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SHORT HEAT EXPOSURE FOR ACCLIMATION

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EXPOSURE FOR ACCLIMATION

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ABSTRACT

Eighteen young adults were subjected to daily treatments of (a) 30 minutes of either light negative and/or moderate to heavy positive work on a laddermill at 22°C followed by (b) 30 minutes of either 3.5 mph walk at 50°C/25°C db/wb room temperatures or sitting under these ambient conditions with additional radiant heat, for 4 days. Their state of acclimatization was tested by exposure, up to 120 minutes, to 50°C/25°C db/wb using the following specific criteria: tolerance time (t) to 3.5 mph walk; elevation of heart rate (HR) and rectal temperature (T_{re}); fall in mean skin temperature (\bar{T}_{sk}); and change of sweating (s). Following the 4 day treatments the acclimatization state improved but not always having reached its final stage. Compared to the final stage, it has reached on the average, 91% of t , 72% of the decrease in HR , 56% of the decrease in T_{re} , 45% of the fall in \bar{T}_{sk} , and no change in s . These changes were similar to those obtained on a group subjected to 4 days of standard heat exposure and compared favorably with those reported by others for the first 4 days of the conventional method of daily 100-120 minute exposures to work in the heat. A method of stints of exercise at room temperature followed by short heat exposures might prove an efficient method of acclimatization for large groups when time and hot spaces are wanting.

rapid acclimatization. Laddermill exercise

//

That acclimatization could be acquired as rapidly as within one week by using daily one and a half to two hours exercise in the heat was noticed quite a while ago in this country (9, 14, 15) and abroad (4, 17, 20, 21). Wyndham questioned the effectiveness of such short daily exposures when acclimatization is required for workers engaged in prolonged daily heat exposures (21). However, his team did confirm the accomplishment of acclimatization within 6-8 days (20).

Exercise, under temperate to cool ambient conditions, has been shown to be somewhat synergistic to heat, in promoting acclimatization (5, 3). This is explainable on ground of the apparent common responses to heat acclimatization and to acquisition of physical fitness, namely; the progressive improvement in the cardiovascular efficiency and, in the drive for sweating, in as much as body core and skin temperatures are elevated by the employed exercise (16).

The relationship between the drive for sweating (S_w) and the elevation in core body (T_c) and mean skin (\bar{T}_{sk}) temperatures above threshold levels (T_{co} , T_{sko}) during exercise under a wide range of ambient air temperatures seems to be linear (16 19).

$$S_w = A(T_c - T_{co}) + B(\bar{T}_{sk} - \bar{T}_{sko})$$

Where the A to B ratio is 8/2, indicating a smaller influence on the thermoregulatory responses from \bar{T}_{sk} as compared to T_c .

Since this S_w , T_c , \bar{T}_{sk} relationships has been established empirically we have theorized that exercise induced elevation in core temperature, outside a heated room, followed by acute elevation in mean skin temperature inside a heated room, might promote heat acclimatization by it's effect on the drive for sweating.

Also, it has been shown that at equal metabolic rates negative work

induces higher HR, \bar{T}_{sk} , and sweating rates and possibly higher T_c as compared to positive work (10,11,12,18). Consequently, it seemed reasonable to assume that involvement of negative work in the exercise phase could enhance the acclimatization process at a relatively low metabolic cost.

In order to test these hypotheses we have designed the following treatments. 1. exercise which, while having cardiovascular training effect will also raise the body's skin and core temperatures followed by 2. short acute heat exposure to elevate the mean skin temperature; both could influence the drive for sweating.

Although, testing whether the central thermoregulatory control mechanism could be effected by the summation of metabolically elevated T_c and heat (external) elevated \bar{T}_{sk} has its academic merits, such a procedure is of practical importance. Enhancing the acclimatization process such that the daily and total heat exposures will be at minimum is applicable to industry and to the military, where present procedures are costly in terms of duration and requirement for prolonged use of heated work spaces.

This paper summarizes the results of a series of tests in which partial acclimatization has been induced by using stints of negative and/or positive work on a laddermill followed by short exposures to acute heat.

METHODS

Subjects were paid volunteer students. The number of participants, their age and physical characteristics, averaged for each treatment group, is given in Table 1.

