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REPORT NO RCS MEDDH-288 (R1)

ANNUAL PROGRESS REPORT

FISCAL YEAR 1978

(1 October 1977 - 30 September 1978)

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

1 Oct[redacted]978

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UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

UNCLASSIFIED

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Acute Mountain Sickness	Anaerobic Work Capacity	Behavior
Aerobic Fitness	Angiography	Biochemistry
Aerobic Power	Anorexia	Biofeedback
Altitude	Auxiliary Cooling	Biophysics
Anaerobic Metabolism	Basal Metabolic Rate	Blood Coagulation (Cont'd)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A report of progress on the research program of the US Army Research Institute of Environmental Medicine for Fiscal Year 1978 is presented, as follows:

Program No.	Project No.	Task No.	Title
6.11.01.A	3A161101A91C	00	In-House Laboratory Independent Research
6.11.02.A	3E161102BS08	05	Defense Research Sciences, Army
6.27.77.A	3E1612777A845	00	Environmental Stress, Physical Fitness & Medical Factors in Military Performance

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Body Composition
Body Fat
Body Temperature
Body Weight Regulation
Brain Interstitial Fluid
Cancer
Carotid and Medullary Chemoreceptors
Chronic Hypoxemia
Climatic Exposure
Cognitive Functions
Cold
Cold Induced Vasodilation (CIVD)
Cold Injury
Cold Injury Prevention
Cold Pressor Test
Continuous Operations
Crew Compartments
Critical Thermal Maximum
Cryobiology
Dehydration
Disabilities
Eccentric Work
Endothelial Cells
Endotoxin
Energy Cost
Energy Expenditure
Environmental Medicine
Environmental Stress
Environmental Tolerance
Esophageal Temperature
Evaporative Cooling Index
Exercise at High Altitude
Facial Rewarming
Fasciotomy
Fitness
Fluid Compartments
Frostbite
Health Risk Factors
Heat
Heat Disabilities
Heat Production
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Height/Weight Standards
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Human Performance at Altitude
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Hypovolemia
Hypovolemics
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Isolated, Perfused Rat Liver
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Lypodystrophy
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Submaximal Workload
Survey Analysis
Sustained Human Performance
Sustained Operations
Sweating Rate of Thermal Regulation
Symptoms
Systemic Hypotension
Team Performance
Terrain Coefficients
Thermal Exchange
Thermography
Thermoregulation
Thyroid Function
Tissue Culture
Tolerance
Tolerance Prediction
Treatment
Ultrastructure
US Military Academy
Vasodilation
Visual Search Performance
VO_2 Max

US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

NATICK, MASSACHUSETTS

01760

ANNUAL PROGRESS REPORT

FISCAL YEAR 1978

(1 October 1977 - 30 September 1978)

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UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

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(81021)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6134	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.01.A	3A161101A91C	00	021
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*
(U) The Effects of Heat on the Structure and Function of Perfused Rat Liver (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
005900 Environmental Biology; 002300 Biochemistry; 012900 Physiology; 010100 Microbiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 04	CONT	DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
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18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	4.0	147
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19. RESPONSIBLE DOD ORGANIZATION
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TELEPHONE: 955-2862
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
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NAME: HAMLET, Murray P., D.V.M. DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U) Heatstroke; (U) Hepatic Necrosis; (U) Isolated, Perfused Rat Liver; (U) Hyperthermia

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The objective of this research is to determine at what temperatures metabolic, histological, and ultrastructural changes occur in the isolated perfused rat liver due to heat exposure. These parameters will then be used to evaluate the role of the liver in heatstroke independent of the complex mechanisms operating in the whole animal. The effects of a variety of heat generated substances can also be ascertained. An understanding of the mechanisms of heat induced lesions may lead to the formulation of therapeutic agents specifically designed to negate these factors.

24. (U) Pathological changes in the liver are among the most consistent findings subsequent to heatstroke. A systematic study of heat-induced injury to the isolated perfused organ should yield valuable insight into the mechanisms of tissue damage independent of the complexities encountered with whole animals. By perfusing fluids at known temperatures, the critical temperatures for endothelial and parenchymal cell injury can be established using light and electron microscopy, potassium release, dye clearance, release of GPT, glucose metabolism and oxygen consumption. The effects of perfusate containing precise amounts of chemically pure substances thought to play a role in heatstroke or containing cellular fluids from heated animals can be ascertained.

25. (U) 77 10 - 78 09 The effects of hypoxia and hypoglycemia, in addition to 43°C heat, were examined. Livers perfused at 42°C, 41°C, 40°C and 39°C were compared with those perfused at 37°C and 43°C. Bile production, potassium, GPT, GOT release, light and electron microscopic structure were studied. Multiple stressors increase extent of damage over a shorter time frame. Exposure to 41°C and 90 minutes produced centrilobular vacuolization while 42°C produced dissociation of hepatocytes. Enzyme leakage and bile production related to specific temperatures and exposure times. Effects of other factors are under study.

*Available to contractors upon originator's approval.

DD FORM 1498, 1 MAR 68 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Project Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	021 The Effects of Heat on the Structure and Function of the Perfused Rat Liver
Study Title:	The Effect of Heat on the Structure and Function of the Perfused Rat Liver
Investigators:	Wilbert D. Bowers, Jr., Ph.D., Roger W. Hubbard, Ph.D., Murray P. Hamlet, D.V.M. and John T. Maher, Ph.D.

Background:

Focal hepatic necrosis is a common finding in both humans (1,2,3,4,5) and animals (6,7) suffering from hyperthermia. These lesions have been described in cross country runners (3), Bantu miners (5), therapeutically hyperthermic patients (8) and in rats where hyperthermia was induced by either exhaustive exercise or sedentary heating (6,7,9).

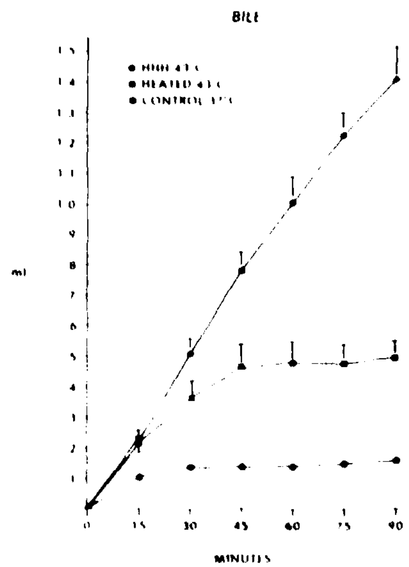
Since the lesions were usually centrilobular, ischemic injury has been considered as a possible cause of the hepatic changes (7,10). However, other causes, such as the direct effects of heated blood (2,11) and undefined toxins (12) on labile populations of cells, have been suggested. Unfortunately, studies concerning the pathogenesis of heat-induced hepatic necrosis have been hampered by the complexities of systemic manifestations occurring during heatstroke.

The isolated perfused liver, studied under precisely defined conditions, provides a means for evaluating the effects of individual or combined parameters on this organ.

A systematic study of heat-induced injury to the isolated perfused liver should yield valuable insight into the mechanisms of tissue damage. The critical temperatures for endothelial and parenchymal cell injury and subsequent events can be established using light and electron microscopy, bile production, potassium release, release of GPT and GOT, and oxygen consumption.

Progress:

Previous studies of the isolated perfused liver indicated that heat alone induced severe hepatic damage which was reflected in inhibition of bile production, release of liver enzymes (GPT and GOT) and K^+, focal hepatocellular damage, and generalized endothelial damage. Current research has shown that the addition of hypoxia and hypoglycemia, which may occur in heatstroke, produces pathological changes similar to those induced by heat alone except that damage is more severe and occurs over a shorter time course (Figures 1,2,3 and 4). In order to insure hypoxia in the heated hypoxic hypoglycemic group (HHH), the flow rate was reduced. The dotted line indicates the curve for this group corrected flow rate. When separate groups of livers were perfused for 90 minutes at different temperatures (37°, 39°, 40°, 41°, 42° and 43°C), bile production reached a plateau in 45 minutes at 43°C, 60 minutes at 42°C, and was slightly stimulated by temperatures between 39° and 41°C (Figure 5). Release of GPT and GOT also indicated damage after 45 minutes at 43°C (Figures 6 and 7). Of greater significance, however, is the fact that exposure to 42°C and 43°C induced dissociation of hepatocytes, while exposure to 41°C induced centrilobular vacuolization as determined by light microscopy. Electron microscopy of these livers is in progress. We are also examining the time course for production of structural lesions at specific temperatures and plan to examine effects of hepato-protective agents.



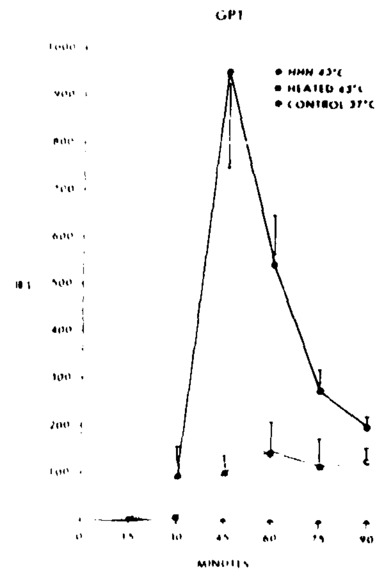
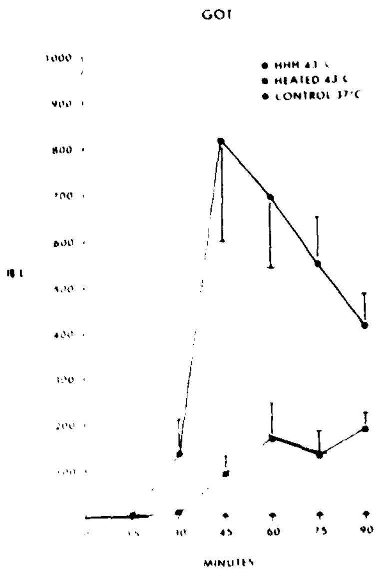


Figure 1. Bile production by the control group was linear over the 90 minute period. Bile production by livers exposed to 43°C reached a plateau after 45 min. The addition of hypoxia and hypoglycemia to the 43° heat exposure (HHH) inhibited bile production after 30 min.

Figure 2. Glutamic-pyruvic transaminase (GPT) was not detected in perfusates from control livers. Livers perfused at 43°C showed an elevation in this enzyme after 45 minutes, with a peak after 60 min. The heated hypoxic group (HHH) showed an elevation after 30 minutes, with a peak after 45 min. This group of livers was perfused at 10 ml/min at a PO_2 57 in order to reduce the available oxygen. Controls and heated livers were perfused at 40 ml/min. Since the amount of enzyme detected/ml is inversely related to the flow rate, the dotted line indicates the curve for the HHH group correct for the difference in flow rate.



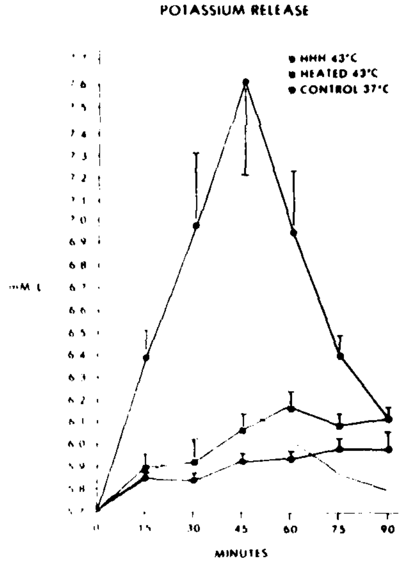
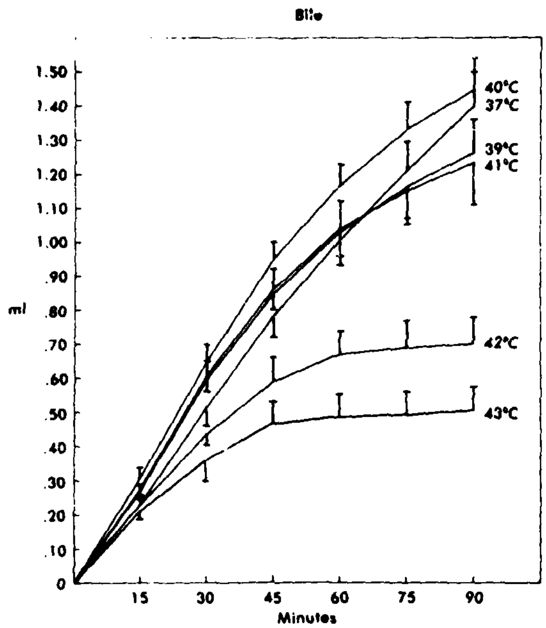


Figure 3. Glutamic-oxaloacetic transaminase (GOT) released into the perfusates of the three groups was similar to that of GPT.

Figure 4. A gradual release of potassium was detected in perfusate from control livers. Heat alone induced release which reached a peak after 60 minutes while HHH showed a peak after 45 min.



