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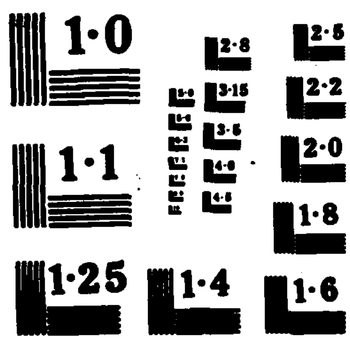
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REPORT NO. T8/86

SELF-PACED HEAT ACCLIMATION PROCEDURES

US ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
Natick, Massachusetts

MARCH 1986

UNITED STATES ARMY
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The purpose of this investigation was to evaluate the effectiveness of self-paced heat acclimation (SPHA) procedures. Fourteen males performed 100 min of intermittent exercise during 9 SPHA work-rest cycles, on eight days. Exercise consisted of 8.279 ± 0.527 to 9.799 ± 0.433 km of treadmill running per day. SPHA trials were effective in improving heat tolerance in that significant ($p < .05$) reductions were observed (day 1 vs day 8) in final heart rate (HR), Δ HR, final rectal temperature (Tre), Δ Tre, final

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) mean weighted skin temperature (Tsk), and ΔTsk. Resting plasma volume expanded significantly ($p < .05$) from day 1 to day 4, but sweat rate was unchanged. Group mean exercise intensities and ratings of perceived exertion were not statistically different from days 2 - 7, yet the number of trials terminated because subjects exceeded HR and Tre safety limits (22 out of 112 trials) declined during heat acclimation (days 1-4 = 16, days 5-8 = 6). Symptoms of heat illness (piloerection, chills, dizziness, vomiting) were observed in 16.1 % of all trials; 11 out of 14 subjects (78.6 %) experienced one or more of these symptoms during SPHA trials. Although SPHA procedures offer many advantages which are not available in other training programs (including frequent rest periods, self-selection of exercise intensity, and medical monitoring) SPHA is not an absolute safeguard against soldiers exceeding HR or Tre safety limits (180 beats$\cdot$min^{-1}, 39.5°C), especially when jogging or running is required or when participants are competitive. Close monitoring of participants is advisable.

TECHNICAL REPORT NO. T8/86

SELF-PACED HEAT ACCLIMATION PROCEDURES

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Abstract

The purpose of this investigation was to evaluate the effectiveness of self-paced heat acclimation (SPHA) procedures. Fourteen males performed 100 min of intermittent exercise during 9 SPHA work-rest cycles, on eight days. Exercise consisted of 8.279 $\pm$ 0.527 to 9.799 $\pm$ 0.433 km (mean $\pm$ SE) of treadmill running per day. SPHA trials were effective in improving heat tolerance in that significant ($p<.05$) reductions were observed (day 1 vs day 8) in final heart rate (HR), ΔHR, final rectal temperature (Tre), ΔTre, final mean weighted skin temperature (Tsk), and ΔTsk. Resting plasma volume expanded significantly ($p<.05$) from day 1 to day 4, but sweat rate was unchanged. Group mean exercise intensities and ratings of perceived exertion were not statistically different from days 2 - 7, yet the number of trials terminated because subjects exceeded HR and Tre safety limits (22 out of 112 trials) declined during heat acclimation (days 1-4 = 16, days 5-8 = 6). Symptoms of heat illness (piloerection, chills, dizziness, vomiting) were observed in 16.1 % of all trials; 11 out of 14 subjects (78.6 %) experienced one or more of these symptoms during SPHA trials. Although SPHA procedures offer many advantages which are not available in other training programs (including frequent rest periods, self-selection of exercise intensity, and medical monitoring), SPHA is not an absolute safeguard against soldiers exceeding HR or Tre safety limits (180 beats·min^{-1}, 39.5°C), especially when jogging or running is required or when participants are competitive. Close monitoring of participants is advisable.

Introduction

Daily exposure to substantial exercise heat stress has been shown to result in improved tolerance to extreme heat. Field studies have established that this state is associated with a decreased incidence of heat casualties, improvements in sustained physical performance, and subjective evaluations of better alertness and overall capability. Known as heat acclimatization, this process has obvious military value for the U.S. Army, especially if it can be induced with minimal risk to the soldier.

Historically, recruits or troops moving to a hot environment have been trained in groups. Drill instructors are assigned to a given port and, having lived and trained in a hot environment, are often more acclimatized than recruits. Recruit training does not allow for individual differences in heat tolerance, fitness, or prior heat exposure. As a result, a new recruit experiences a great deal of physiological strain from a given amount of environmental stress; this is especially true if a recruit's point of origin was in the northern United States. Also, aerobic training and heat acclimatization training are usually viewed as one process, when actually they each have different goals, unique training procedures, and separate inherent risks. The risk of heat injury increases dramatically when aerobic training is conducted in environments which are conducive to heat acclimatization; aerobic training is best conducted early in the day, when temperatures are low.