Climbing was used as the mode of exercise, utilizing a motor driven ladder (6), inclined 30 degrees from the vertical with the rungs spaced

at 1 foot. All climbing exercises were performed at room air temperature ($21 \pm 1^\circ\text{C}$). The different modes of climbing, shown for each group in Table 1, involved: 30 minutes of downclimb only (group A); 30 minutes of upclimb only (group B); 15 minutes of downclimb followed by 15 minutes of upclimb (group C); 30 minutes of upclimb only (group D). Group D has been subjected to a different heat exposure as will be described below.

Heat Exposure. Except for group D all heat exposures involved level walking at 5.6 km/hr (25 - 30% $\dot{V}O_2$ max) under hot dry ambient conditions of DB/WB temperatures of 50/25°C; wind at 1m/sec. These were the conditions for the 30 minute heat exposure that followed the 30 minute climbing exercise for groups A to C and for the standard heat challenge to test for state of acclimatization. For group D, the 30 minutes of heat exposure involved sitting at this ambient conditions with an addition of radiant heat from a set of quartz lamps on a side wall, aimed at the profile of the sitting subject. Therefore, he turned around every 15 minutes. The globe temperature taken at the sitting place was 63.5°C.

Standard test for state of acclimatization (groups A to D), and the acclimatization procedure (group E) involved our routine method of level walking in the above mentioned dry heat conditions for 120 minutes, if tolerated.

Measurements. Oxygen uptake ($\dot{V}O_2$) was measured by the open circuit method; expired air was collected, usually for 1 minute, in Douglas bags; volume and O_2 concentration measured respectively in a Tissot wet spirometer and Beckman O_2 analyzer. Heart rate (HR) was continuously monitored on a tachometer using chest surface electrodes. Rectal temperature (T_{re}) was continuously monitored from a thermocouple in a probe, inserted 20 cm. Skin temperatures were measured every 10 minutes moving a thermocouple "bow" over the forehead, chest, back (scapula), left upper forearm, lower forearm and the two thighs.

The averaged values were taken as the mean skin temperature (\bar{T}_{sk}).

PROCEDURES

Preliminary sessions were devoted to familiarization with the procedures, the equipment and for testing to estimate maximal aerobic capacity ($\dot{V}O_2 \text{ max}$).

$\dot{V}O_2 \text{ max}$ was estimated from measurements of $\dot{V}O_2$ and HR, during submaximal work loads on the laddermill. Each subject climbed up the laddermill at three successive speeds, for 5 minutes each, with 10 minutes rest inbetween. $\dot{V}O_2 \text{ max}$ was calculated by extrapolation of the HR/ $\dot{V}O_2$ linear relationship (7) to the maximum age expected HR of 195.

Each subject participated only in one of the groups listed in Table 1, except for one subject who took part in series C and E with an inbetween time lapse of 65 days, during which he abstained from exposures to heat or exercise. Each subject was tested, in a post absorptive state, at the same hour every day.

Upon arrival to the laboratory he prepared himself, placing the chest electrodes, inserting the rectal probe and resting for 20-30 minutes.

A series of tests for a group involved: one pretreatment standard test for state of acclimatization (pre-test) usually sustained less than the allocated 120 minutes; 3-4 weeks of in exposure to heat and physical activities, to ensure loss of any effect of the one pretreatment heat exposure; 4 days of daily treatment of 30 minutes of the heat exposure; 3-4 days of repeated tests for state of acclimatization each aimed at 120 minutes which also served to complete the acclimatization process, if necessary.

Evaluation of the state of acclimatization was based on the increased tolerance time above, and the fall in HR, T_{re} and \bar{T}_{sk} below, the values obtained for the pretreatment standard test. Hence the consideration for full or partial acclimatization, using each of these criteria was as follows: a.) the difference between the end values for the last posttreatment test and

the pretreatment test was taken as the value representing full acclimatization; b.) the difference between the first posttreatment test and the pretreatment test represents partial acclimatization c.) the ratio of b over a quantified the partial acclimatization. In other words the improvement towards acclimatization, tested immediately after the 4 days treatment, was expressed as percentage for each criteria from:

$$\frac{\text{Pretreatment value} - \text{First Posttreatment value}}{\text{Pretreatment value} - \text{Last Posttreatment value}} \cdot 100$$

Group E underwent 9 days of the standard acclimatization procedure only. The group's state of acclimatization was compared to that of groups A to D by treating the end values for day 1, day 5, and day 9, similar to respectively; the pretreatment, first posttreatment and last posttreatment days in group A to D.