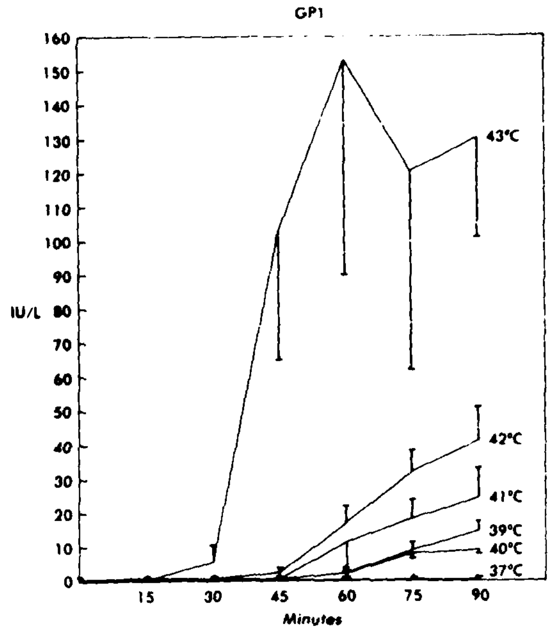


Figure 5. When groups of livers were heated for 90 minutes at temperatures from 37° to $43^{\circ}C$, bile production reached a plateau after 45 minutes at $43^{\circ}C$ and after 60 minutes at 42°. Bile production was essentially the same at temperatures from 37° to $41^{\circ}C$.

Figure 6. GPT released by livers perfused for 90 minutes at 37° - $43^{\circ}C$ indicated significant damage at 41°, 42° and $43^{\circ}C$ and mild damage at 39° and $40^{\circ}C$.

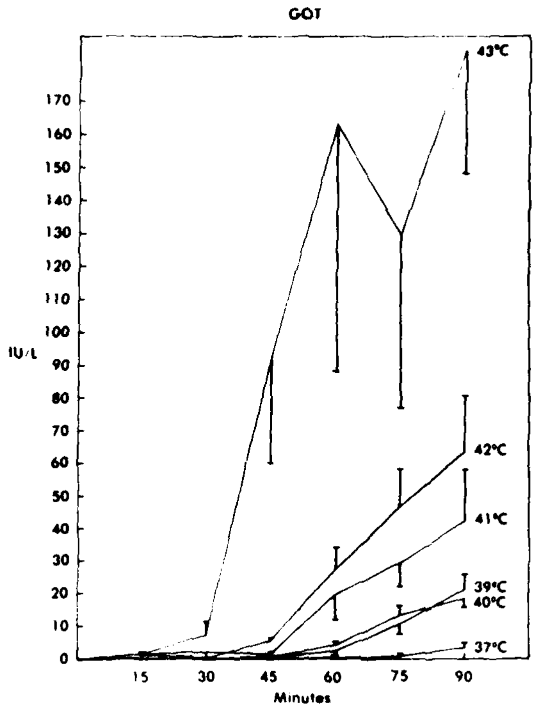


Figure 7. GOT in perfusate from livers perfused for 90 minutes at 37^{o} to $43^{o}C$ was similar to that of GPT.

Presentations:

Bowers, W. D., Jr., R. Hubbard, D. Wagner, P. Chisholm, M. Murphy, I. Leav, M. Hamlet and J. Maher. Effects of heat on the structure and function of perfused rat liver. Presented at the Federation Proceedings in Atlantic City, NJ, April 9-14, 1978.

Publications:

Bowers, W. D., Jr., R. W. Hubbard, I. Leav, R. Daum, M. Conlon, M. Hamlet, M. Mager and P. Brandt. Alterations of rat liver subsequent to heat overload. Arch. Pathol. Lab. Med. 102:154-157, 1978.

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(81022)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
	DA 0B 6132	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
78 04 14	D. Change	U	U	N/A	N/L	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.01.A	3A161101A91C	00	022
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)

(U) Ventilatory Control Mechanisms at High Altitude (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS

012900 Physiology; 005900 Environmental Medicine; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
75 01	CONT	DA	In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER: NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	3	89
	CURRENT 79	2	80

19. RESPONSIBLE DOD ORGANIZATION

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ADDRESS: Natick, MA 01760

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TELEPHONE: 955-2851

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: GABEL, Ronald, A., M.D.

NAME: 955-2828 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Chronic Hypoxemia; (U)Carotid and Medullary Chemoreceptors; (U)Brain Interstitial Fluid; (U)Exercise at High Altitude

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The physiologic processes which control ventilation of man at high altitude are not fully understood. The objective of this work unit is to gain new knowledge of ventilatory control, with emphasis on adaptations within the control system during exposure to chronic hypoxemia, as experienced during sojourn at high terrestrial altitudes. A thorough understanding of this aspect of altitude physiology is essential in defining new approaches for enhancing adaptation of the soldier to high terrestrial elevations.

24. (U) An integrated program is under way to analyze contributions of both the carotid body and medullary chemoreceptors to the ventilatory adaptations of man to hypocapnic hypoxia, including interactions between the two chemoreceptors. Studies are also being carried out to determine contributions of the peripheral and central chemoreceptors to the increase in ventilation during muscular exercise exceeding the anaerobic threshold, as would be seen frequently at high altitude.

25. (U) 77 10 - 78 09 In 6 unanesthetized goats, artificial cerebrospinal fluid (CSF) was perfused from cerebral ventricle to cisterna magna to measure indirectly the $[HCO_3^-]$ in the cerebral interstitial fluid (CISF) before and after acclimatization (A) to high altitude (HA). After 5 days at HA, the $[HCO_3^-]$ and estimated pH in CISF were lower than before A, and were lower than the $[HCO_3^-]$ and estimated pH in cisternal CSF after A. Alterations in ventilation (V) during isocapnic progressive hypoxia were found in 5 unanesthetized goats to be qualitatively similar to those found in humans; V was rectilinearly related to percentage saturation of hemoglobin in the arterial blood.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	022 Ventilatory Control Mechanisms at High Altitude
Study Title:	Cerebral Fluids in Prolonged Acid-Base Imbalance
Investigators:	Vladimir Fencl, M.D., Ronald A. Gabel, M.D. and Danney L. Wolfe, CPT, VC

Background:

In the past it was widely accepted that the gradual increase in pulmonary ventilation at high altitude (HA) results from increased acidity of cerebrospinal fluid (CSF), owing to a fall in CSF [HCO_3^-] (1). This explanation for acclimatization no longer appears plausible, in view of the newer data showing that CSF becomes more alkaline in this process. This has been shown for lumbar CSF in humans (2,3,4,5) and cisternal CSF in humans (5), ponies (6), and dogs (7).

The cerebral interstitial fluid (cISF) would be an alternative site in which acid-base changes might occur to produce alveolar hyperventilation in adaptation to high altitude. At sea level, in normal acid-base balance, as well as in stable metabolic acidosis or alkalosis, the ionic composition of cISF is the same as in CSF (8), and the acidity of these fluids correlates with the level of resting pulmonary ventilation. The ionic composition of cISF, and its acidity, during alveolar hyperventilation in respiratory adaptation to HA, is unknown. It is possible that the acidity of the cISF in contact with intracranial chemoreceptors is higher than that seen in CSF.

Progress:

Nine goats were successfully operated on and provided with carotid loops for repeated sampling of arterial blood, and with chronically implanted nylon guide tubes for repeated punctures of the lateral ventricles and of cisterna magna, for sampling of the goats' CSF, and for aseptic ventriculo-cisternal perfusions with sterile artificial CSF of various ionic composition. The techniques of Pappenheimer et al. (9) and Fencl et al. (8) were applied.

Measurements were made of resting ventilation and CO_2 production while the goats inhaled room air; concurrently, an anaerobic sample of cisternal CSF was obtained. After repeated respiratory measurements during inhalation of 100% O_2, the ventriculo-cisternal system of the animals was perfused, as described below. All these measurements were made twice, once at sea level, and again at simulated high altitude, after 5 days' adaptation. For this the goats were kept in the USARIEM hypobaric chamber. The pressure was kept at 446 torr (range to $\pm$ 5 torr), temperature at 21 $\pm$ 1 C, and air flow through the chamber was such that FCO_2 never exceeded 0.004. The goats moved freely in stalls, were fed regularly and had free access to water and salt licks.

During each experimental day, perfusions were done with three fluids. One approximated the ionic composition of cisternal fluid of normal goats (9); the other two fluids differed in the concentration of HCO_3^-, being about 15 and 28 mM/l (with complementary changes in $[Cl^-]$). Approximately 1 nanocurie of ^{3}H-inulin (specific activity 160 millicurie per 1 gram) was added per 1 ml perfusion fluid, for measurement of bulk absorption and formation of CSF (10), and for calculation of net transependymal fluxes. Net transependymal fluxes of HCO_3^-, Cl^- and lactate were calculated using equations derived by Pappenheimer et al. (11):

$$\dot{n} = \dot{V}_i (c_i - c_f) - (\dot{V}_o + C_{In})(c_o - c_f)$$

where $\dot{n}$ = net flux of the ion (μM/min) between the perfusate and cISF,

$\dot{V}$ = rate of flow of perfusion fluids (ml/min),

c = concentration of the ion (mM/L)

i, o, f = subscripts referring respectively to inflow, outflow, and freshly formed CSF (8),

C_{In} = clearance of inulin from ventricular system ($\dot{V}_i c_i - \dot{V}_o c_o$/co (ml/min)).

The flux thus calculated is corrected for the entry of the ion under consideration via bulk formation of CSF, and for exit of the ion via bulk reabsorption of fluid in arachnoid villi. This transependymal flux of an ion represents the net passive exchange between the ventriculo-cisternal perfusate and cISF, across the leaky ependyma in the cerebral ventricles, and pia-glia on the cerebral surface. Therefore, concentration of an ion in an inflowing perfusate that produces zero flux indicates the concentration of that ion in cISF (8).

Satisfactory data on ventilatory measurements, arterial blood and CSF analyses, and ventriculo-cisternal perfusions were obtained in 6 goats, both at sea level (SL) and after 5 days at HA. Table 1 summarizes the respiratory data:

TABLE 1

Respiratory Adaptation of Goats after 5 Days at Simulated High Altitude (4300 m)(n=6; means ± SE)

Inhaled gas:	Room Air			100% O_2		
	SL		HA	SL		HA
$\dot{V}CO_2$ ml/min STPD	151 ± 34	N.S.	152 ± 24	-		-
$\dot{V}_A$ l/min BTPS	2.9 ± 0.1	$p < 0.001$	3.9 ± 0.2	3.1 ± 0.2	$p < 0.02$	4.0 ± 0.4
$PaCO_2$ torr	41 ± 1	$p < 0.001$	34 ± 1	43 ± 2	$p < 0.02$	38 ± 1

There was no appreciable difference between the resting metabolic rate ($\dot{V}CO_2$) at SL and HA. Alveolar ventilation ($\dot{V}_A$) increased significantly at HA (t-test for paired samples); concomitantly, $PaCO_2$ decreased. The hyperventilation at high altitude also persisted with hyperoxia (inhalation of 100% O_2).

Measurements made in arterial blood while the goats were quietly breathing room air, are shown in Table 2:

TABLE 2

Arterial Blood at Sea Level and After 5 Days at Simulated High Altitude (4300 m)
Data on 6 Goats Breathing Room Air (means $\pm$ SE)

	SL	HA	Significance[1]
PO_2, torr	104 ± 2	43 ± 2	$p < 0.001$
PCO_2, torr	41 ± 1	34 ± 1	$p < 0.001$
pH	7.438 ± 0.015	7.449 ± 0.015	N.S.
$[HCO_3^-]$, mM/L plasma	29 ± 1	23 ± 0.5	$p < 0.02$
$[Cl^-]$, mM/L plasma	106 ± 1	112 ± 0.5	$p < 0.01$
[Lactate], mM/L whole blood	0.6 ± 0.1[3]	1.2 ± 0.2[4]	N.S.[2]

1 t-test for paired samples

2 t-test for means of unpaired samples

3 mean of 3 goats

4 mean of 4 goats

PaO_2, as expected, was reduced at HA. $[HCO_3^-]$ in plasma decreased, and $[Cl^-]$ increased at HA. Concentration of lactate in whole blood doubled at high altitude (this did not reach statistical significance in our data).

Composition of the cisternal CSF at SL and HA is shown in Table 3:

TABLE 3

Cisternal CSF at Sea Level and After 5 Days at Simulated High Altitude(4300 m)

Data on 6 Goats (means ± SE)

	SL	HA	Significance[2]
pH	7.300 ± .009	7.322 ± .006	$p < 0.001$
PCO_2, torr	47 ± 1	39 ± 1	$p < 0.001$
$[HCO_3^-]$, mM/L	23 ± 0.5	20 ± 0.4	$p < 0.001$
$[Cl^-]$, mM/L	128 ± 1	130 ± 0.5	$p < 0.02$
$[Lactate^-]$,[1] mM/L	2.9 ± 0.1	4.1 ± 0.1	$p < 0.02$

1 4 goats

2 t-test for paired samples

There was a significant alkaline shift in cisternal CSF at HA, although both $[Cl^-]$ and lactate increased, and $[HCO_3^-]$ was reduced. The mean drop in $[HCO_3^-]$ was stoichiometrically matched by the combined increase in $[Cl^-] + [Lactate^-]$. The CSF alkalosis at HA was thus produced by a marked reduction in CSF PCO_2.

