized men. The low average heart rates must be regarded as exceptional for this heat-stress test, and are definitely lower than any previously recorded at this laboratory. The high capacity of the subjects for physical work must be the major reason for their good performances. The re-test results (Test 2) indicate that the intermittently exposed group compares favourably with the fully acclimatized subjects in regard to heart rates and rectal temperatures. During the first two hours, they still maintained their advantage of better acclimatization, but they were slightly worse off than the standard group during the final two hours. Only their average of fourth-hour rectal temperatures was shown to be statistically significantly higher (2 per cent level) than that of the fully acclimatized group.

Comparison with the data for unacclimatized subjects indicates that the intermittently exposed group remained fairly well-acclimatized. Their average rectal temperatures and heart rates were significantly lower (0,1 per cent level) than those obtained for the unacclimatized group. According to the previous test[7] on the effectiveness of acclimatization procedures, this group would have qualified for an A rating and were thus still very well adapted to heat.

Practical Applications

Intermittent exposure to heat on every seventh day of absence from underground work decreases the extent of the loss of heat acclimatization, but does not necessarily prevent such a loss. The extent of acclimatization retained is, however, sufficient to safeguard the individual against heat stroke, especially as the men involved would not normally be required to do such strenuous tasks as shovelling.

Exposure to heat should be arranged on every seventh day, and, if any weekly acclimatization session is missed, or if the interval between exposures is more than seven days, this procedure should be discarded in favour of existing acclimatization arrangements. The danger that men may develop excessive body temperatures during such intermittent exposures is already fairly high, and failure to follow this recommendation would make this risk totally unacceptable. The usual precautions and procedures used in climatic rooms should be observed.

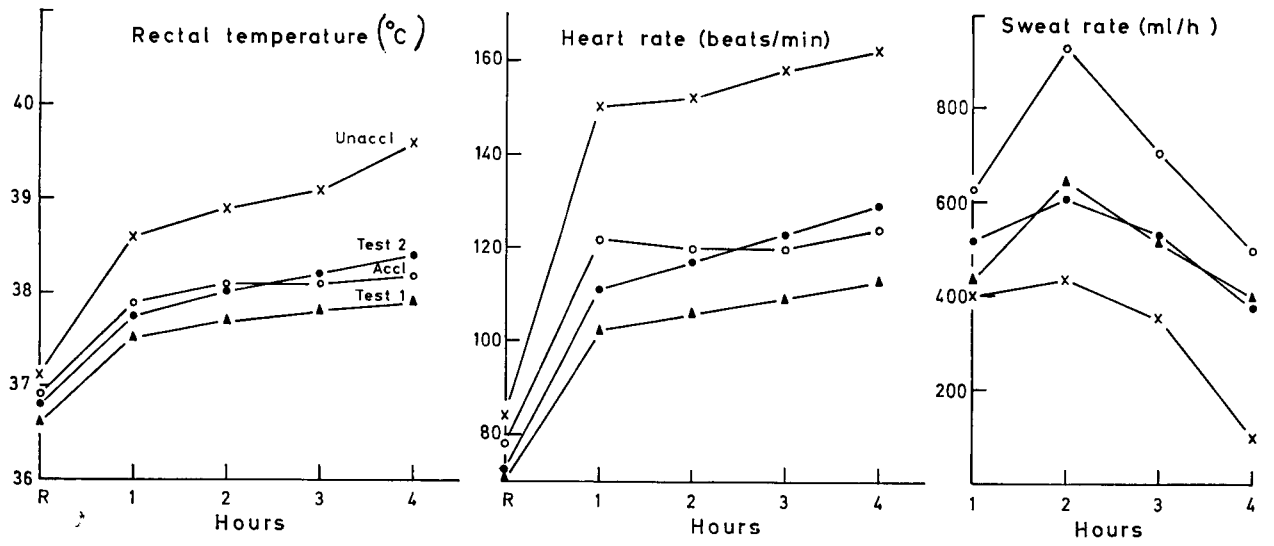

Fig. 1—Physiological responses, which prove that heat acclimatization can be retained with intermittent exposure to heat during an absence from working daily in heat

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