RESULTS

The combined stints of ladderclimb and short heat exposure is termed hereafter, the treatment. The mode of climbing the laddermill for the first 30 minutes of the 4 days treatment differed for the 4 groups as shown in Table 1, groups A to D. Actually groups A and B, each involving 2 subjects, served as a pilot study designed to involve respectively downclimb (negative work) and upclimb (positive work). Although in terms of relative $\dot{V}O_2$, test A demanded less than B; 32% as compared to 55% $\dot{V}O_2$ max, in terms of work load it was reversed 992 and 534 kg·m/min for tests A and B respectively.

Since both, tests A and B were effective in improving the state of acclimatization a third test (group C) was designed in which the 30 minutes of climbing were divided into 15 minutes of downclimb followed by 15 minutes

of upclimb at the average of 30% and 65% $\dot{V}O_2$ max respectively.

Typical examples of the HR and Tre responses to treatments given to groups A and C are shown in fig. 1. The data points represent the end values for the daily 30 minutes laddermill climb as well as for the following 30 minutes of short heat exposure while walking on the treadmill. During the first day of the downclimb series, the HR continuously rose to reach high values at the end of the 30 minutes. However the rise in HR dropped upon the successive days of climbing and by the 4th day it leveled off within the first 10 minutes at a much lower level, as compared to the end value for the first day, which accounts for the sharp fall in the end values shown for the 4 days of the downclimb treatments (fig.1). This phenomena was less apparent in group C where only 15 minutes of downclimb were administered.

In general, all 4 groups revealed some cardiovascular training effect as well as some improved thermoregulatory responses in that, the end values of HR and Tre were lower on day 4 as compared to day 1 for both phases of the treatment; the exercise stints and the heat exposures. This is shown in Table 2. However none of the subjects in group D has shown the expected fall in HR due to the exercise stints, thus, the group's mean values on day 1 and day 4 were similar (Table 2, D). Tre was somewhat lower on day 4 as compared to day 1 for the exercise stints as well as the heat exposure of the treatments for groups B, C and D.

\bar{T}_{sk} was measured on one, mostly the last day, of the treatments except for few subjects whose \bar{T}_{sk} was measured daily. The few measurements did suggest a fall in \bar{T}_{sk} from day 1 to day 4 for the heat exposure phase. However in general, the values for the exercise stints were at 33-34°C, which was similar, or slightly less than the resting value for each individual, but the heat exposure resulted in a rise to 36-37°C for groups A, B and C,

and up to 38°C in group D.

Fig. 1 also shows the end values of HR, Tre and \bar{T}_{sk} for the heat challenge that has been used as the test for state of acclimatization. The pretreatment standard test that has been given 3-4 weeks prior to the 4 days of the treatment, clearly showed a state of nonacclimatization for all the participants. This has been based on the following criteria; heat exposure could not be tolerated for the 120 minutes (the average endurance was 71 minutes); HR, Tre and \bar{T}_{sk} continuously rose to the end of the tolerated exposure time. The test for state of acclimatization the day immediately after the 4 days treatment did reveal better adaptation to the heat challenge. As the typical examples in fig.1 show, the end values of HR, Tre and \bar{T}_{sk} were less than those obtained for the pretreatment exposure. In addition, the tolerance time improved to the point that in most cases the whole 120 minutes could be tolerated. But, the posttreatment daily standard heat exposures that followed the first posttreatment test have indicated further improvements towards acclimatization in that; HR, Tre and \bar{T}_{sk} continued to fall until days 3 or 4.

Table 3 summarizes the mean percent improvement towards complete acclimatization (see procedure) derived from the 4 day treatment, for each group, separately for each criteria. It can be seen that some improvement has been derived in each of the 5 groups. However the degree of improvement differed for each criteria. This was the case for each individual. For example in one subject the respective percent improvement for HR, Tre, \bar{T}_{sk} and tolerance time were 83, 55, 25, and 100 and in another they were respectively 45, 0, 75, and 100. The wide individual differences are reflected in the large standard deviation from the means, except for the tolerance time which was more

homogenous; except for 3 individuals all subjects revealed 100% improved tolerance time due to the treatments. Finally it can be seen that all 5 groups were similar in the degree shown for their improved state of acclimatization following the 4 days of treatment, including the conventional method administered to group E. Analysis of variance to test for differences among the 5 groups indicated no significant differences.