The difference between CSF and arterial PCO_2 was reduced from the SL value of 6.1 ± 0.6 torr, to 3.6 ± 1.1 torr at HA, ($p < 0.01$), suggesting that cerebral blood flow (CBF) was possibly higher at HA than at SL, assuming there was no marked change in cerebral CO_2 production (which was not measured in our experiments).

Thus, in the 6 goats, the ventilatory acclimatization to HA was established (Table 1), with hypoxic hypocapnia in blood (with almost complete renal compensation of the respiratory alkalosis in blood, Table 2). In cisternal CSF, pH was more alkaline at HA than at SL (Table 3), similar to findings in humans (2,3,4,5), ponies (6), and dogs (7). There may have been an increase in CBF analogous to findings in human sojourners at HA (12).

Technically satisfactory measurements of transependymal fluxes were measured for HCO_3^-, 25 times at SL and 22 times at HA; for Cl^-, 24 times at SL and 17 times at HA; and for lactate, only in 4 goats, 17 times both at SL and HA.

Figures 1 and 2 show the plots of net transependymal fluxes of HCO_3^- and Cl^-, respectively, versus the differences between the concentrations of these ions in the ventricular inflow, and those found in the goat's CSF ($\Delta[HCO_3^-]$ and $\Delta[Cl^-]$, respectively). Thus, if this difference equals zero, the concentration of the ion in the fluid entering the ventricles is equal to its concentration in the goat's CSF. Positive flux means uptake of the ion into cISF, negative flux means washout of the ion from cISF. The plots are least-square linear regression lines derived from the experimental data.

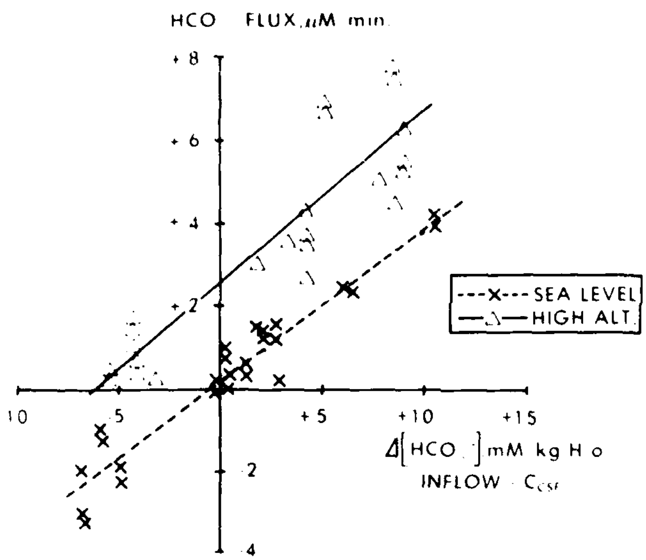

Figure 1: Net transependymal fluxes of HCO_3^- in goats adapted to sea level and to high altitude. Fluxes are plotted against the bicarbonate concentration difference between the inflowing perfusate and the goat's CSF under the two conditions of respiratory adaptation. The straight lines are least-squares regressive lines (see Table 4 for parameters of the regressions).

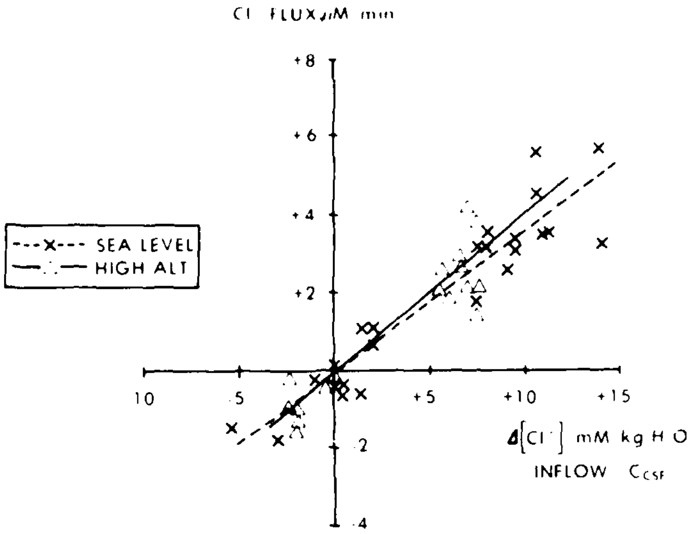

Figure 2: Net transependymal fluxes of Cl^- in goats adapted to sea level and high altitude. These plots are analogous to those for HCO_3^- shown in Figure 1.

Table 4 gives the equations relating the flux of an ion (y) to the difference between the concentration of that ion in the inflowing flux, and that in the goat's CSF (x): $y = a + bx$.

TABLE 4

Parameters of Regression Lines Relating Net Transependymal Fluxes of HCO_3^- and Cl^- (y) to the Concentration Differences of these Ions in the Inflow Perfusates and that in the Goat's CSF (x). Data Shown in Figures 1 and 2

HCO_3^-	flux	SL	$y = 0.2 + 0.37x$;	$r = 0.96$
		HA	$y = 2.6 + 0.42x$;	$r = 0.90$
Cl^-	flux	SL	$y = -0.1 + 0.36x$;	$r = 0.94$
		HA	$y = -0.1 + 0.40x$;	$r = 0.92$

The intercepts (a) are statistically indistinguishable from zero for HCO_3^- flux at SL and for Cl^- flux both at SL and at HA; however, for the flux of HCO_3^- at HA, this intercept is significantly ($p < 0.001$) different from zero. This means that the condition for zero flux is fulfilled for Cl^- when inflow $[Cl^-]$ equals $[Cl^-]$ in the goat's CSF, both at SL and HA. In the case of HCO_3^-, zero flux at SL also occurs when $[HCO_3^-]$ in inflow equals that in CSF. However, at HA, zero HCO_3^- flux occurs when inflow $[HCO_3^-]$ is significantly lower (by 6 mM/L, according to the plot in Figure 1) than $[HCO_3^-]$ in the goats' CSF.

The interpretation is that, at SL, concentrations of Cl^- and HCO_3^- in CSF are indistinguishable from those in cISF. This is in agreement with previous findings in goats at SL in normal acid base balance (8). In goats adapted to HA, the concentration of Cl^- is also the same in CSF and cISF, however, the concentration of HCO_3^- in cISF is significantly lower than that in cisternal CSF. Thus, after adaptation to HA, a steady-state concentration gradient of $[HCO_3^-]$ (and not for $[Cl^-]$) appears to exist between CSF and cISF, across the leaky ependyma and pia-glia, presumably due to a concentration gradient of lactate going in the opposite direction. The latter notion is corroborated by the finding that the transependymal *flux (washout) of lactate, measured in 4 goats, was 16 times greater at HA than at* SL: -0.09 ± 0.04 μM/min at SL vs 1.47 ± 0.17 μM/min at HA ($p < 0.001$).

Thus, if $[HCO_3^-]$ in the fluid surrounding the central chemoreceptors were equal to that predicted for cISF from Figure 1, pH in this fluid, with PCO_2 prevailing in the brain (CSF PCO_2, Table 3) would be 7.13, substantially more acid than at SL, (7.30, Table 3). If the model of Pappenheimer et al. (11) were applied to the system of cerebral fluids, and a steady state diffusion gradient postulated for $[HCO_3^-]$ between the cisternal CSF and cISF, pH in the fluid around the central chemoreceptors would be 7.23, still more acid than at SL.

It is concluded that the hyperventilation observed in goats after 5 days of adaptation to HA could be the result of an increased acidity in the fluid surrounding the central chemoreceptors for respiration, submerged in cISF, in spite of the alkalotic pH measured in the cisternal CSF.

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Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	022 Ventilatory Control Mechanisms at High Altitude
Study Title:	Role of Cerebral Fluids in Respiratory Adaptations to Acute Acid-Base Imbalance
Investigators:	Ronald A. Gabel, M.D., Vladimir Fencl, M.D., and Danney L. Wolfe, CPT, VC

Background:

The soldier may be required to perform heavy muscular exercise at high terrestrial altitudes. Both exercise and the prolonged hypoxia associated with sojourn at high altitude induce changes in pulmonary ventilation that are poorly understood.

During moderate muscular exercise, pulmonary ventilation increases in proportion to increases in oxygen consumption and carbon dioxide production; therefore, the partial pressures of oxygen and carbon dioxide in arterial blood (PaO_2 and $PaCO_2$) remain unchanged from their resting values. The mechanisms for regulating this isocapnic hyperpnea have not been clarified (1). When, with heavier exercise, the threshold for anaerobic work is exceeded and systemic lactic acidosis develops, hyperventilation is superimposed on the exercise hyperpnea, and $PaCO_2$ falls below normal. The workload representing the anaerobic threshold is frequently exceeded during muscular exercise at high altitude.

Hyperventilation during exercise has been ascribed to stimulation of the peripheral (carotid) chemoreceptors by an acute increase in arterial hydrogen ion concentration (2). If this were the case, the $PaCO_2$ should fall almost instantaneously after the workload representing the anaerobic threshold is exceeded. Wasserman and colleagues, however, observed that when workloads were increased at one-minute intervals, hyperventilation was delayed for several minutes after the anaerobic threshold was exceeded; i.e., hyperventilation did not coincide with exposure of the carotid chemoreceptors to acute lactic acidosis in the blood (3).

Fencl and colleagues have shown that when metabolic acidosis is induced by rapid intravenous infusion of hydrochloric acid, pH and bicarbonate concentration

($[HCO_3^-]$) in the cerebral interstitial fluid (CISF) is lowered rapidly, within minutes, in contrast with the sluggish change in pH and $[HCO_3^-]$ of cerebrospinal fluid (CSF)(4). We are testing the hypothesis that a change in acidity of the CISF might be involved in the delayed onset of hyperventilation in systemic acidosis produced by exercise.

Changes in the concentrations of the $[H^+]$, $[HCO_3^-]$, and $[Cl^-]$ in CSF during long-term acid-base disturbances have been extensively described (5-9). In stable metabolic acidosis and alkalosis, the distribution of these ions across the "blood-brain barrier" (between capillary blood and CISF) is controlled by a poorly-understood homeostatic system that reduces the variation in $[H^+]$ in cerebral fluids to a small fraction of that seen in blood (5,6). The limited variation in acidity of the CISF in stable metabolic acidosis or alkalosis in turn serves to regulate the pulmonary ventilation via the "central chemoreceptors" (6,8) and to regulate cerebral blood flow (8,12).

The "central chemoreceptors" for respiration are exposed to the CISF and not to the CSF in the cerebral ventricles (6,10). Similarly, the loci that regulate cerebrovascular resistance (and cerebral blood flow) are surrounded by CISF (12). Therefore, to gain insight into the mechanisms involved in respiratory adaptions to various types of acid-base disturbances, as during exercise at high altitude, it is important to consider how compositions of the two cerebral fluids are interrelated. Because CISF, unlike CSF, cannot be sampled directly for analysis, its composition must be explored indirectly. The ionic compositions of CSF and CISF are the same in normal acid-base balance and in chronic steady-state metabolic acidosis and alkalosis (6,13). Thus, in these conditions, the composition of CSF gives direct information about the ionic composition of the CISF. This does not apply to non-steady-state transients of metabolic acidosis or alkalosis, however, and there can be "paradoxical shifts" in pH of the CSF (14).

During this investigation, the time course of changes in the pulmonary ventilation of unanesthetized goats will be assessed while metabolic acidosis is induced over about 30 minutes by intravenous infusions of dilute hydrochloric acid (HCl). This intervention is designed to simulate the gradual onset of metabolic acidosis after the anaerobic threshold is exceeded during muscular exercise. Animals used in this study will be members of a colony of goats established at USARIEM, each of which has a plastic guide tube surgically implanted in the base of the skull to facilitate repeated aseptic sampling of cisternal CSF. The goats also have one common carotid artery isolated in a denervated loop of skin to permit easy and painless sampling of arterial blood. Methods for respiratory measurements in goats, using specially-fabricated latex rubber masks, have been developed and previously used by us at USARIEM.

Before and after induction of the metabolic acidosis, the PO_2 and PCO_2 in samples of mixed-expired gas will be measured to permit calculation of oxygen consumption and carbon dioxide production. Arterial blood samples, withdrawn from a plastic cannula percutaneously inserted into the isolated carotid artery, will be analyzed for PO_2, PCO_2, pH, and hemoglobin concentration. Samples of CSF, withdrawn from a needle inserted into the cisterna magna through the implanted guide tube, will be analyzed for PCO_2 and pH. All respiratory, blood, and CSF measurements will be repeated at 20-minute intervals for 120 minutes after induction of metabolic acidosis in the arterial blood.