It is obvious that regimentation of recruit activities is necessary and desirable, yet when improved methods of training are discovered, it is in the best interest of command officers to implement these methods. An article in Soldiers magazine (1) has emphasized the need for individualized PT sessions. SSgt Lewis Hayes, a NCOIC at Fort Bragg, NC, stated that he has employed ability groups. "With ability grouping, everybody benefits. ...(The) faster people increase their heart rates and the slower group exercises without the threat of injury and can progress at its own pace." Thus, highly conditioned soldiers are challenged and less fit soldiers are not subjected to high-risk exercise levels.

Previous Research

Our interest in self-paced heat acclimation (SPHA) arose from the perspective of providing heat injury prevention guidance while recognizing the need to improve the aerobic fitness of soldiers. Previous studies conducted by LCDR David A. Miller, Naval Medical Research Institute, Bethesda, MD (2) tested the advantages/disadvantages of using SPHA procedures aboard ships which were en route to hot weather operations. It was recognized that transit time provided an opportunity for pre-acclimatization of troops. These SPHA procedures were designed to give the U.S. Marines a shipboard heat acclimation capability for the purpose of reducing heat casualties. The heat acclimation chamber was large (70 x 80 ft.), but not large in relation to the number of Marines involved. Approximately 1600 men participated in daily SPHA trials, and individual monitoring was not feasible. Self-paced running was selected to allow "self regulation" of work load by each participant. NMRI researchers assumed that each person would select a work rate of approximately 45 $\%VO_2max$ (2), and that control of work intensity, and not duration, would provide the necessary safeguard against hyperthermia and heat injury.

Environmentally controlled laboratory trials were also conducted by NMRI (2). These trials utilized heart rate (HR) and rectal temperature (Tre) measurements as the primary indices of heat acclimation. Mean HR and Tre measurements indicated that statistically significant heat acclimation was achieved by day 6, and could be maintained indefinitely by one SPHA trial every third day. Other NMRI measurements included: oral and mean weighted skin temperatures, sweat rate, water intake, and distance run.

Rationale

The purpose of this investigation was to evaluate the effectiveness and safety of SPHA procedures in recruit training or in the preparation of unacclimatized troops deploying to hot environments on short notice. If these procedures proved to be successful, the following benefits could be gained: enhancement of sustained physical performance, avoidance of a major source of battle casualties, decreases in the patient load of the combat casualty care system, and improvement of the ability of a military unit to achieve its mission.

The Heat Research Division, USARIEM, investigated SPHA to verify the aforementioned NMRI results and to extend NMRI findings by observing oxygen uptake, ventilation, plasma Na^+ and K^+, change in plasma volume, rating of perceived exertion, heat illness symptoms, selected treadmill speed, daily body weight, and entering urine specific gravity. Three practical questions regarding SPHA formed the foundation of this investigation: (a) do physiological measurements indicate improved heat tolerance due to SPHA? (b) do Tre and HR exceed USARIEM Human Use Committee safety limits (39.5°C, 180 beats$\cdot$min^{-1})? (c) do participants exhibit heat illness symptoms during SPHA?

In addition, the following statement was evaluated:

> Self-paced running is internally controlled and permits "custom fitting" of work load (approx. 45 %VO_2max) to the ability of the soldier. This exercise intensity causes Tre and HR to enter a safe range (< 39.5°C and < 180 beats$\cdot$min^{-1}) and remain there during all subsequent work.

Methods

The subjects were 14 males of various ages (range: 19 - 46 yr), body types (weight range: 57.967 - 110.517 kg), and physical fitness levels (VO_2max range: 38.77 - 61.60 ml$\cdot$kg$^{-1}\cdot$min^{-1}). Descriptive characteristics (mean $\pm$ SE) of these volunteers appear in Table 1. After informed consent was obtained, all subjects completed a health questionnaire, activity questionnaire, and history of heat exposure prior to testing. These forms and outdoor temperatures during SPHA were examined to determine if each subject was unacclimatized prior to SPHA trials. Three-day dietary records were completed immediately before and after the investigation. Dietary records were analyzed for food energy,

TABLE 1 - SELECTED SUBJECT CHARACTERISTICS (mean ± SE, n = 14).

	Age (yr)	Height (cm)	Weight (kg)	Body fat (est. %)	$\dot{V}_{O_2 max}$ $(ml \cdot kg^{-1} \cdot min^{-1})$	Surface area (m^2)
MEAN	28.4	177	79.771	18.7	45.74	1.96
± SE	±1.9	±2	±3.784	±1.4	±1.96	±0.50

sodium, potassium, protein, carbohydrate and fat. One day prior to testing, skinfold thickness, height and weight were measured and subjects performed a maximal oxygen consumption (VO_2max) test.

This investigation consisted of eight days of treadmill exercise in an environmental chamber maintained at 41.2 $\pm$ 0.5°C, 39.0 $\pm$ 1.7 %RH. Days 1 and 8 of SPHA were control heat acclimation trials. Days 2 - 7 of SPHA involved completely self-paced treadmill running. Two days of rest were taken between day 4 and day 5, to simulate a weekend free of training-induced heat stress.

CONTROL SPHA TRIALS - DAYS 1 AND 8

Subjects were encouraged to drink adequate water when they were not in the climatic chamber. Upon arriving at the testing site each day, subjects produced a urine sample which was analyzed for specific gravity. If any subject had a urine specific gravity greater than 1.030, he drank water until a more dilute urine was produced (specific gravity $<$ 1.030).