Table 4 provides the mean hourly sweating rates for each group during the following: pretreatment test; day 1 and day 4 of the treatments; the first and last posttreatment tests. It shows that a) within the 4 days of treatment the hourly sweating rate did not change (values for day 1 did not differ from those for day 4); b) the sweating rate was, for all practical purposes, the same for all the standard heat exposures. Although a trend towards higher sweat rates due to acclimatization can be noticed, statistically as well as a practically the sweating rate did not differ for the pretreatment (nonacclimatized state) as compared to the first and last posttreatment (partially and fully acclimatized states).

DISCUSSION

Acquisition of acclimatization to heat can be safely tested during winter when the summer's natural acclimatization has ebbed. Therefore the tests described in this paper have been carried out during the last 2 winters. Indeed, the subjects were in a nonacclimatized state as evidenced by the pretreatment standard exposure to moderate work in the heat. Furthermore, one of the participants in series C who returned, after 65 days of in exposure to heat, to take part in series E did reveal the expected non-acclimation responses as judged by his tolerance time and elevation of HR, T_{re} and \bar{T}_{sk} . In addition, it was assumed that minimal physical activity and in exposure to heat for 3-4 weeks will abolish any partial acclimation that the one heat exposure could accrue.

Although relative to the mechanical load prolonged negative work demands little in O_2 cost (3, 6), it provokes "training" effect which is reflected in HR fall (2, 8). Consequently, our observation of day to day substantial fall in HR during the downclimb was not unexpected, for group A. Moreover, the HR which revealed a continuous rise during the 30 minutes of the first day of the downclimb, not only fell to lower levels but also tended to show consequent leveling off, which by the fourth day appeared within the first 10 minutes. These changes in rise of, and leveling off of, the HR accounted for the substantial daily drops shown in fig. 1, for the end values. Furthermore, high HRs existed during the heat exposure that followed the negative work. Hence, the substantial differences between day 1 and day 4 were also seen for the second heat exposure phase of the treatment (table 2, group A). Although less than in group A, a fall in HR during the 4 days treatment was also apparent in groups B and C, indicating some training effect due to both the climbing outside and the walking inside the heated room. The treatment for group D involved high relative work load outside, but sitting resting, inside the heated room. The fact that no fall in HR was witnessed during the 4 days of treatment for this group, seem to indicate that the walking in the heat was a contributing factor to the "training" effect, observed in the other groups.

Evidence for the effectiveness of the 4 days treatment could also be found in the day 1 to day 4 drop in the T_{re} , during the exercise stint, as well as the heat exposure. \bar{T}_{sk} however, hardly changed from its resting level, during the exercise phase but, rose sharply during the walking and resting in the heat. Nevertheless, the treatments were effective in inducing some improvement towards the acclimatization sought in this experiment.

Actually, all the criteria used here as evidence for acclimatization did show some degree of improved adjustment to the heat when the first posttreatment responses were compared to those of the pretreatment standard heat challenge test. Thus, an intensity duration threshold has been exceeded during the treatments, to the extent that the needed adaptation for acclimation was provided. However, the percentage of improvement differed for each criteria on any one subject, and showed wide individual differences among the subjects for each criterion, which probably accounted for the observed insignificant differences between the treatment groups and between them and group E, in the state of acclimation, achieved after 4 days.

To further verify the usefulness of the exercise stints plus the short heat exposure, in inducing acclimatization we have compared our results, pooled for groups A to C, to those reported by others who used the routine prolonged heat exposure. The comparison shown in fig.2, in the form of histograms, was based on the relative improvement reported for day 5 as compared to day 8 or 9 of the acclimatization, and presented either in graphical form (9, 14, 15) or in a table (20). It can be seen that our method compares favorably with those used by the others. Although s.d. could not be computed from these reports, it should be mentioned that the graphical presentations (14, 15) did show wide individual differences for each criteria. Roughly, the range of improvement towards acclimatization, for the data by Robinson et al (15) were; 50-100% for HR; 40-100% for \dot{V}_{E} and; 30-100% for \bar{T}_{sk} . Indeed the authors have mentioned that 2 out of the 5 subjects tested, have reacted slower to the heat exposures and practically "never reached as complete a state of acclimatization as the other three." Such interindividual differences should be taken into account in the practical application of enhanced acclimatization, and a method to screen the less acclimatizable subjects should be designed.

Since the hot ambient conditions employed in this study were not humid, the nonsignificant trend towards higher sweating was expected. However, the drop in T_{re} during the 4 days treatment and the resulting improved state of acclimatization can be taken as an indicator that sweating got to be more efficient, probably due to its earlier onset at lower \bar{T}_{sk} and T_{re} (1).