To assess the contribution, if any, of the peripheral (carotid) chemoreceptors to changes in pulmonary ventilation in response to acute metabolic acidosis, we plan to repeat the above protocol in each goat after surgical excision of both carotid bodies. If unanesthetized goats after peripheral chemodenervation hyperventilate in response to acute metabolic acidosis, this will indicate that the carotid bodies are not essential for the acute ventilatory response to metabolic acidosis. If a "paradoxic alkalotic shift of pH" in the cisternal CSF occurs during hyperventilation in peripherally-chemodenervated goats, this will suggest that acidification of the CISF is responsible for the hyperventilation. Furthermore, the necessity for ionic changes in the blood to become reflected in the CISF would explain the delay seen in the onset of hyperventilation after the development of metabolic acidosis during heavy muscular exercise. It would point to changes in the ionic composition of the cerebral interstitial fluid to explain the exercise-induced hyperventilation seen when workloads exceed the anaerobic threshold.

Progress:

This investigation has been divided into several sequential phases:

1. Pilot study to determine a satisfactory combination of rate of intravenous infusion of HCl to produce a base excess of approximately -10 mEq/L

in the arterial blood, when the HCl is infused over about 30 minutes.

2. Predenervation studies of each experimental goat's ventilatory response to progressive isocapnic hypoxia, to use as a control value to assess completeness of peripheral chemodenervation.

3. Predenervation study of the time course of changes in ventilation, PO_2, PCO_2, and pH in arterial blood, and PCO_2 and pH in CSF, in response to the production of acute metabolic acidosis.

4. Surgical excision of each goat's carotid-body chemoreceptors, bilaterally.

5. Postdenervation studies of each goat's ventilatory response to hypoxia, to assess completeness of denervation (repeat of 2 above).

6. Postdenervation studies of the time course of ventilatory, blood, and CSF changes in response to acute metabolic acidosis (repeat of 5 above).

Phase 1 has been completed, and phase 2 is in progress.

Phase 1

In three unanesthetized goats, we administered various concentrations of HCl at various rates of intravenous infusion to determine a satisfactory combination for inducing acute metabolic acidosis. We found that infusion of 0.3 mM HCl/kg body weight as a 0.1 N solution over 30 minutes produces a base excess of -10 to -15 mEq/L in the arterial blood. Sequential measurements of $PaCO_2$ and pHa disclosed that the metabolic acidosis, thus induced, remains stable at $\pm$ 1.0 mEq/L for 120 minutes after stabilization at the end of the infusion.

Phase 2

Ventilatory responses to progressive isocapnic hypoxia have been measured in five unanesthetized goats, each with a carotid loop and cisternal guide tube available. These studies have been hampered by a persistent problem encountered in each animal: inability to predict, and therefore, to control consistently, the $PaCO_2$ by monitoring end-tidal PCO_2. In all studies, the end-tidal PCO_2, measured with an infrared CO_2 analyzer, exceeded to a variable degree the $PaCO_2$ measured with a conventional PCO_2 electrode. The gradient tended to narrow with increasing pulmonary ventilation but never disappeared and was of unpredictable magnitude. As we gained experience in performing the tests, by guessing the end-tidal-to arterial gradient, we were able to maintain isocapnic conditions in the arterial blood during an occasional progressive hypoxia test.

The origin of the increased PCO_2 in the end-tidal gas appeared to be the goat's rumen. In early studies, we noted frequent belching of CO_2 during ventilatory measurements. By withholding grain and hay for 12 hours prior to respiratory studies, we were able to decrease markedly the frequency of belching and the concentration of CO_2 in each belch. The steady-state end-tidal PCO_2, however, remained higher than the $PaCO_2$.

In progressive hypoxia tests in which arterial isocapnia was successfully maintained, ventilation was found to be rectilinearly related to percentage saturation of hemoglobin in the arterial blood (SaO_2)(Figure 1). SaO_2 was estimated from the PaO_2 and pHa, using algorithms for the oxygen hemoglobin equilibrium curve and the Bohr factor for goat blood (15,16). The rectilinearity of ventilation with SaO_2, which is similar to that seen in human beings (17), persisted when $PaCO_2$ was elevated to a steady-state value above resting $PaCO_2$ (Figure 2). We have insufficient data at this point to say whether or not there is interaction between hypoxia and hypercapnia in stimulating ventilation of the goat (i.e., more than additive effects when the two stimuli are applied concurrently).

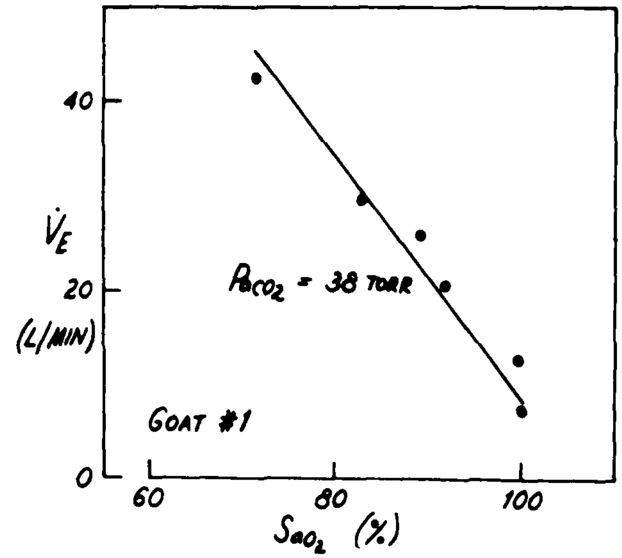

Figure 1. Ventilation was a rectilinear function of the percentage of oxygenated hemoglobin in the arterial blood.

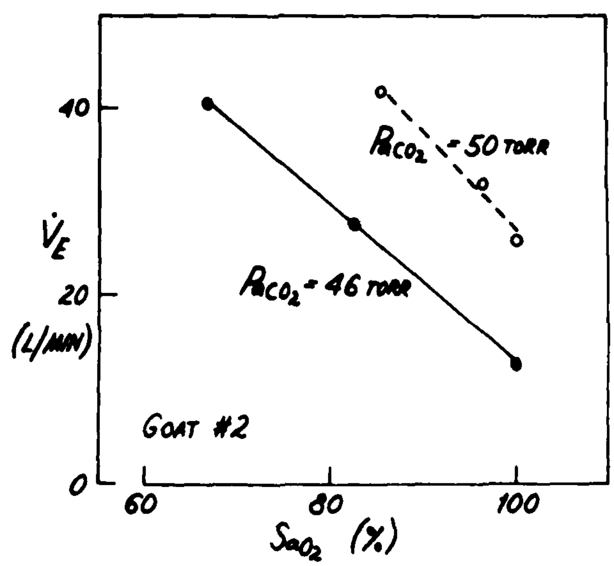

Figure 2. The relationship between ventilation and oxygen saturation remained rectilinear when the arterial carbon dioxide tension was elevated above normal values.

Before continuing this phase of the investigation, we plan to seek a solution to the problem of the unpredictable relationship between end-tidal PCO_2 and $PaCO_2$. One alternative we are considering is the use of a permanent tracheostomy to separate the respiratory from the gastrointestinal tract. A potential difficulty with this is that the goat might have to breathe against a closed glottis in order to emply the rumen of excess gas; tracheostomy might, therefore, lead to bloating.

When the above problems are solved, we intend to continue working on phase 2 of the project, with anticipated completion of all phases of the investigation during the next fiscal year.

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(81023)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*: DA OC 6128
2. DATE OF SUMMARY*: 78 10 01
REPORT CONTROL SYMBOL: DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
	A. New	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.01.A	3A161101A91C	00	023
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*
(U) Role and Significance of Endotoxin in Heatstroke (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
005900 Environment Biology; 010100 Microbiology; 02300 Biochemistry

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
78 8	Cont	DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER*: NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	1.0	8
	CURRENT 79	5	14

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
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RESPONSIBLE INDIVIDUAL
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20. PERFORMING ORGANIZATION
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SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: HAMLET, Murray P., D.V.M.
NAME: 955-2865 DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)
(U) Endotoxin; (U) Reticuloendothelial; (U) Tolerance; (U) Heatstroke

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The presence of endotoxin in heatstroke has been documented in man and in both dog and rat models for heatstroke. To date the significance of this association is not known. This study is designed to further understand the role and significance of endotoxin in heatstroke.

24. (U) The relationship between presence of endotoxin and severity of heat exposure will be studied in the rat heatstroke model using the limulus amoebocyte lysate test. To determine the significance of any association of endotoxin with heatstroke the study of endotoxin tolerant animals under heatstroke conditions will be undertaken. The finding of an increase in survival with tolerant animals would indicate a significant role for endotoxin in the pathophysiology of heatstroke. If animals can be protected from heatstroke by this form of tolerance, this may be indicative of an applied method by which man may be made more resistant to the effects of heatstroke.

25. (U) New Work Unit.

*Available to contractors upon originator's approval

Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	023 Role and Significance of Endotoxin in Heatstroke
Study Title:	Role and Significance of Endotoxin in Heatstroke
Investigators:	David A. DuBose, M.S., Murray P. Hamlet, D.V.M., Lynn R. Trusal, CPT, MSC, Ph.D., Wilbert D. Bowers, Jr., Ph.D. and Roger W. Hubbard, Ph.D.

Background:

Due to the similarities between the clinical pictures of endotoxic shock and of heatstroke, there has been an interest in the role of endotoxin in this form of environmental stress. Investigators, using the Limulus Amoebocyte Lysate (LAL) test, have documented the presence of endotoxin in some cases of human heatstroke (1,2). Data collected by this laboratory have also shown positive LAL tests in both the rat and dog models for heatstroke. Though the presence of endotoxin has been indicated, its effect on heatstroke survival is unknown.

The LAL test has been used successfully in biological fluids such as urine (3) and cerebral spinal fluid (4). Its use in plasma has been in question due to the presence of not only inhibitors of the test (5) but possible mimickers (6). Thus, there is a need to determine the reliability and validity of this test in animal models for heatstroke.

Progress:

Table 1 shows a survey for positive LAL tests in healthy populations of laboratory animals and human subjects. Only human and dog plasma samples had positive tests. Further study indicated that positive tests in dogs were associated with the presence of intestinal parasites (Table 2). Positive human plasma samples may have been due to similar intestinal problems or to the presence of some endotoxin mimicker associated with the plasma.

TABLE 1

LAL Test on Normal Populations of Humans, Mongrel Dogs, Rats, Mice, Rabbits, and Squirrel Monkeys

Species Tested	LAL (+)/total tested (1 hr. reading)*	% Positive
Dog	13/29	44.8
Human	7/22	31.8
Rat	0/39	00.0
Mouse	0/16	00.0
Rabbit	0/06	00.0
Monkey	0/10	00.0

*Etoxate lysate employed for all test except in the rat in which 17 of the 39 rats were tested with Pyrotell Lysate.

TABLE 2

Relationship of Positive LAL Test and Presence of Parasites in Dogs

Type or State of Infestation	LAL (+)/no. tested at reaction time: 1h	18h (%)
Hookworm	0/7	5/7 (71/4)
Roundworm	2/6	3/6 (50.0)
All infested dogs	2/13	8/13 (61.5)
Noninfested dogs	0/13	1/13 (7.7)

In these studies, chloroform extraction was utilized to remove plasma inhibitors. This form of extraction may result in questionable positive tests, since its effect on possible mimickers is unknown. Therefore, normal human plasma, previously spiked with an E. coli endotoxin standard was extracted by a variety of procedures to determine if any were as sensitive as chloroform extraction (Table 3).

TABLE 3

Comparison of Plasma Extraction Procedures

Designed to Remove inhibitors of the LAL Test

Type of Extraction	Sensitivity Ng of endotoxin/ml of plasma
pH Shift	> 5.0
Dilution	1.0
Chloroform	0.2
Dilution & Heating	0.2
Modified Dilution	0.06
Gel Filtration	0.04

Gel filtration was found to be the most sensitive. Theoretically, this procedure could separate possible mimickers from endotoxin by differences in molecular weight. Unfortunately, this procedure was not suitable for a research or clinical laboratory due to the difficultly in consistently prepare endotoxin-free columns. The most practical procedure, dilution and heating, was found to be as sensitive as chloroform extraction. In addition, it had an advantage over chloroform extraction in that possible mimickers might be denatured by the heat treatment. Furthermore, our modification of this method, by using phosphate buffer as a diluent rather than endotoxin-free water, improved its sensitivity so that this procedure was now more sensitive than chloroform extraction.

To determine if the modified dilution extraction procedure removed questional positive tests in healthy human subjects, a comparison of this method with chloroform extraction was conducted (Table 4). Two limulus lysates, Etoxate (Sigma Chemical Co.) and Pyrotell (Associates of Cape Cod), were employed.