A 20 minute standing equilibration period in the heat preceeded each antecubital blood sample (days 1, 4 and 8 only) and body weight (all days; Sauter balance, accuracy $\pm$ 10 g). A second antecubital blood sample and body weight were taken immediately post exercise. Blood samples were analyzed for hematocrit, hemoglobin (Hycel reagents), as well as serum sodium (Na^+) and potassium (K^+) (Rainin Instruments, FLM3 flame photometer) Changes in plasma volume were calculated from changes in hematocrit (Δ%PV) and hemoglobin (3). Body weight differences were used to calculate sweat rate, and were corrected for water intake and urine output.

Subjects ran in pairs, one subject per treadmill. All trials were run at 0% grade. Ratings of perceived exertion (RPE) were recorded at the same time as VO_2 values, using a 20 point RPE scale created by Borg (4). The following parameters were calculated for each subject each day: mean treadmill speed selected, mean $\%VO_2max$ for exercise, distance run, and energy expended. Heart rate (HR) was monitored continuously using a Hewlett-Packard telemetry system. A semi-automated system was used to collect and analyze expired gases. A Hewlett-Packard 85B computer, scanner, and digital voltmeter were interfaced with a gas meter (Parkinson-Cowan), oxygen analyzer (Applied Electrochemistry S3A), and carbon dioxide analyzer (Beckman LB2). Each subject was equipped with a rectal probe (inserted 8 cm beyond the anal sphincter) and three skin probes placed on the chest, forearm and calf. Rectal temperature (Tre) and mean weighted skin temperature (Tsk) readings were taken every four minutes using the semi-automated data collection system. Water was drunk _ad libitum_ throughout all trials, but could not be sprayed or poured on the body.

Day 1 and day 8 consisted of identical 100 min control trials, allowing comparison of physiological parameters before and after SPHA. On days 1 and 8, subjects walked at 0.95 $m \cdot sec^{-1}$ (2.12 mph) during the first two exercise periods, at 1.58 $m \cdot sec^{-1}$ (3.53 mph) during the next two exercise periods, and then performed self-paced running during periods 5 - 9 of all trials. All treadmill speeds selected on day 1 were duplicated on day 8.

Treadmill speed was decreased by the investigator if HR exceeded 180 beats·min^{-1}. Exercise was terminated if HR did not decrease below 160 beats·min^{-1} during rest, if TRE exceeded 39.5°C or if signs of heat stress (chills, piloerection, etc) warranted termination. If exercise was terminated on day 1, an identical revised protocol was conducted on day 8.

SELF-PACED WORK - DAYS 2 THROUGH 7

On days 2 - 7, subjects were encouraged to "jog or run" during all nine work periods; walking occurred only if subjects deemed it necessary, because of fatigue or discomfort. Treadmill belt speeds were measured during each of 1008 work periods (8 days, 9 work periods, 14 subjects), using a hand-held digital tachometer. Subjects were unaware of the actual treadmill belt speed, HR, or Tre during SPHA trials. An investigator slowly increased or decreased the treadmill speed until the subject signalled him to stop. Subjects selected their own treadmill speed and were allowed to change the belt speed at any time during the trial, but were instructed that steady-state expired gas measurements required a constant pace. To preclude rate changes and/or investigator exhortations, subjects were further instructed to select a pace that they felt they could maintain during the measurement interval. There were nine work periods of 5 - 10 min duration, each followed by rest periods of 2 - 10 min duration. This protocol (Table 2) was identical to the one used in NMRI tests of SPHA, with the exception that a majority of the work periods were run at constant rates selected by subjects.

TABLE 2 - DAILY WORK-REST PERIODS DURING SPHA TRIALS, DAYS 1 - 8

Time (min)	Event
- 60	Dress. Drink 2 glasses water (30 swallows).
- 30	Produce urine sample. Drink water if sp. gr. exceeds 1.030.
- 25	Enter climatic chamber. Stand 20 minutes.
- 5	Venous blood sample. Body weight. Final urine sample.
0	Drink 1/2 canteen water. Stretch, warmup calisthenics (5 min).
5	Exercise #1 (5 min) *
10	Rest (2 min)
12	Exercise #2 (8 min) *
20	Rest (2 min)
22	Exercise #3 (8 min) *
30	Rest (5 min)
35	Exercise #4 (5 min) *
40	Rest (10 min)
50	Exercise #5 (10 min)
60	Rest (5 min)
65	Exercise #6 (5 min)
70	Rest (5 min)
75	Exercise #7 (5 min)
80	Rest (5 min)
85	Exercise #8 (5 min)
90	Rest (5 min)
95	Exercise #9 (5 min)
100	Rest. Body Weight. Venous blood sample. Cool down. Final status check. Drink <u>ad libitum</u>.

* - All exercise periods involved running or jogging except periods 1 - 4 on days 1 and 8 (control trials). Days 1 and 8 were identical trials.

Appropriate t-tests, one-way ANOVA and two-way ANOVA were utilized to analyze differences between means (.05 confidence level). A subject's data was not included on a day when the treadmill speed was decreased by the investigator (due to elevated HR) or when his trial was terminated (due to HR or Tre in excess of safety limits). This accounts for the unequal sample sizes across days.