The partial success with the pilot study on groups A and B encouraged us to pursue the idea of exercising outside the heated room prior to the short heat exposure, with an attempt to intensify the exercise stints. Since there is a limit to the speed at which downclimb can be performed without additional strain, unless specially trained (6), a limit of 60 steps/min was set for the downclimb, and the intensification of the exercise was based on increasing the positive work load (group C). In order to stay within a reasonable non-exhaustive range of exercise, a combined negative and positive work has been designed; the first served as the least strenuous exercise that nevertheless could effectively stimulate the thermoregulatory systems; the second served to continue these stimuli and in addition be effective in taxing the cardiovascular system.

The incorporation of stints of negative work was based on the observations made in several laboratories that at equal metabolic requirement, compared to positive work, negative work was expected to drive the physiologic responses towards higher \bar{T}_{sk} and sweating rates (10, 11, 12) possibly towards higher T_{re} (10, 18) for at least the first 2 days (2) and elicit higher HRs. Prolonged negative work results in muscle soreness (3), for at least the first 2 days, which indeed was the complaint of the subjects in group A of this study. However, group C did not witness such soreness presumably because of the shorter period (15 minutes) of their downclimb.

Since resting in the heat has been designed for group D, higher relative work load could be performed outside of the heated room. However

it seems that this method was not effective in inducing cardiovascular training.

In summary, exercise stints could be effective in driving the physiological responses towards acclimatization, provided short heat exposure follows each exercise session. In practical terms this method could save in time and heated spaces particularly when a large number of persons have to be acclimatized. Whether additional few days of similar treatment or other method of intensified exercise and/or heat exposure could accomplish the acclimation process remains to be tested.

REFERENCES

1. Belding, H.S. Biophysical principles of acclimatization to heat. In Physiological adaptations, desert and mountain. Yousef, M.K., S.N. Horvath, and R.W. Bullard Edits. Academic Press 1972.
2. Davies, C.T.M. and C. Barnes. Negative (Eccentric) work. I. Effects of repeated exercise. Ergonomics 15: 3-15, 1972.
3. Davies, C.T.M. and C. Barnes. Negative (Eccentric)work II. Physiological responses to walking uphill and downhill on a motordriven treadmill. Ergonomics 15: 121-123, 1972.
4. Fox, R.H., R. Goldsmith, D.J. Kidd, and H.E. Lewis. Acclimatization to heat in man by controlled elevation of body temperature. J. Physiol. 166: 530-547, 1963.
5. Gisolfi, C. and S. Robinson. Relations between physical training, acclimatization, and heat tolerance. J. Appl. Physiology. 26: 530-534, 1969.
6. Kamon, E. Negative and positive work in climbing and stepping upon a laddermill. J. Appl. Physiol. 26: 530-534, 1969.
7. Kamon, E., and K.B. Pandolf. Maximal aerobic power during laddermill climbing, uphill running, and cycling. J. Appl. Physiol. 32: 467-473, 1972.
8. Klausen, K., and H.G. Knuttgen. Effect of training on oxygen consumption in negative muscular work. Acta Physiol. scand. 83: 319-323, 1971.
9. Lind, A.R., and D.E. Bass. Optimal exposure time for development of acclimatization to heat. Fed. Proc., 22: 704-708, 1963.
10. Nadel, E.R., U. Bergh, and B. Saltin. Body temperatures during negative work exercise. J. Appl. Physiol. 33: 553-558, 1972.
11. Nielsen, B. Thermoregulation in rest and exercise. Acta Physiol. scand. suppl. 323, 1969.
12. Nielsen, B., S.L. Nielsen and F. Bonde Patersen. Thermoregulation during positive and negative work at different environmental temperatures. Acta. Physiol. scand. 85: 269-257, 1972.
13. Piwonka, R.W., S. Robinson, V.I. Gay, and R.S. Manalis. Pre-acclimatization of men to heat by training. J. Appl. Physiol. 20: 379-384, 1965.