TABLE 4

Comparison of Limulus Reaction after Either Chloroform or Modified Dilution Extraction Using Several Types of Lysate

Lysate Type	Chloroform	Modified Dilution
	Extraction Procedure	
Pyrotel	0/23	0/23
Etoxate	3/23	7/23

Results indicated that regardless of the extraction procedure employed, only tests using Etoxate were positive. No positive tests were obtained using Pyrotell. An additional 15 subjects also had negative tests using this lysate. These results were surprising since Pyrotell was consistently found to be more sensitive to endotoxin than Etoxate using our endotoxin standard (E. coli). Further work is ongoing to determine if Pyrotell is more sensitive than Etoxate to a variety of endotoxins. If so, questionable positive tests in healthy human subjects may be due to the use of some lysate sources which are not as endotoxin-specific as others.

Rats considered of a normal healthy state have never been found to be endotoxin-positive by the LAL test with either Etoxate or Pyrotell. Thus, it appears to be a suitable test animal in which to use this technique of endotoxin detection. The modified dilution extraction procedure has been found to be a more sensitive extraction method for plasma inhibitors. Pyrotell is a very sensitive lysate and appears to be more endotoxin specific. Using this knowledge, heat treatments which induce circulating endotoxin can now be identified.

Future Plans:

The (LAL) test will be used to determine which heat treatments result in the presence of circulating endotoxin. Animals made tolerant to endotoxin would then be subjected to these heat treatments. If endotoxin plays a significant role, then animals made tolerant to endotoxin should show improved survival rates. Thus, to evaluate the significance of endotoxin in heatstroke, a comparison of survival rates of tolerant and non-tolerant rats will be initiated. In addition, the effects of other forms of reticuloendothelial stimulation on heatstroke survival will be investigated. This work may lead to a means of prophylaxis or protection from some of the toxic effects of heat induced injury.

Presentations:

DuBose, D. A. Comparison of plasma extraction techniques in preparation of samples for endotoxin testing by the limulus amebocyte lysate test. Presented, Annual Meeting of the American Society for Microbiology, Las Vegas, NV, 14-19 May 1978.

Publications:

1. DuBose, D. A., M. LeMaire, J. Brown, D. Wolfe and M. Hamlet. Survey for positive limulus amoebocyte lysate test in plasma from humans and common research animals. J. Clin. Microbiol. 7(2):139-141, 1978.

2. DuBose, D. A. and M. LeMaire. Comparison of plasma extraction techniques in preparation of samples for endotoxin testing by the limulus amoebocyte lysate test. Submitted to: J. of Clin. Microbiol.

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6. DuBose, D. A., M. LeMaire, J. Brown, D. Wolfe and M. Hamlet. Survey for positive limulus amoebocyte lysate test in plasma from humans and common research animals. J. Clin. Microbiol. 7(2):139-141, 1978.

(81024)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OC 6125	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
78 04 14	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.01.A	3A161101A91C	00	024
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*

(U) Regulation of Body Weight (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 012400 Personnel selection and maintenance (medical); 012900 Physiology; 003500 Clinical medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
77 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	1.0	19
	CURRENT 79	1.0	18

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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RESPONSIBLE INDIVIDUAL

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20. PERFORMING ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* GOLDMAN, Ralph F., Ph.D.

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SOCIAL SECURITY ACCOUNT NUMBER: [redacted]

PII Redacted

21. GENERAL USE

Foreign Intelligence Not Considered

ASSOCIATE INVESTIGATORS

NAME: BURSE, Richard L., Sc.D.

NAME: DANFORTH, E. & ROBBINES, D. (UVM,VT)DA

22. KEYWORDS (Precede EACH with Security Classification Code)

(U) Fitness; (U) Body Weight Regulation; (U) Obesity; (U) Anorexia; (U) Lipodystrophy

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) In collaboration with clinical research groups, assess the metabolic (USARIEM) and endocrine (clinical collaborators) responses of individuals with no body fat (lipo-adystrophy), limited body fat (anorexia nervosa and lipoatrophy), normal body fat but difficulties with weight regulation ("hard" and also "easy gainers") and excess body fat (obesity).

24. (U) Measure metabolic heat production and heat loss during exercise, pre- and post-prandial rest and basal conditions of such individuals on normal high and low caloric intake levels, with varied proportions of dietary carbohydrate, fat and protein, while simultaneously measuring their endocrine responses, with particular attention paid to thyroid regulation of body heat production and, consequently, body weight.

25. (U)77 10 - 78 09 A collaborative study has been conducted on one newly diagnosed female patient with anorexia nervosa who was compared with two still underweight, but recovering, anorectics and two normal controls on a normal caloric diet (5 days), when overfed 33% more calories (2 days) and when totally fasted for 36 hours. Compared to the controls, the 3 underweight anorectics showed a slight, but consistant, pattern of calorie conservation at rest during both the fed and fasted conditions. However, when walking for 15 min, the anorectics showed a greater calorie expenditure per kg body weight. When fasting, walking RQ values in the controls fell below fed levels indicating increased metabolism of fat; RQ remained at fed levels in the anorectics, suggesting that their body fat stores were inadequate to support this moderate, short-term exercise metabolism. Neither the newly diagnosed nor the recovering anorectics differed from the controls in their thyroid hormonal responses; this suggests no marked alteration in their thyroid mechanisms at the time they were evaluated.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	024 Regulation of Body Weight
Study Title:	Metabolic and Thyroid Effects of Overfeeding and Fasting in Normal and Anorexic Women
Investigators:	Richard L. Burse, Sc.D. and Ralph F. Goldman, Ph.D., in collaboration with David C. Robbins, M.D., Edward S. Horton, M.D. and Ethan A. H. Sims, M.D. (University of Vermont)

Background:

The disorder of anorexia nervosa is characterized by a constellation of symptoms: disturbed bodily self-image manifested by excessive desire for thinness; abstention from, or regurgitation of, food with consequent undernutrition; amenorrhea or impotence; reduction of physiological defenses against both heat and cold stress and may include mental and physical hyperactivity (1,6,7,10,11). The hypothalamo-pituitary-gonadal axis is clearly disturbed (1,8), but the hypothalamo-pituitary-thyroid axis appears somewhat less so by virtue of circulating concentrations of TSH and thyroxine which may be in the normal range (1,8,10). However, basal metabolism and circulating levels of 3-3'-5' triiodothyronine (T_3) have been shown to be low (9,10,14) and the TSH response to the hypothalamic releasing factor, TRF, may be delayed (14). Similar metabolic and thyroid status has been found in protein-calorie malnutrition and may be indicative of a generalized adaptive physiological response to caloric insufficiency (4).

Studies of the metabolic, thermogenic and thyroid hormone responses to adequate, excessive or inadequate caloric intake in individuals with this condition offer a unique opportunity for interrelating these responses in very lean individuals, with unloaded or "starved" fat cells. Unlike the results of clinically controlled starvation diets, anorexia nervosa is typically of long duration, which gives body mechanisms adequate time in which to adapt to caloric insufficiency.

Previous investigation has shown that obese individuals with normal but filled fat cells manifest an hypermetabolic response during exercise to caloric

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overfeeding of carbohydrate (CHO), with elevated levels of the active thyroid hormone, T_3 (2,5). Similar thyroid, but not metabolic, response occurs in normal individuals with only partially filled fat cells (3,5). Excess calories are stored as fat in the non-obese, but are less readily stored in the filled adepocytes of the obese and may therefore be more readily available for metabolism.

Anorectic patients with low body weight have low body fat content. They have not been shown to have abnormal fat cells, which accords with their ability to increase body weight and fat content upon refeeding. Because their apparently normal, but empty, adipocytes can readily assimilate fat, they provide a unique model of thyroid hormone and metabolic response to caloric overfeed or fasting.

Progress:

One newly identified anorectic patient was hospitalized by our collaborators at the University of Vermont, along with two patients identified earlier who had been under treatment for 9-20 months and two normal controls of similar lean body mass. All subjects were women aged 18-27. The objective was to determine the resting and exercise metabolic response to baseline and hypercaloric diets and to fasting.

After 1-2 days ad lib feeding, the 3 anorectics and 2 controls were placed on diets containing 45% CHO, 15% protein and 40% fat which were varied in caloric content throughout the study. Starting at noon, intake was 1500 $kcal/m^2 \cdot day$ for 5 days. Metabolic assessments at rest and during light exercise were made during the fifth day. Blood samples were drawn on the mornings of days 4 and 5 for analysis of circulating thyroid hormone concentrations and the results were pooled. Following this, intake was raised to 2000 $kcal/m^2 \cdot day$ for 2 days, after which the metabolic and thyroid assessments were repeated. The 38 hour fasting period was then begun with food withheld from the noon meal onwards; the measures were then repeated, beginning the following morning. The fasting period and the experiment ended at 2200 hours.

Exercise metabolism was determined in the post-absorptive state by open circuit spirometry and subsequent analysis of expired O_2 and CO_2 while the subjects walked at 3.0 mi/hr (1.34 m/s) on a level treadmill. Metabolic rates (MR) were calculated according to the method of Weir, assuming combustion of 15%

protein. Supine resting MR were determined before and after the evening and morning mealtimes, with the average of the replicated samples upon arousal taken to be the basal MR (BMR). Subjects were continually supervised to assure that the intended diets were actually consumed.

Inspection of the data showed that there were no metabolic or thyroid differences between the newly identified and treated anorectics, so their results were pooled for comparison with those of the controls by analysis of variance.

TABLE 1

Subjects' Physical Characteristics

Group	Subject	Age (yr)	Height (cm)	Weight (kg)	BSA (m^2)	Fat (%)
Control	KK	18	162	57.9	1.61	27
	MP	20	162	54.4	1.57	20
Anorectic	DT	25	156	35.0	1.27	5
	EP	27	162	37.3	1.34	8
	SS	19	167	44.1	1.47	18

Table 1 shows the subjects' physical characteristics. Surface area was estimated from the Dubois-Meeh equation, while body fat was estimated by the method of Durnin and Womersley (6).

Figure 1 shows MR in W/m^2 and Respiratory Quotient (RQ) in the basal state and for the first two hours and second hour and one-half after breakfast. There were no differences in BMR between levels of intake or between anorectics and controls. Basal RQ was significantly lower during the fast than after the higher intake for both groups, however. The post-prandial elevations in MR are evident on both diets, but, as expected, are missing during the fast. There is a tendency towards carbohydrate metabolism evident in the post-prandial RQ's when the mixed diets were fed, but there was no pronounced indication of fatty acid oxidation during the fast, except from 2 to 3-1/2 hours after breakfast time. Then the RQ values appeared to be associated with the caloric content of the diet. Although anorectics and controls do not differ significantly, there was a consistent pattern of calorie conservation by the anorectics in both the fed and fasted conditions. These same trends are evident in Figure 2, the MR before and after supper. Pre-supper resting MR were significantly reduced when fasting from those when on the higher calorie diet. Post-prandial MR are elevated above resting levels when meals are consumed, but are the same as the pre-mealtime MR when fasting. The pattern of calorie sparing by the anorectics was continued, reaching significance during the first two hours after the evening meal time, irrespective of intake.

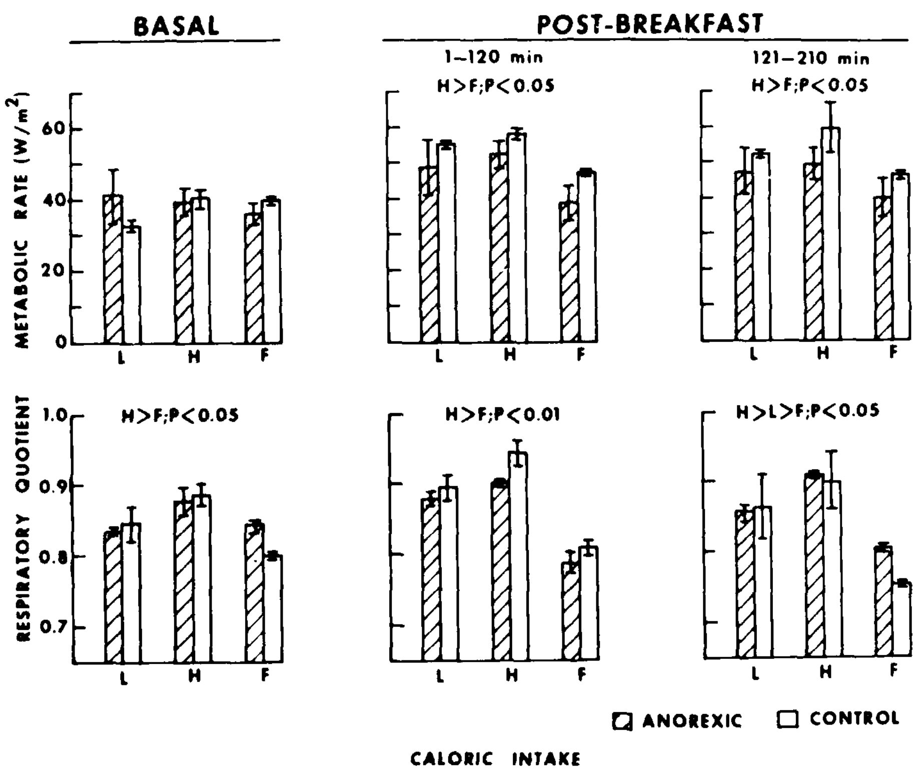

Figure 1. Resting metabolic rates and respiratory quotients in the basal and post-breakfast states for anorexic and control subjects on low (L = 1500 kcal/m^2), high (H = 2000 kcal/m^2) diets and during a 36 hour fast (F).