Results

All subjects were unacclimatized at the beginning of this investigation. Weather data for the months of January, February, March, April and May were obtained from the National Climatic Data Center, Asheville, NC. Mean daily outdoor maximum temperatures (°C) for these months were: -2.8 ± 0.7, 2.7 ± 1.3, 8.2 ± 1.1, 14.1 ± 1.2, 20.3 ± 1.0, respectively. Mean outdoor minimum temperatures (°C) for January through May were: -10.4 ± 0.7, -6.4 ± 1.2, -2.5 ± 0.9, 3.0 ± 0.8, and 8.3 ± 0.7. Mean outdoor dewpoints (°C) were: -13.6 ± 1.0, -9.0 ± 1.4, -8.6 ± 1.3, -1.1 ± 1.2, and 6.5 ± 1.0.

No significant differences were found when comparing mean entering BW or mean daily entering urine specific gravity across days 1-8 (Table 3). In addition, there were no significant differences in pre-SPHA (day -5 to day -2) and post-SPHA (day +6 to day +8) dietary records. Mean food energy (kcal) consumed pre-SPHA was 1926 ± 135 vs 2033 ± 131 during post-SPHA. Mean % protein, % carbohydrate and % fat were: 25.3 ± 2.0, 53.4 ± 2.2 and 21.2 ± 1.5 (pre-SPHA) vs 28.1 ± 2.3, 51.0 ± 2.4 and 19.2 ± 1.5

TABLE 3 - Entering body weight and urine specific gravity (mean ± SE, n = 14) on days 1 - 8.

Measurement	Trial Day 1	2	3	4 *	5 *	6	7	8
Body Weight (kg)	79.960	79.996	79.818	79.765	80.762	80.179	79.803	79.575
	± 3.761	± 2.725	± 3.761	± 3.781	± 3.855	± 3.736	± 3.654	± 3.601
Urine Specific Gravity	1.021	1.021	1.021	1.022	1.021	1.021	1.022	1.022
	± 0.022	± 0.022	± 0.022	± 0.022	± 0.022	± 0.010	± 0.002	± 0.002

* - Two days of rest (without SPHA trials) were taken between days 4 and 5.

(post-SPHA). Energy expended during each daily trial (exercise + rest) ranged from 352 to 910 kcal (range of daily group mean: 598 $\pm$ 38 to 707 $\pm$ 31 Kcal). Exercise intensities ranged from 51-95 $\%VO_2max$ during jogging and running. Total distance run-walked each day (mean $\pm$ SE) was 8.279 $\pm$ 0.527 to 9.799 $\pm$ 0.433 km (range: 4.7 - 13.8 km). Table 4 presents mean treadmill speed selected and mean exercise intensity selected each day. When compared using an ANOVA, there were no significant differences in these parameters across days 2-7. RPE was analyzed using a two-way ANOVA comparing the between-days and within-days variance. RPE (on all days 2 - 7) during work period 2 was significantly lower ($p<.05$) than during work period 5, 7 or 9. RPE was also significantly lower on day 8 (vs day 1) when corresponding work periods 2, 5, 7 and 9 were compared.

To examine the physiological effects of daily SPHA trials, group mean ($\pm$ SE) final HR, ΔHR, final TRE, ΔTRE, final Tsk and Tsk were compared from days 1 through 8 (Table 5). All of these variables on day 1 were significantly reduced ($p<.05$) by day 8, but no significant differences were found in any of the variables from days 2 - 7 of SPHA. The changes in Tre and Tsk during SPHA are illustrated in Figure 1. Day 8 values for Tre and Tsk were significantly lower during work periods 7, 8 and 9 (Tre) and periods 7 and 9 (Tsk).

Ve (L) and VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) on days 1 vs 8 were compared by work periods 1 or 2, 3 or 4, and 5 through 9 because subjects ran-walked at different speeds (see methods). No significant differences were found in Ve or VO_2, as a result of SPHA trials.

TABLE 4 - SELECTED TREADMILL SPEEDS, EXERCISE INTENSITIES, AND RATINGS OF *PERCEIVED EXERTION DURING RUNNING SPHA TRIALS*

Measurement (unit)	Experimental day							
	1	2	3	4	5	6	7	8
Treadmill belt speed	2.82^{+}	2.52	?.61	2.68	2.75	2.75	2.74	2.82^{+}
selected (m/sec)	± .09	± .11	± .13	± .12	± .13	± .12	± .13	± .09
Exercise intensity	71.8^{+}	63.0	65.1	67.6	69.1	68.4	68.8	71.8^{+}
selected (% $\dot{V}_{O_2max}$)	± 2.9	± 2.8	± 2.6	± 2.3	± 3.1	± 3.0	± 3.7	± 2.9
RPE - period 2^{**}	8 ± 1	10 ± 1	9 ± 1	10 ± 1	9 ± 1	9 ± 1	8 ± 1	$7 \pm 1^{*}$
- period 5	11 ± 1	12 ± 1	11 ± 1	12 ± 1	12 ± 1	12 ± 1	12 ± 1	$10 \pm 1^{*}$
- period 7	13 ± 1	13 ± 2	11 ± 1	12 ± 1	11 ± 1	12 ± 1	13 ± 1	$11 \pm 1^{*}$
- period 9	14 ± 2	12 ± 2	12 ± 1	13 ± 2	12 ± 1	13 ± 1	14 ± 1	$11 \pm 2^{*}$

+ - represents self-paced running only (periods 5 - 9); periods 1 - 4 involved walking

* - different ($p < .05$) from day 1; no statistical comparison of days 1 and 8 vs 2 - 7 was made

** - all period 2 values are different ($p < .05$) from period 5, 7, 9 values, within days

TABLE 5 - HEART RATE AND TEMPERATURE MEASUREMENTS DURING DAYS 1 - 8 OF SPHA EXERCISE TRIALS.