14. Robinson, S., E.S. Turrell, H.S. Belding, and S.M. Horvath. Rapid acclimatization to work in hot climates. Am. J. Physiol. 140: 168-176, 1943.
15. Robinson, S., H.S. Belding, F.C. Consolazio, S.M. Horvath, and E.S. Turrell. Acclimatization of older men to work in heat. J. Appl. Physiol., 20: 583-586, 1965.
16. Saltin, B. and A.P. Gagge. Sweating and body temperatures during exercise. Int. J. Biometeor. 15: 189-194, 1971.
17. Shvartz, E., D. Benor, and E. Saar. Acclimatization to severe dry heat by brief exposures to humid heat. Ergonomics 15: 563-571, 1972.
18. Smiles, K.A., and Robinson. Regulation of sweat secretion during positive and negative work. J. Appl. Physiol. 30: 409-412, 1971.
19. Stolwijk, A.S., and E.R. Nadel. Sweating response in human thermoregulation. In Regulation and controls in Physiol. Systems. Iberall, A.S. and A.C. Guyton Edits. IFAC Publ. 1973.
20. Williams, C.G. and A.J.A. Heyns. Differential acclimatization as a function of duration of exposure. Int. Z. angew. Physiol., 27: 198-211, 1969.
21. Wyndham, C.H. The physiology of exercise under heat stress. Ann. Rev. Physiol. 35:193-220, 1973.

Fig. 1. End values for heart rates (HR), rectal (T_{re}) and mean skin (\bar{T}_{sk}) temperatures for the treatments inside the heated room, and for the standard heat tests.