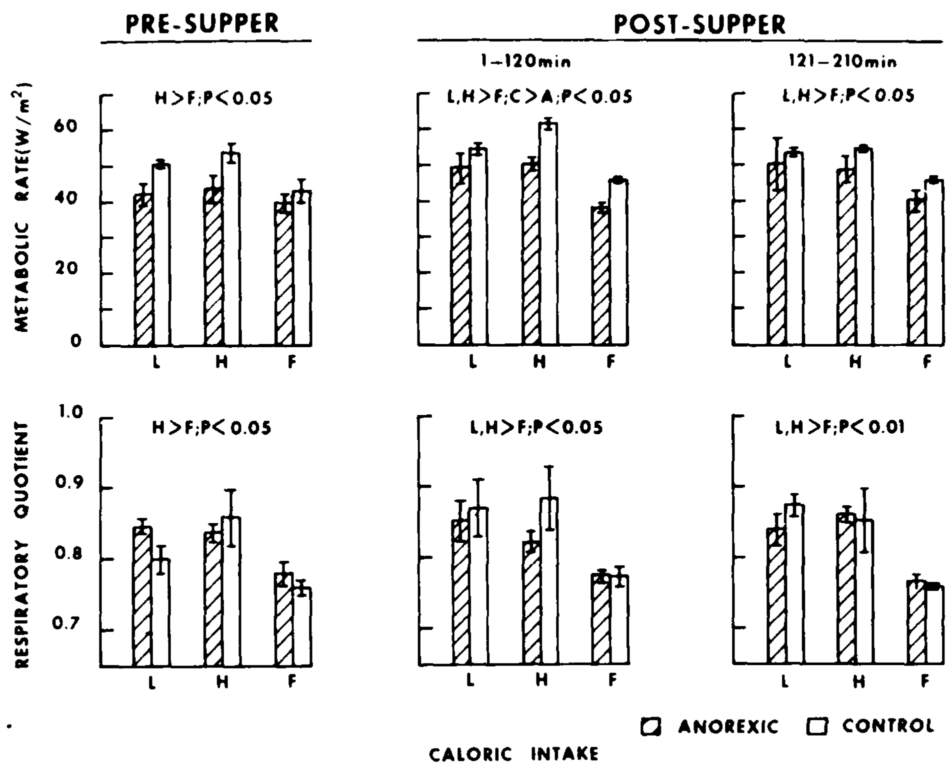

Figure 2. Resting metabolic rates and respiratory quotients before and after the supper meal. Dietary intake same as Figure 1.

The resting RQ values after 33-38 hours of fast are almost identically depressed for both groups, generally ranging from 0.75 - 0.78, with one value at 0.81. This suggests similar substrate utilization by both groups, despite the reduced fat reserves of the anorectics. Figure 3 shows that such was not the case during exercise. In Watts per kg, the anorectics consistently showed the higher exercising MR, as opposed to their calorie conservation at rest. On the mixed diets, the RQ ranged between 0.82 and 0.95 for both groups. The control group exercise RQ fell to 0.74 - 0.76 when fasting, similar to their resting RQ. However, the anorectic exercise RQ remained in the 0.80 - 0.93 range during the fast, indistinguishable from their values when they were on a mixed diet. This suggests that their fat stores and their mobilization were adequate to support resting metabolism throughout 1-1/2 days of fasting, but were inadequate to support moderate, short-term exercise metabolism without combustion of lean body mass.

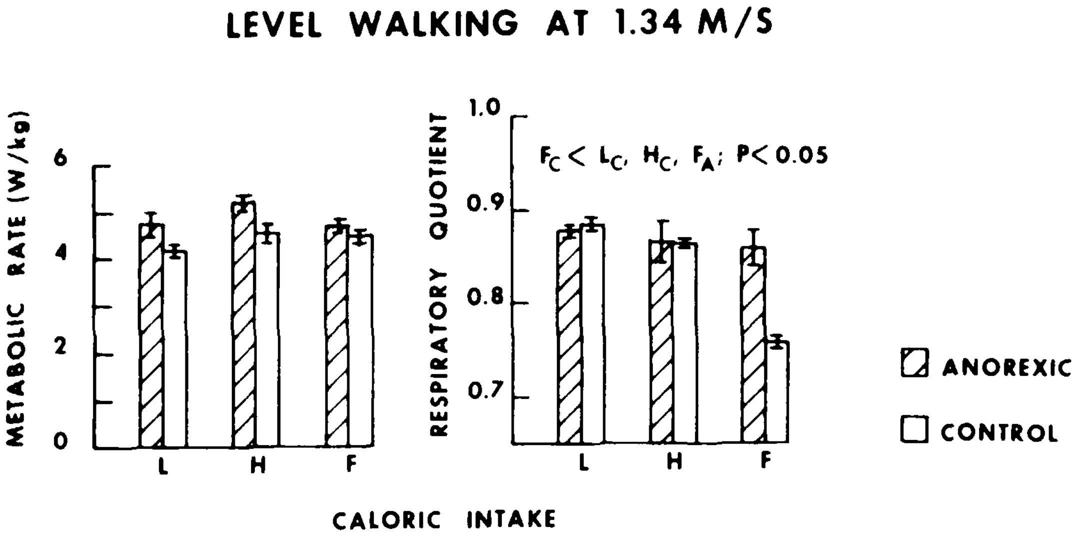

Figure 3. Metabolic rates and respiratory quotients during level treadmill walking at 1.34 m/s. Dietary intake same as Figure 1.

There have been several reports (9,10,14) of anorectics showing reduced serum concentrations of 3-5-3' triiodothyronine (T_3) accompanying normal (or low-normal) concentrations of thyroxine (T_4) and normal levels of TSH, and one report of their having elevated levels of the metabolically inactive isomer 3-3'-5' triiodothyronine (rT_3). This has been postulated as occurring as an adaptive shift in the peripheral conversion of T_4 to rT_3 instead of to T_3 (13). This would result in the observed lessened basal metabolism during a time of caloric undernutrition. Accordingly, we investigated serum levels of T_3 and rT_3 during our caloric manipulations.

Table 2 shows that the T_3 levels under all 3 dietary conditions are within the normal range and do not differ between groups, which is consistent with the observed BMR, but not what we had expected in anorectics. The pattern in the rT_3

TABLE 2

Mean Values ± Standard Deviation for Serum Concentrations of T_3 and rT^3 in Anorectic and Control Women

Diet (kcal/m^2•day)	T_3 (ng/dl) Anorectic	T_3 (ng/dl) Control	rT^3 (ng/dl) Anorectic	rT^3 (ng/dl) Control
1500	108 ± 26	108 ± 23	28 ± 6	30 ± 4
2000	92 ± 30	98 ± 5	21 ± 6	26 ± 3
Fast	98 ± 18	114 ± 11	26 ± 5	34 ± 9

values are more consistent with what we expected to see. After the higher calorie intake, rT_3 was depressed marginally in both groups and rebounded upwards in response to the fasting. However, results are suggestive rather than significant, as there were no significant differences between groups. It is clear that the anorectics had lower rT_3 values than the controls (albeit within the normal range), rather than the higher values expected from the literature. These patients displayed no metabolic differences from the normal controls, except a slight tendency towards continued caloric conservation in spite of their normal T_3 and rT_3 concentrations and a different substrate for exercise metabolism during fasting.

This study will be terminated after the results are published. Should new clinical patients with lipodystrophy or anorexia nervosa be identified at the University of Vermont Metabolic Research Unit, additional studies will be initiated.

Presentations:

Burse, R. L., D. C. Robbins, R. F. Goldman, E. S. Horton and E. A. H. Sims. Metabolic and thyroid effects of overfeeding and fasting in normal and anorexic women. Fed. Proc. 37:401, 1978.

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(81025)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. Agency Accession	2. Date of Summary	Report Control Symbol
DA OC 6126	78 10 01	DD-DR&E(AR)636

3. Date Prev Sum'ry	4. Kind of Summary	5. Summary Scty	6. Work Security	7. Regrading	8. Dissem Instr'n	9. Specific Data Contractor Access	10. Level of Sum
78 04 14	D. Change	U	U	NA	NL	[X] Yes [ ] No	A. Work Unit

10. No./Codes	Program Element	Project Number	Task Area Number	Work Unit Number
a. Primary	6.11.01.A	3A161101A91C	00	025
b. Contributing				
c. Contributing				

11. Title (Precede with Security Classification Code)

(U)Evaluation of fitness reference standards of body composition (22)

12. Scientific and Technological Areas

012400 Personnel selection and maintenance (medical); 012900 Physiology

13. Start Date	14. Estimated Completion Date	15. Funding Agency	16. Performance Method
77 10	CONT	DA	C. In-House

17. Contract Grant

a. Dates/Effective — Expiration

b. Number — NOT APPLICABLE

c. Type — d. Amount

e. Kind of Award — f. Cum. Amt

18. Resources Estimate		a. Professional Man Yrs	b. Funds (In thousands)
Fiscal Year	Preceding 78	.4	11
	Current 79	.4	12

19. Responsible DoD Organization

Name: USA RSCH INST OF ENV MED

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21. General Use

Foreign Intelligence Not Considered

20. Performing Organization

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Social Security Account Number

Associate Investigators

Name: BURSE, Richard L., Sc.D.

Name: 955-2849 DA

22. Keywords (Precede Each with Security Classification Code)

(U) Fitness; (U) Body fat; (U) Height weight standards; (U) Body composition

23. Technical Objective, 24. Approach, 25. Progress

23. (U)Criteria for the overweight underweight aspect of physical fitness by incorporating skinfold evaluations of body fat. Studies will involve both assessment of subcutaneous fat by skinfold measurement and height weight tables and various height weight ratios (body mass index, ponderal index and the like) which have been suggested or used for establishment of entry standards for Armed Forces Enlistment Stations; such standards are also used for assessing physical fitness of servicemen for retention, re-enlistment and/or promotion. Heavily muscled individuals and those with genetically determined, unusual fat depositions may be extremely fit for duty but may be unable to meet these standards.

24. (U)Measure subcutaneous fat deposition (and alterations) in individuals who have difficulty meeting current height weight standards, evaluate the application of the various height weight ratios to such individuals and attempt to implement subcutaneous fat measurement by skinfold thickness determination as a better criterion of the overweight underweight aspect of physical fitness.

25. (U)77 10 - 78 09 In collaboration with the local U.S. Army dispensary, a pool of 3 males exceeding height weight standards in AR 600-9 has been identified and their weights, lean body masses and fat percentages have been followed for the 6 months they have been on a weight control program. All had original body fats exceeding 98th percentile for their ages and were expected to have difficulty losing large amounts of weight. For two of these individuals, lean body masses (bone, muscle, gut and nerve) were so large that their predicted body fat at the required weights will be below the 20th percentile for their ages, which is hypothesized as being an unrealistic goal to achieve and maintain. In 6 months these individuals have lost from 3 to 20 pounds, but none have met the required weight standard, two are still above 95th percentile body fat and one is 82nd percentile.

*Available to contractors upon originator's approval

DD Form 1498, 1 Mar 68 — Previous editions of this form are obsolete. DD Forms 1498A, 1 Nov 65 and 1498-1, 1 Mar 68 (for Army use) are obsolete.

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Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	025 Evaluation of Fitness Reference Standards of Body Composition
Study Title:	Evaluation of Fitness Reference Standards of Body Composition
Investigators:	Richard L. Burse, Sc.D. and Ralph F. Goldman, Ph.D.

Background:

Heavily-muscled or highly conditioned individuals and those with genetically determined unusual depositions of body fat may be extremely fit for military duty but unable to meet current standards of body mass index, ponderal index or height-weight tables (1). Recent guidance has been provided examining physicians to separate the heavily-muscled fit individual from the merely overweight (3), but which establishes more scientific criteria for reference standards of body composition and, therefore, may qualify a greater proportion of stocky, heavily-muscled or genetically high-fat, but fit, individuals for entry into service, retention, re-enlistment and promotion.

The purposes of this project are to measure sub-cutaneous fat deposition (and changes due to dietary modification) in men and women who have difficulty meeting current height-weight standards, to evaluate the utility of applying various height/weight ratios to such individuals and to attempt implementation of subcutaneous fat determination by skinfold thickness measurement as a better criterion of the overweight/underweight aspect of physical fitness.