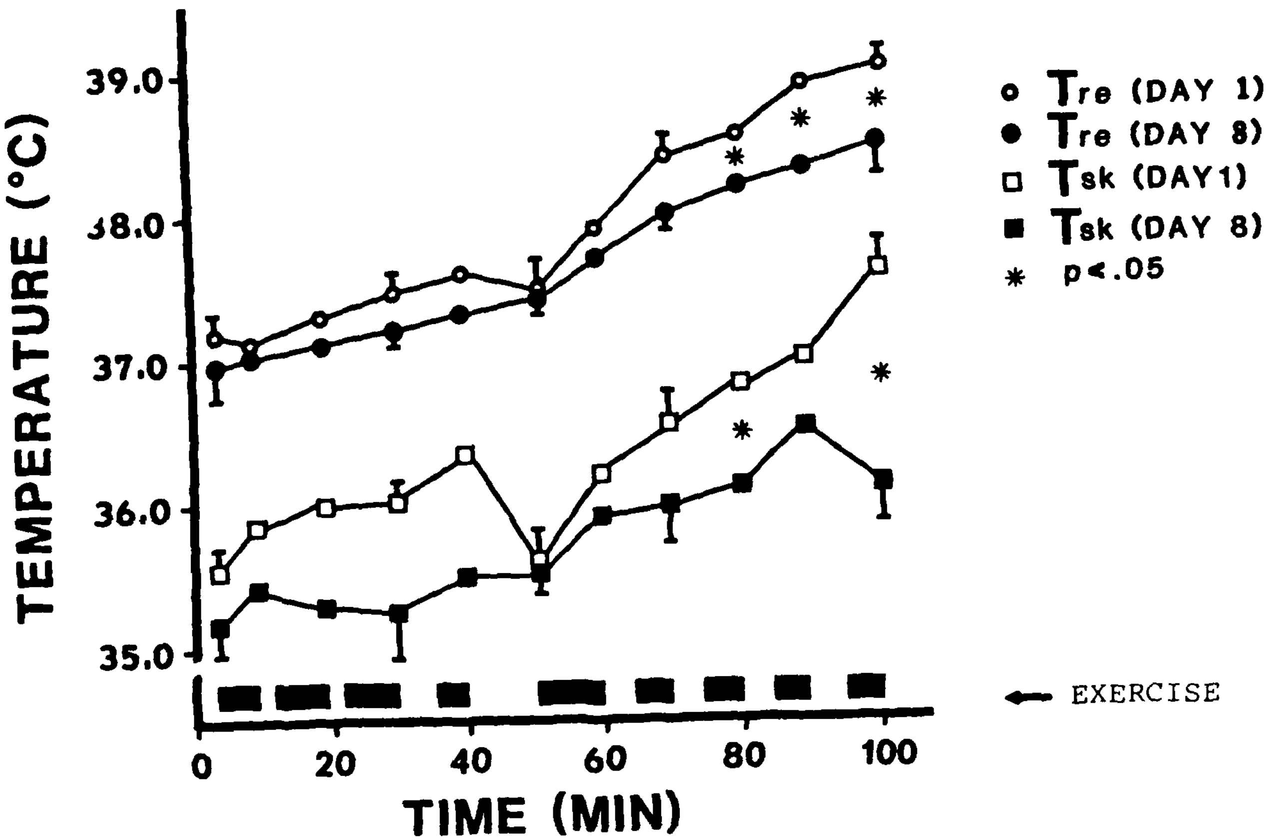
	Experimental days							
Measurement (unit)	1+	2	3	4	5	6	7	8+
Final heart rate (beats·min^{-1})	170	165	168	164	170	170	165	144*
	± 3	± 7	± 3	± 5	± 2	± 3	± 3	± 5
Change in heart rate (beats·min^{-1})	84	84	87	87	92	85	87	68*
	± 3	± 8	± 6	± 4	± 4	± 2	± 4	± 6
Final rectal temperature (°C)	39.17	39.05	38.92	38.77	38.69	38.64	38.61	38.52*
	± 0.10	± 0.15	± 0.12	± 0.10	± 0.10	± 0.15	± 0.07	± 0.16
Change in rectal temperature (°C)	2.04	2.14	1.89	1.75	1.74	1.61	1.72	1.46*
	± 0.09	± 0.18	± 0.12	± 0.14	± 0.14	± 0.16	± 0.09	± 0.18
Final MWST (°C)	37.58	36.27	35.82	36.26	35.83	35.51	35.50	36.53*
	± 0.23	± 0.34	± 0.26	± 0.23	± 0.28	± 0.32	± 0.28	± 0.29
Change in MWST (°C)	1.68	0.18	0.16	0.74	0.44	0.45	- 0.21	1.29*
	± 0.21	± 0.35	± 0.36	± 0.33	± 0.40	± 0.44	± 0.48	± 0.40

* - different ($p < .05$) from day 1

+ - days 1 and 8 were matched control trials to measure the effectiveness of SPHA; includes walking (per. 1 - 4) and self-paced running (per. 5 - 9).