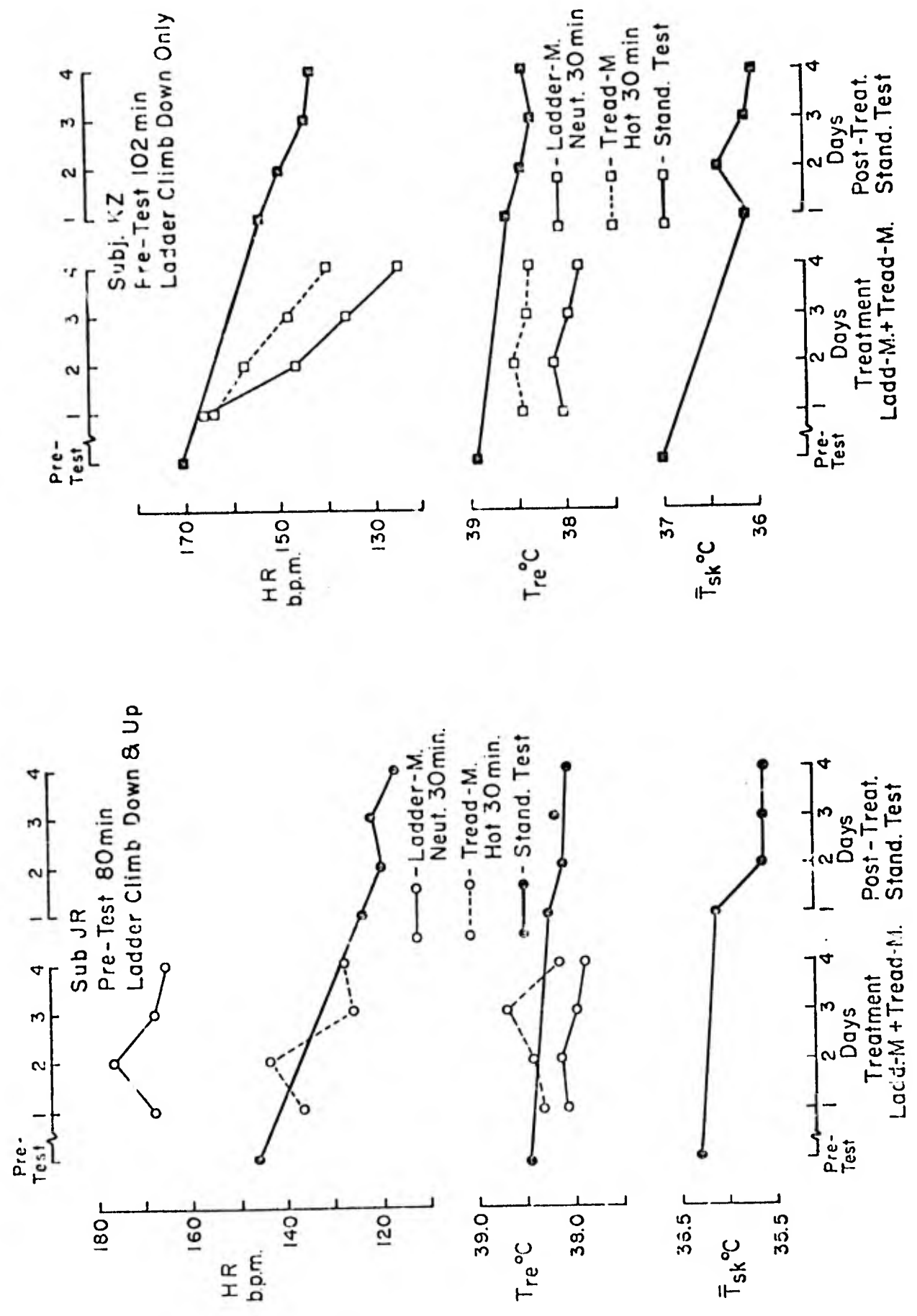


Fig. 2. Histograms, comparing the improvement towards acclimatization on the first day after the 4 days treatment in this study to the 5th day of acclimatization in the other studies. Bars represent standard deviations from the mean.

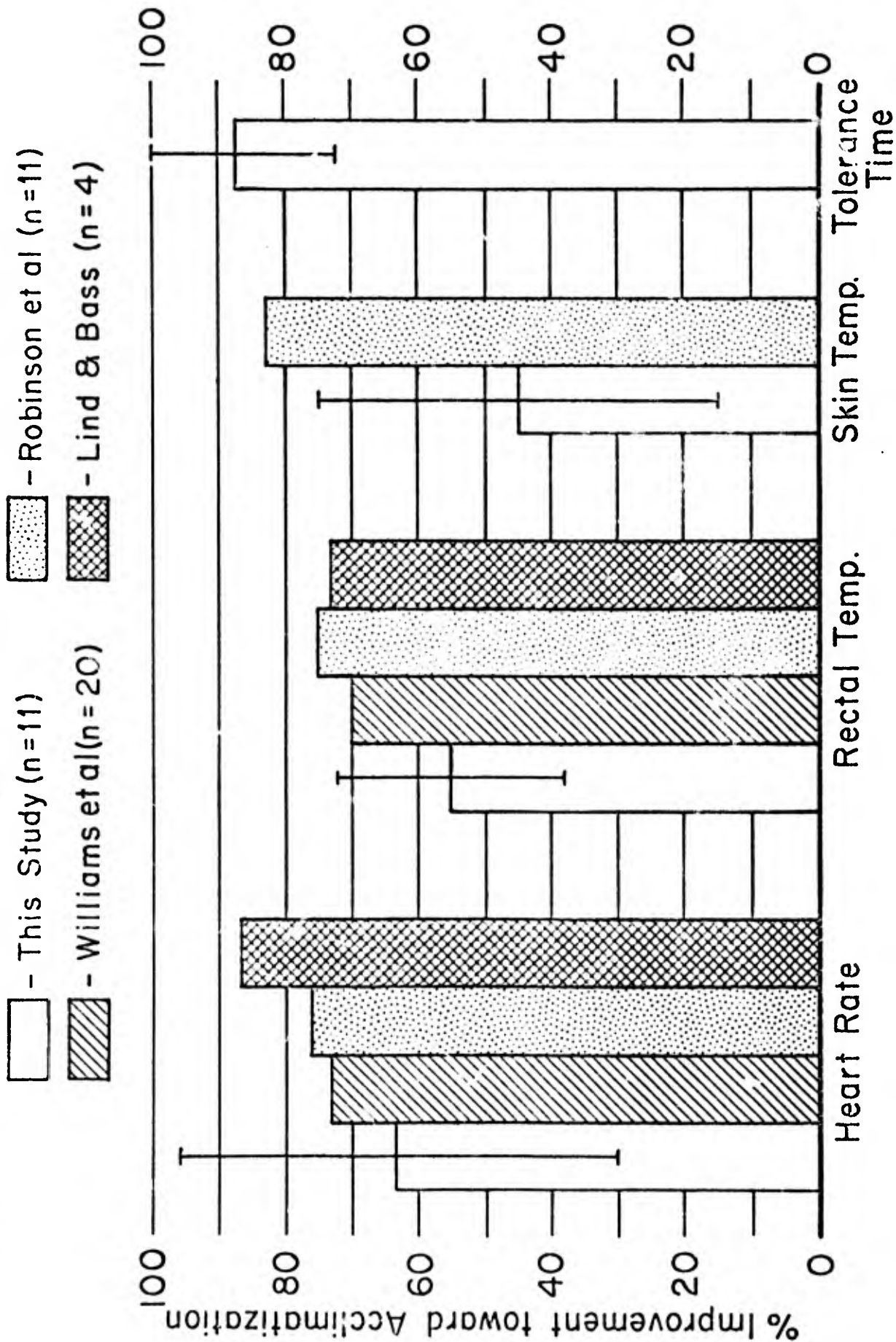


Table 1: Age, physical characteristics, laddermill climb information, its O₂ cost (VO₂) and relative aerobic cost (3 VO₂ max), for each group.