Progress:

In collaboration with the local U. S. Army Dispensary a cohort of 8 men and 2 women who cannot meet current height-weight standards (1) has been evaluated by the skinfold prediction method used in the most extensive recent body fat survey of men and women available (2). The median values from this survey and the limits for the 10th to 90th percentile of the population for each sex by decade of age are summarized in Table 1. Each individual's body fat content has been related to a percentile value from this distribution, which ranks him according to the percentage of the survey distribution that had a lower body fat content than his/hers. Table 2 summarizes the data from each individual measured upon entry into the cohort and shows the required target weight, from current height-weight standards (1), the actual percentile body fat upon entry and the calculated weight of each individuals if he/she had no body fat at all (lean body mass or LBM). Of the 8 males, 6 were above the 95th percentile value for body fat of men their age and unquestionably were overweight. However, subject M-1, a former football player who trained with weights, had a calculated lean body mass 11 pounds greater than the maximum allowed under the current regulations; even if he lost all of his body fat, he would still weigh more than the standard permits. Two subjects (M-7, M-8) were less than 90th percentile for their age. Subject M-7 was 82nd percentile with 26% fat who might easily lose some weight but not the 25 pounds by which he exceeds the current standard. Subject M-8 was a runner with only 22% fat, which is below the median for his age. Although he well may be able to lose the required 6 pounds, maintaining the standard may prove extremely difficult for this heavily muscled athlete. The same is true for the 44th percentile woman (F-2). She may lose 13 pounds and get to the standard, but such a weight will be difficult to maintain, as indicated by the median for women her age who have 1% more fat than she does now.

TABLE 1

Body Fat Percentages (Median 10th and 90th Percentile) for Men and Women by Decade of Age. After Durnin and Womersley, 1974 (2). Percentiles Estimated from Mean and Ranges of Published Distributions.

		Body Fat Content (%)		
Sex	Age	Median	10th Percentile	90th Percentile
Male	17-19	15	12	19
	20-29	15	10	21
	30-39	23	19	27
	40-49	25	20	29
Female	16-19	26	21	31
	20-29	29	22	36
	30-39	33	27	39
	40-49	35	30	41

TABLE 2

Ages, Physical Characteristics and Target Weights of Cohort Overweight by Current Standard (1).

Subj. No.	Age	Height (in)	Weight (lb.)	% Fat	Percentile	LBM (lb.)	Target Weight	Comment
M-1*	37	69	297	34	99	197**	186	ex-football player
M-2	41	71	226	38	99	141	197	
M-3	34	73	232	28	95	166	208	ex-miner
M-4	36	72	235	30	98	163	203	ex-soccer player
M-5	35	71	210	29	96	149	197	
M-6	28	74	236	24	97	178	214	
M-7	32	72	228	26	82	170	203	
M-8	30	71	203	22	35	160	197	runner
F-1	21	65	170	37	92	107	142	
F-2	31	66	160	32	44	108	147	

NOTES: * = transferred, no longer in cohort
** = LBM exceeds target weight

Of the 3 men who have been followed for 6 months (M-2, M-3, M-4), none have met the standard. M-3 has lost 20 pounds and is only 4 pounds away, but still has more fat than 95% of the men his age. M-4 has lost 14 pounds and is 83rd percentile body fat, but still must lose (and keep off) 18 more pounds. The third man (over 40) has only lost 5 pounds, which reflects the difficulty of reversing long established eating habits.

Future Plans:

Future work will be directed towards enlarging the cohort as overweight individuals are identified during annual physical examinations and re-measuring individuals within the cohort every 3-6 months. Body mass and ponderal indices will be calculated and compared with percentile rankings of body fat content for use as objective criteria of overweight status throughout their weight-control program. To date, no underweight individuals have been identified.

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2. Durnin, J. G. V. A. and J. Womersley. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. Br. J. Nutr. 32:77-97, 1974.

3. Headquarters, Department of the Army. Telecommunication DAPE-MPE-CS 112023Z Jul 78, Subj: Weight Control Program.

(81026)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OC 6133	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
78 04 14	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.01.A	3A161101A91C	00	026
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)* (U) Heat production and heat loss in chronic obesity as a function of endocrine patterns (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
012900 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
75 03	CONT	DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	.1	3
	CURRENT 79	.1	4

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760
RESPONSIBLE INDIVIDUAL
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NAME:* GOLDMAN, Ralph F., Ph.D.
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SOCIAL SECURITY ACCOUNT NUMBER: [redacted]
ASSOCIATE INVESTIGATORS DANFORTH, Elliot, M.D.
NAME: 090-26-2209; Un of VT College of Med
NAME: Tel:(802) 656-2530 DA

PII Redacted

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)
(U)Basal Metabolic Rate:(U)Heat Production;(U)Metabolic Regulation;(U)Thyroid Function

23. TECHNICAL OBJECTIVE.* 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Evaluate the thermogenic responses to ingestion of excess carbohydrate and/or fat by normal individuals, "easy or hard gainers," and those with distinct overweight problems. Understanding the mechanisms involved could extend cold tolerance by indicating ways of obtaining increased heat production. Collaborative study combines our heat production/loss expertise with endocrinology expertise at Univ. of Vermont Clinical Research Unit.

24. (U)Measure heat production and loss responses pre- and post-prandially before and after a 3-week hyperalimentation of approximately 2000 kcal per day. Temperature and heat production measurements will be made at USARIEM, overfeeding and endocrine assays at the Univ. of VT Med. Center under an NIH protocol.

25. (U) 77 10 - 78 09 Results from 3 collaborative studies conducted earlier on groups of normal men (N = 5 or 6) overfed protein, fat or carbohydrate from 2-3 weeks have shown that ingestion of excess calories of any of the 3 dietary components elevated basal and resting pre- and post-prandial metabolic heat production, without affecting exercise metabolism. Since thyroid hormone T_3 and reverse T_3, but not T_4, levels also varied with the dietary component overfed, the hormonal responses are being correlated with the metabolic responses to determine their association. Preliminary analysis shows that the circulating T_3 and rT_3 hormonal levels do not correlate very highly with the magnitude of the enhanced heat production. Accordingly, more complicated models of metabolic regulation involving the changes in hormone levels from baseline values, the ratio of T_3/rT_3 levels and hormonal turnover rates are being examined statistically for their association with the observed changes in metabolic heat production.

*Available to contractors upon originator's approval

DD FORM 1498, 1 MAR 68 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	026 Heat Production and Loss in Chronic Overweight as a Function of Endocrine Patterns
Study Title:	Hypermetabolic Response to Excess Calories in Normal Men
Investigators:	Richard L. Burse, Sc.D. and Ralph F. Goldman, Ph.D., in collaboration with Eliot Danforth, Jr., M.D., Ethan A. H. Sims, M.D., David C. Robbins, M.D. and Edward S. Horton, M.D. (University of Vermont)

Background:

Previous studies (1,2,6,7,8) have shown that overfeeding of carbohydrate (CHO) for periods ranging from 1-3 weeks resulted in metabolic heat production which was in excess of that expected from the increases in body weight. However, when fat was overfed for prolonged periods, metabolic heat production was not in excess of that expected as an accompaniment to the weight gain. Because the various studies comparing excess intake of fat or CHO calories were conducted at different times, one cannot be assured that conditions were controlled to the extent that the studies were strictly comparable.

Progress:

The heat production and heat loss responses were measured pre-and post-prandially before and after a 3-week overfeeding of either fat or CHO and a 2-week overfeeding of protein. The hypothesis was that ingestion of excess CHO calories results in greater thermogenesis, with correspondingly lower weight gain, than ingestion of the same number of calories of fat or protein.

Basal and resting metabolism were slightly elevated in response to overfeeding, CHO, fat and protein, but were most readily elevated with protein (3,4). There was no concomitant elevation in exercise metabolism with any dietary constituent, above that required for transporting the added body weight. This was unlike the earlier results from spontaneously obese men who increased their exercise metabolism 25% in response to being overfed CHO for 3 weeks (2).

The thermic effect of the meals (SDA) was enhanced both in extent and duration by overfeeding each dietary constituent. Some of the enhanced response persisted after dietary supplements were withdrawn, indicating that the greater thermic effects were not just responses to the larger meals during the overfeeding period.

Thyroid hormone changes were generally, but not consistently, changed in the expected direction. Thyroxin (T_4) serum concentration levels did not change, but the metabolically active hormone Tri-iodo thyronine (T_3) showed increases in serum concentration levels, production rates and metabolic clearance rates in response to overfeeding each dietary constituent. However, fractional turnover rate was increased only in response to overfeeding protein. Surprisingly, the serum concentration level of the metabolically inactive isomer reverse T_3 (rT_3), which usually changes inversely to that of T_3, decreased in response to overfeeding CHO and protein, but not fat (5). Weight changes during the overfeeding period showed a calorie of protein to be 2.9 times as effective in inducing weight gain as CHO and 2.5 times as effective as fat.

The changes in thyroid hormone levels and kinetics agreed generally in direction, but not magnitude, with the observed changes in metabolism. To statistically test the association between the hormonal and metabolic changes, the metabolic results have been submitted to our collaborators at the University of Vermont Medical College for correlation with their hormone results by their Biostatistics research team. Initial results from simple correlations between metabolic response and T_3 and rT_3 hormone concentrations have been most disappointing, accounting for less than 50% of the variance. This means that more complicated models of metabolic regulation will have to be explored. Accordingly, the changes in hormone concentrations, the ratio of T_3/rT_3 concentrations and the hormonal clearance and turnover rates will be individually correlated as an initial step. Should these fail to satisfactorily account for the metabolic results, multiple correlation techniques will have to be employed.

It is clear that the thyroid hormone changes are not associated with any large wastage of surplus calories, despite an apparent increase in the peripheral conversion of T_4 to T_3 during the overfeeding period. Our findings are not consistent with our earlier hypothesis that individual dietary constituents (particularly CHO) induce constituent-specific changes in metabolism, nor are they consistent with the hypothesis that the level of basal metabolism is determined by the circulating levels of T_3 peripherally converted from circulating T_4.

Presentations:

1. Burse, R. L., R. F. Goldman, E. Danforth, Jr., E. S. Horton and E. A. H. Sims. Effect of excess carbohydrate and fat intake on resting metabolism. Fed. Proc. 36:546. 1977.

2. Burse, R. L., R. F. Goldman, E. Danforth, Jr., D. C. Robbins, E. S. Horton and E. A. H. Sims. Effect of excess protein intake on metabolism. The Physiologist. 20:13, 1977.

3. Danforth, E., Jr., E. S. Horton, E. A. H. Sims, A. G. Burger, A. G. Vagenakis, L. E. Braverman and S. H. Ingbar. Increased triiodothyronine (T_3) metabolic clearance rate during overnutrition. Proc. XIth Acta Endocrin. Cong. (Lausanne), June, 1977.

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1. Apfelbaum, M., J. Bostsarron and D. Lacatis. Effect of caloric restriction and excessive caloric intake on energy expenditure. Am. J. Clin. Nutr. 24:1405–1409, 1971.

2. Burse, R. L., R. F. Goldman, W. Crowley, E. Danforth, Jr., and E. A. H. Sims. Elevated metabolism in obese males after excess carbohydrate intake. Fed. Proc. 35:402, 1976.

3. Burse, R. L., R. F. Goldman, E. Danforth, Jr., E. S. Horton and E. A. H. Sims. Effect of excess carbohydrate and fat intake on resting metabolism. Fed. Proc. 36:546, 1977.

4. Burse, R. L., R. F. Goldman, E. Danforth, Jr., D. C. Robbins, E. S. Horton and E. A. H. Sims. Effect of excess protein intake on metabolism. The Physiologist. 20:13, 1977.

5. Danforth, E., Jr., E. S. Horton, E. A. H. Sims, A. G. Burger, A. G. Vagenakis, L. E. Braverman and S. H. Ingbar. Increased triiodothyronine (T_3) metabolic clearance rate during overnutrition. Proc. XIth Acta Endocrin. Cong. (Lausanne), June, 1977.

6. Durnin, J. V. G. A. and N. Norgan. Variations in total body metabolism during "overfeeding" in man. J. Physiol. (London) 202:106P, 1969.

7. Goldman, R. F. Bioenergetics and the response to overfeeding. In: Obesity in Perspective, Vol. II, Fogarty International Series on Preventive Medicine, G. A. Bray, (ed.) Washington, D.C., U. S. Government Printing Office, 1976.

8. Miller, D. S., P. Mumford and M. J. Stock. Gluttony 2: Thermogenesis in overeating man. Am. J. Clin. Nutr. 20:1223-1229, 1967.

(81027)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OC 6127	78 10 01	DD DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
78 04 14	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.01.A	3A161101A91C	00	027
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*

(U) Temperature and Sweat Production during Eccentric Work (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology; 016200 Stress Physiology; 005900 Environmental Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
77 10	CONT	DA	C. In-House

17. CONTRACT GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	1.1	19
	CURRENT 79	1.0	19

19. RESPONSIBLE DOD ORGANIZATION

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SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: KNUTTGEN, Howard G., Ph.D.

NAME: 955-2800 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Eccentric Work;(U)Negative Work;(U)Sweating Rate of Thermal Regulation

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Eccentric exercise is a situation where the muscle contracts to resist stretching or lengthening of the muscle as opposed to shortening of the muscle in concentric or positive exercise. Preliminary observations have indicated that sweat production is inordinately high during eccentric (negative) exercise as compared to standard concentric (positive) exercise. This high sweat rate appeared to diminish with eccentric training but returned to the high rate promptly after cessation of training. Temperature regulation during eccentric work has not been described. Core and skin temperature responses to eccentric work and their relation to these sweat rate observations have not been previously studied.