Days 2 - 7 involved self-paced running during all 9 periods.

FIGURE 1 - Mean rectal and skin temperatures during identical trials on days 1 and 8 (n=14). Representative ± SE bars are shown.



In addition to the above variables, SR was analyzed across all days. SR ($ml \cdot m^{-2} \cdot hr^{-1}$) for days 1-8 were as follows: 401 $\pm$ 35, 534 $\pm$ 37, 530 $\pm$ 33, 563 $\pm$ 29, 513 $\pm$ 33, 613 $\pm$ 39, 587 $\pm$ 38, and 380 $\pm$ 45. Sweat rates on days 1 and 8 were significantly lower ($p < .05$) than days 2 - 7, reflecting the lower SR produced by walking exercise performed during periods 1 - 4 of these control trials.

Table 6 presents plasma volume and serum electrolyte data for day 1, 4 and 8. Plasma volume expanded +5.9 % during the first four days of SPHA, but there was no change during the final four days. There was a better defense of PV ($p<.05$) during exercise on day 8 than on day 1. No significant differences were found in serum sodium. Serum potassium was significantly higher post-exercise on each of the three blood analysis days.

Subjects experienced a variety of heat illness symptoms throughout the investigation. Most were minor and did not warrant termination of exercise. Symptoms and the number of early terminations (Table 7) were less frequent during days 5-8 than during days 1-4. For example, six out of 14 trials were terminated on day 1, in comparision to 1 out of 14 on day 8. Table 7 summarizes the occurence of heat illness symptoms (HIS) and instances of premature termination of trials (PTT).

Discussion & Military Applications

This investigation was designed to evaluate the effectiveness and safety of SPHA procedures. The authors recommend that every reader of this technical report also read the NMRI studies

TABLE 6 - BLOOD VALUES DURING SPHA (mean ±SE).

Measurement (unit)		Experimental days 1	4	8
Mean corpuscular hemoglobin concentration		2.67 ± 0.02	2.72 ± 0.03	2.73 ± 0.03
Change in plasma volume (%ΔPV) from day 1 (resting)			+ 5.9 ± 2.6	+ 5.2 ± 1.7
Change in plasma volume (%ΔPV) from pre to post (exercise)		- 7.1 ± 0.9	- 6.8 ± 2.1	- 5.1* ± 1.1
Plasma Na^+	- pre	141 ± 1	141 ± 1	140 ± 1
	- post	140 ± 1	140 ± 1	141 ± 1
Plasma K^+	- pre	4.3 ± 0.1	4.5 ± 0.1	4.4 ± 0.1
	- post	4.7 ± 0.1+	4.7 ± 0.1+	4.8 ± 0.1+

* - different from day 1 ($p < .05$)   + - different from pre ($p < .005$)

TABLE 7 - HEAT ILLNESS SYMPTOMS[+] AND TRIALS WHICH WERE PREMATURELY TERMINATED[*].

Subject	Experimental days							
	1	2	3	4	5	6	7	8
A		*						
B				l				
C	*	s						
D	*	s				f		
E						c		
F		*						
G	*	*	f*c	fch				
H		*	f		c		i	
I	*							sv
J				*			*	
K	p			d*	*			
L	*		*	f*	*	*	*	
M	pc*f	pc*f						s
N								svl*

* - premature termination of trial (PTT) by investigator because HR or Tre was in excess of safety limits

\+ - heat illness symptom legend:

- p - piloerection
- c - chills
- f - flushed head, torso
- d - dizziness
- i - irritable, angry disposition
- s - stomach cramps
- h - elevated HR during rest
- l - legs very tired
- v - vomiting

Most symptoms were minor and did not warrant premature termination.

published in January, 1984 (2). SPHA procedures, although not perfect, clearly offer many advantages to the safety-minded commander which are not offered by training systems in which: (1) all soldiers perform exercise of the same intensity and duration, and (2) soldiers are not monitored in some way. In fact, a singularly outstanding aspect of SPHA procedures involves the thorough monitoring of soldiers.

Comparison of physiological measurements (Table 5) on control days 1 and 8 (identical trials) indicated that typical heat acclimation adaptations occurred during the eight days of SPHA, in final HR (170 vs 144), ΔHR (84 vs 68), final Tre (39.17 vs 38.52), ΔTre (2.04 vs 1.46), final Tsk (37.58 vs 36.53), and Tsk (1.68 vs 1.29). The mean group Δ%PV from day 1 to day 4 (resting) was +5.9; this value stabilized at nearly the same volume on day 8 (Δ%PV = +5.2 between days 1 and 8). Sweat rate did not increase significantly from day 1 to 8. This has been observed elsewhere (6) and is not uncommon in light of the fact that approximately 10-12 days are required for full sweat gland adaptation (5,6).