GROUP	N	AGE yrs.	WEIGHT kg	HEIGHT cm	LADDERMILL CLIMB		kg·m min	VO ₂	
					$\frac{\text{rungs}}{\text{min}}$ ^{a)}	$\frac{\text{m}}{\text{min}}$ ^{b)}		$\frac{\text{l.}}{\text{min}}$	% max
A	2 \bar{M}	22.5	73.7	182.5	+ 51	13.5	992	1.20	32
		±S.D.	.7	.2	.7	2.8	.7	111	.03
B	2 \bar{M}	20.5	67.8	181	+ 30	8	534	1.57	55
		±S.D.	.7	4.8	10	0	0	38	.24
C	6 \bar{M}	21.7	76.3	179	+ 56.7 ^{c)}	15.2	1145	1.08	30
					2.3	.75	181	.13	2
					+ 45.2 ^{c)}	11.8	893	2.40	65
					3.4	.75	127	.35	4
D	4 \bar{M}	22.8	70.1	174.8	+ 43.2	11.2	781	2.02	65
		±S.D.	2.1	11.6	3.0	4.0	.96	82	.40
E	4 \bar{M}	22.2	82.2	179.8					
		±	.5	14	1.7				

a) +downclimb, +upclimb

b) vertical climb

c) 15 minutes downclimb followed by 15 minutes upclimb

Table 2: Group mean end values and standard deviations of heart rates (HR) and rectal temperatures (Tre) for day 1 and day 4 of treatment.

	CLIMBING		EXERCISE		HEAT EXPOSURE			
	HR bpm day 1	day 4	Tre°C day 1	day 4	HR bpm day 1	day 4	Tre°C day 1	day 4
	146±28	106±26	37.6±.6	37.8±.8	167±4	128±17	38.5±.1	38.5±.1
	158±14	143±7	38.1±.1	37.7±.3	145±10	136±13	38.5±.4	38.1±.2
	174±14	165±8	38.1±.1	37.9±.3	141±14	132±7	38.4±.4	38.2±.2
	167±8	164±6	38.3±.3	38.2±.2	108±11	109±8	38.2±.2	38.0±.2

Table 3: Percent improvement towards acclimatization, due to the four days treatment, as evidenced by each criteria. Mean and ranges are given for each tested group.

GROUP		HEART RATE bpm	RECTAL TEMP. °C	SKIN TEMP. °C	TOLERANCE minutes
A	mean range	62.5 54-71	63 54-75	38.5 13-64	60 20-100
B	mean range	83.5 71-96	65 64-66	55.5 47-64	100 -
C	mean range	67.5 74-95	54.5 37-76	47.6 14-88	93 62 ^{x)} -100
D	mean range	68.8 45-100	38.2 0-74	40 0-75	100 -
E	mean range	79.2 55-100	68 54-90	43 0-65	89.2 57 ^{x)} -100

x) obtained on one subject while all the rest showed 100% improvement.

Table 4: Mean hourly sweating rate (\pm S.D.) during the pretreatment test, days 1 and 4 of the treatment and days 1 and 4 of the posttreatment tests, for each group.

GROUP	N	PRETREATMENT	TREATMENT		POSTTREATMENT	
			day 1	day 4	day 1	day 4
A	2	1175 \pm 191	988 \pm 188	883 \pm 32	1168 \pm 74	1250 \pm 120
B	2	1200 \pm 21	805 \pm 106	730 \pm 113	1168 \pm 60	1160 \pm 71
C	6	1150 \pm 173	939 \pm 137	948 \pm 128	1204 \pm 130	1205 \pm 160
D	4	1168 \pm 271	889 \pm 246	929 \pm 224	1163 \pm 267	1216 \pm 265
E	4	1241 \pm 213			1251 \pm 169	1290 \pm 192
TOTAL	18	1182 \pm 182	913 \pm 167 ^{x)}	901 \pm 157 ^{x)}	1197 \pm 156	1226 \pm 170

x) 14 subjects (group A - D) only.