Days 2 - 7 of SPHA were designed to evaluate the nature of subject selection of exercise intensity and to determine whether self-paced exercise in the heat resulted in elevated Tre, excessively high HR, or heat illness symptoms. Daily group means indicated that subjects selected treadmill belt speeds and exercise intensities (Table 4) which were statistically similar on days 2 - 7. The RPE scores (periods 2, 5, 7, 9) also indicated that subjects perceived exercise similarly during comparable work periods on days 2 - 7, while final HR remained relatively constant and final Tre decreased (Table 5).

Evans et al. (7) observed that hard self-paced work involved 46 %VO_2max for males and 44 %VO_2max for females, while walking for 1-2 hours over four different terrains and carring no load, 10 kg, and 20 kg loads. Saha et al. (8) reported that 35 %VO_2max was a reasonable exercise intensity during 8 hours of sustained, low intensity physical activity. In the present investigation, however, subjects were encouraged to "jog or run", and self-paced exercise intensities were surprisingly high (51 - 95 %VO_2max). It appears that walking typically limits self-paced exercise intensities to less than 50 %VO_2max and that nearly all jogging or running will typically exceed 50 %VO_2max.

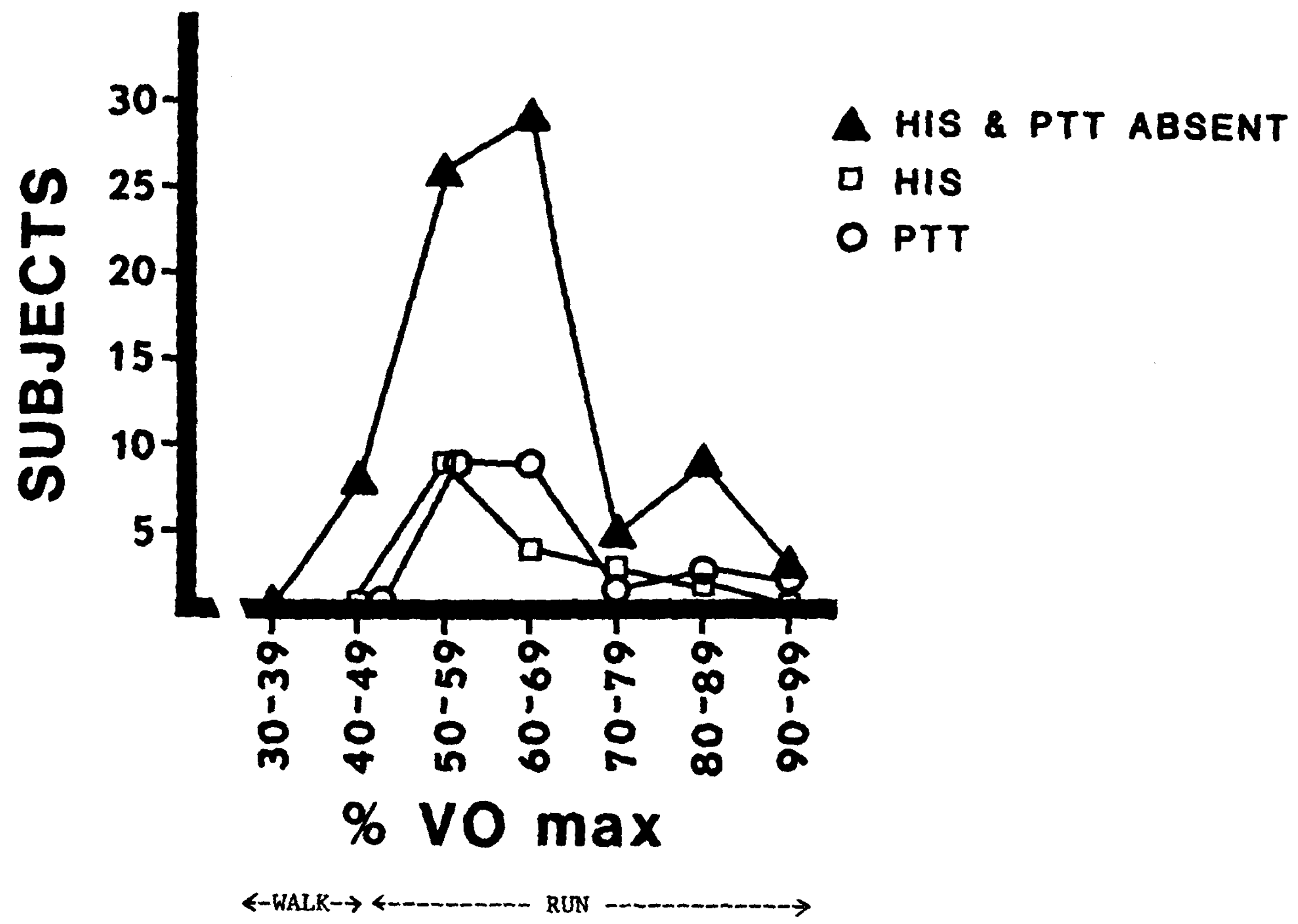
Although NMRI studies did not report absolute or relative oxygen consumption during SPHA, they expected SPHA to result in exercise intensities approximating 45 %VO_2max (2). The exercise intensities of the present investigation indicate that this assumption is incorrect, if soldiers "jog or run" in pairs; such exercise is likely to involve exercise intensities in excess of 50 %VO_2max. The present investigation differed from the NMRI studies in this important aspect of work intensity, and we cannot speculate on the success of NMRI studies because we have no way to determine the exercise intensities selected by soldiers in NMRI studies. We found that our subjects selected exercise intensities which were well above those originally anticipated by NMRI investigators (approximately 45 %VO_2max). The present investigation unintentionally achieved what it set out to avoid: a heat acclimation program which involved intense exercise. This may have been due to the pairing of subjects on adjacent treadmills (encouraging competition?), the fact that subjects knew that trials involved only 100 min of heat exposure per day, the instructions to "jog or run", or the requirement to request the investigator to reduce the treadmill speed (an admission of failure to some competitive personalities?).

Although SPHA procedures offer many advantages that other training systems do not, SPHA in which soldiers "jog or run" cannot be viewed as a panacea for elimination of heat illness symptoms, or as an absolute safeguard against soldiers exceeding HR and Tre safety limits, if soldiers "jog or run", or if they are highly competitive. During days 2 - 7 (Table 7), subjects exceeded USARIEM Human Use Review Committee safety limits for HR (180 beats$\cdot$min^{-1}) and Tre (39.5^{o}C) in 22 out of 112 trials (19.6 %). One subject was removed from the climatic chamber prematurely on 6 out of 8 days because of elevated Tre. In addition, 11 out of 14 volunteers (78.6 %) experienced at least one heat illness symptom at some time (Table 7). It is clear that SPHA procedures cannot guarantee that soldiers will be free of heat illness symptoms if they "jog or run". The authors believe that several other subjects would have pushed themselves to dangerously high Tre, if SPHA trials had not been monitored closely and terminated.

To accomodate large group heat acclimation, NMRI researchers replaced routine Tre measurements with, "... a heirarchy of observational monitoring... (including a) buddy system.... (and) on-site medical monitors." Although the potential for exercise-induced heat injury was present in those studies, careful visual monitoring (without continuous Tre and HR observations) decreased the chances of it occurring. The NMRI report (2) argued that heat illness symptoms, per se, were not a cause for alarm: "... allowing occasional persons to present with beginning (heat illness) symptoms is considered safe as well as practical...", because of the logistical problems associated with exposing 1600 men to SPHA trials each day. The present investigation supports this position. Although volunteers may have been approaching heat exhaustion (heat illness symptoms were observed at least once in 78.6 % of all volunteers), the Tre and HR safety limits prevented serious heat injuries during each of the 112 trials, and none of the 14 volunteers missed a trial.

Heat illness symptoms (HIS) and premature termination of trials (PTT) were distributed in the same way that asymptomatic trials were distributed (with regard to exercise intensity) and were not skewed to the right (Fig. 2). Therefore, the difficulties experienced by subjects (HIS and PTT) were not solely the result of high intensity exercise. In fact, the greatest number of PTT and HIS were observed at exercise intensities of 50 - 69 %VO_2max (Fig. 2). Ironically, one would expect HIS and PTT to occur most often in individuals who are exercising at very high exercise intensities (> 70 % VO_2max). Because HIS (Table 7) totalled 11 on days 1 - 4, but totalled 7 on days 5 - 8 (and because PTT totalled 16 on days 1 - 4 and totalled only 6 on days 5 - 8), heat acclimation status apparently played a more important role in the appearance of heat-related difficulties than did self-paced exercise intensity.

FIGURE 2 - DISTRIBUTION OF MEAN EXERCISE INTENSITY (% VO_2max) SELECTED BY SUBJECTS ON DAYS 1 - 8 (n = 112 TRIALS). HIS = HEAT ILLNESS SYMPTOMS, PTT = PREMATURE TERMINATION OF TRIALS.



To define a statistically safe SPHA program, confidence limits were calculated for the length of SPHA trials (using the plan outlined in Table 2) which would allow 98 % of all soldiers to finish with Tre and HR below USARIEM Human Use Review Committee safety limits, when jogging/running at exercise intensities of 51 - 95 %VO_2max. The lower confidence limits for time (on days 1 - 8) were calculated as follows: 92, 88, 88, 90, 94, 96, 96, and 92 min. Therefore, SPHA trials of 7 work-rest periods (80 min total, see Table 2) instead of 9 would theoretically eliminate the problem of HR and Tre which exceed safety limits.

Although aerobic training and heat acclimatization training are often viewed as one process, the risk of heat injury increases dramatically when aerobic training is conducted in environments which are conducive to heat acclimatization. These two types of training have different goals and unique inherent risks. Aerobic training is best conducted early in the day, when temperatures are low. Heat acclimatization training is best conducted in hot environments, using medical officers and trained observers to monitor soldiers closely. The above findings describe safeguards which should be included in any heat acclimatization program.

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Disclaimers

The views, opinions, and/or findings contained in this report are those of the authors and should not be construed as official Department of the Army position, policy or decision, unless so designated by other official documentation.

Human subjects participated in these studies after giving their informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 for use of volunteers in research.

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