24. (U) The observations concerning high sweat rates will be confirmed on subjects performing eccentric exercise on a motor driven bicycle ergometer. Skin and core temperatures will be recorded and compared to standard concentric exercise. If eccentric exercise is found to ellicit a temperature regulating response different from concentric work, training will be evaluated as a modifier.

25. (U) 77 10 - 78 09 A bicycle ergometer suitable for eccentric exercise has been designed, fabricated and calibrated. Data collection will begin on 1 October 1978.

*Available to contractors upon originator's approval

Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	027 Temperature and Sweat Production during Eccentric Work
Study Title:	Body Temperature Regulation Following Training with Eccentric Muscle Contractions
Investigators:	Howard G. Knuttgen, Ph.D., John F. Patton III, Ph.D. and Kent B. Pandolf, Ph.D.

Background:

When muscles are to contract concentrically (shortening contractions), a portion of the energy produced by the muscles is converted into potential energy if weight has been lifted during the effort. This weight could consist of either an external object or the person's own body weight. The process of lowering an object or a person's weight involves eccentric (lengthening) contractions. Work is actually being performed on the muscles and the process has been referred to as negative work (1,2).

The pattern of body temperatures has been well described during concentric exercise (3) but little is known regarding body temperatures during eccentric exercise (4). This latter form of exercise presents a special problem in that the working muscles resist elongation due to external force, resulting in the addition of heat to the body above that produced by metabolism.

Progress:

An experiment is planned for early FY 80. Developmental problems with the eccentric ergometer have prevented an earlier starting date. This experiment will consist of a pretraining test, five weeks of training with eccentric contractions and then a post-training test.

The pre- and post-training tests will be identical for each subject. During these periods respiratory, circulatory and thermal responses to a constant level of eccentric exercise will be determined. Exercise will be performed on a cycle ergometer driven by electric motor so that the subject resists the tendency of the ergometer to increase the rpm of the pedals from 60 to 66. The ergometer is calibrated so that the subject has to provide a predetermined resistance power in order to maintain 60 rpm.

Pulmonary ventilation, oxygen uptake and respiratory exchange will be determined by the Douglas bag technique with Beckman LB-2 analyzer for CO_2 and Applied Electrochemistry S3-A analyzer for O_2. Heart rate will be measured electrocardiographically. Core temperature will be recorded each minute from a thermister in the esophagus at the level of the heart. Mean skin temperature will be computed from proportionate weighting of eight local skin temperature measurements according to surface area (4). Intramuscular temperature will be measured by thermister (26 - gauge needle) introduced into the quadriceps according to the technique of Nadel et. al. (4). Body weight will be recorded immediately pre-and post-exercise with a Sauter K-120 scale.

Exercise intensities will be assigned to each subject on the basis of aerobic power capacity ($\dot{V}O_2$ max) while performing concentric exercise on the same ergometer and by general body proportions. In the pre-training test each subject will exercise at 60 rpm as long as possible up to 60 min. duration.

The training period will be for five weeks with each training session consisting of 60 min. of exercise at the same intensity. The frequency will be three times per week.

LITERATURE CITED

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2. Knuttgen, H. G., F. Bonde-Petersen and K. Klousen. Oxygen uptake and heart rate responses to exercise performed with concentric and eccentric muscle contractions. Med. Sci. Sports 3:1-5, 1971.

3. Saltin, B., A. P. Gagge and J. A. J. Stolwijk. Muscle temperature during submaximal exercise in man. J. Appl. Physiol. 21:1757-1762, 1966.

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(81028)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
DA OB 6137	78 10 01	DD DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8. DISB'N INSTR'N	8b. SPECIFIC DATA CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.01.A	3A161101A91C	00	028
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)

(U) Physiologic Correlates of Induced Severe Hyperthermia in Man (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS

012900 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY		16. PERFORMANCE METHOD
76 10	CONT	DA	NIH	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER: NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	.5	4
	CURRENT 79	.5	6

19. RESPONSIBLE DOD ORGANIZATION

NAME: USA RSCH INST OF ENV MED

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TELEPHONE: 955-2849

SOCIAL SECURITY ACCOUNT NUMBER: [redacted]

ASSOCIATE INVESTIGATORS: BULL, Joan, M.D., NIH

NAME: National Cancer Institute

NAME: (301) 496-6919 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U) Hyperthermia; (U) Critical Thermal Maximum; (U) Esophageal Temperature; (U) Cancer; (U) Prediction

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Evaluate physiological effects of 107 ± 1°F body temperature, considered the threshold for heatstroke, in collaborative study with National Institutes of Health. USARIEM focus is on mechanisms involved in heatstroke; NIH proposes studying therapeutic effects of such body temperatures.

24. (U) Participation in NIH clinical trials to 107 ± 1°F level, to contribute our experience in measuring and regulating hyperthermia, provide maximal safety, and gather data for improving prediction of the correlates of extreme body temeprature elevation.

25. (U) 77 10 - 78 09 Data to date, and other observations, suggest that heatstroke results from a combination of elevated body core temperature and exposure time, rather than a critical threshold body temperature alone. A mathematical model has been developed which appears to have been validated by animal studies under another work unit. A preliminary report (American Journal of Physiology) is currently in press which supports this mathematical model from NIH clinical patient trials of extreme body temperature elevation (107 ± 1°F). Further patient evaluation at NIH has resulted in data collection from over two dozen individuals. These data, which are accessable to USARIEM only through these experiments, are being formulated into our current prediction equations involving elevated body temperature.

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*Available to contractors upon originator's approval.

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Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	028 Physiologic Correlates of Induced Severe Hyperthermia in Man
Study Title:	Collaboration in Clinical Evaluations of Hyperthermia ($T_{re} \simeq 42^oC$) at National Cancer Institute
Investigators:	Kent B. Pandolf, Ph.D., Gaither D. Bynum, M.D., MC, Joan Bull, M.D. and Ralph F. Goldman, Ph.D.

Background:

Upon completion of the exposures of volunteers to induction of hyperthermia to a $39.2^oC \pm 0.3^oC$ level using the circulating water suit and controller at USARIEM (1), recommended modifications in the HCA-II controller were performed. The system was then shipped to NCI, Bethesda and studies involving patient exposure were initiated there. USARIEM collaboration continued, with a view toward contributing both our general expertise in hyperthermia and the experience gained in the studies at USARIEM and also to gain otherwise unavailable information on physiologic responses and status of essentially normal (i.e. nondebilitated, despite cancer) individuals with body temperatures induced to 41.8 ± 0.2^oC.

Progress:

The individual physiological responses of volunteers tested at USARIEM and five cancer patients at NCI to hyperthermic exposures were reported previously. These observations have been recently formulated into an open literature publication which contributes or supports two concepts. The concept of critical thermal maximum (CTM) has been defined in the literature as the minimum high deep body temperature which is lethal to an animal (3). In man the CTM has been estimated at $41.6^oC - 42.0^oC$ (5). However, we reported data for sedated unacclimatized, well-hydrated men (cancer patients) heated one hour until esophageal temperatures of $41.6 - 42^oC$, without sequelae, except for modest elevation of serum enzymes in 2 of 5 patients. Typical experimental findings which illustrate this point from one patient are presented in Figure 1. These data, when combined with other observations in the literature (4), suggest that CTM be redefined as the particular combination of exposure time at elevated body temperatures which results in either subclinical (CTM_s) or clinical (CTM_c) injuries.

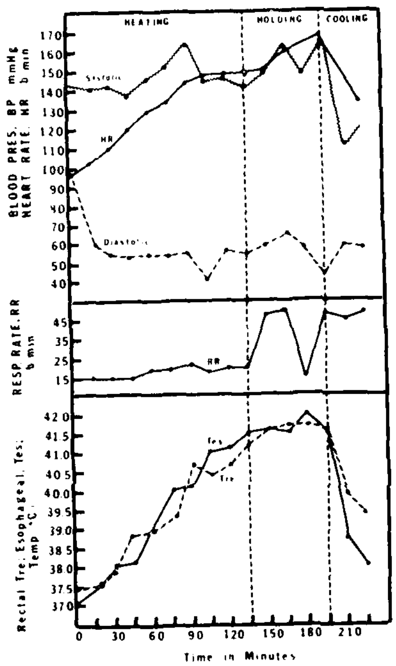

FIGURE 1. Physiological responses (RR, HR, BP, T_{re} and T_{es}) of a male patient (National Cancer Institute) to induced hyperthermia (holding $T_{es} = 41.8 \pm 0.2^{o}C$) using an insulated suit through which $46^{o}C$ water was circulated.

The second major concept involves the presentation of a mathematical technique, equivalent time at $42^{o}C$ (T_{eq} 42^{o}), for expressing hyperthermia in terms of body temperature and exposure time. The regression equation for these functions is of the form, Time $= ae^{-bT}$ where "a" and "b" are constants and T is the temperature in ^{o}C. Time - temperature exposure data may then be normalized into equivalent times at $42^{o}C$, by use of a modified regression equation. This equation is determined by solving the original equation for "a" using the approximate average rate constant "b" (b=1.353) from our data, along with a time increment equal to 1 and a temperature T of $42^{o}C$. The value for "a" obtained in this manner is equal to 4.7178×10^{24}. Temperature records may then be normalized to equivalent times at $42^{o}C$ by the summation of the following expression: $42^{o}C$ equivalent time = $\left[\Sigma \Delta \text{ Time}/4.7178 \times 10^{24})e^{-1.353T}\right]$. The hyperthermia experienced by three of the subjects at three different rates of temperature rise and maximum T_{es} is expressed as equivalent time at $42^{o}C$ (T_{eq} 42^{o}), and presented in Figure 2. Though the time - temperature interaction for these three individuals is markedly different, the thermal exposure can be easily compared when expressed as T_{eq} 42^{o}. A similar, or perhaps the identical, relationship may be usefully applied to studies of heat stroke mortality.

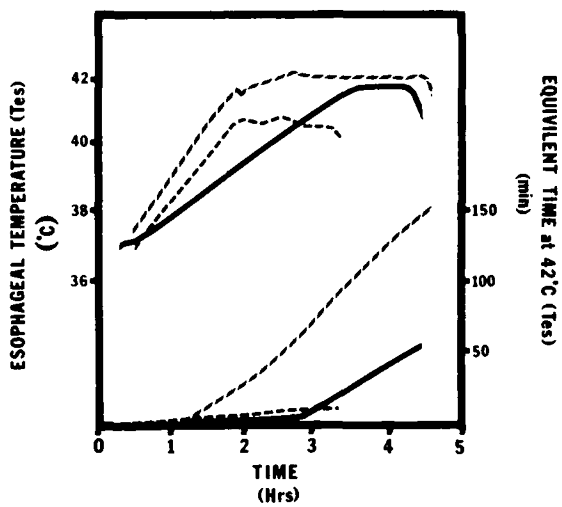

FIGURE 2. The esophageal temperatures (T_{es}) of three male patients (National Cancer Institute) to induced hyperthermia are plotted as a function of time (a). The corresponding calculated equivalent time required to achieve the same thermal injury at a T_{es} of $42^{o}C$ (T_{eq} 42^{o}) is plotted as a function of actual exposure time (b). The equation relating T_{eq} 42^{o} as a function of actual exposure time and T_{es} is T_{eq} 42^{o} = $(\Sigma \Delta \text{ Time}/4.7178 \times 10^{24})e^{-1.353}T_{es}$.

Currently, about two dozen cancer patients have been evaluated during hyperthermic exposures. Multiple hyperthermic exposures (6 or more exposures) have been conducted on approximately half this group of patients. Our goal is to retrieve the cardiovascular and thermal response data of these patients and to organize and analyze these findings. These results should be most instructive in assessing factors which contribute to heat exhaustion collapse. While no new data collection will be initiated at USARIEM, collaborative contact with NCI on this project will be continued.

Presentations:

1. Bynum, G., K. B. Pandolf and R. F. Goldman. Human hyperthermia induction: Comparison of circulating water suit with other methods. Federation Proceedings. 36(3):512, 1977.

2. Bynum, G., K. B. Pandolf, R. F. Goldman and J. Bull. A comparison of current methodologies for induction of human hyperthermia. Proceedings of the International Union of Physiological Sciences. 13:112, 1977.

Publications:

Bynum, G. D., K. B. Pandolf, W. H. Schuette, R. F. Goldman, D. E. Lees, J. Whang-Peng, E. R. Atkinson and J. M. Bull. Induced hyperthermia in sedated humans and the concept of critical thermal maximum. American Journal of Physiology. 235(5):R228-R236, 1978.

LITERATURE CITED

1. Bynum, G. D., K. B. Pandolf, W. H. Schuette, R. F. Goldman, D. E. Lees, J. Whang-Peng, E. R. Atkinson and J. M. Bull. Induced hyperthermia in sedated humans and the concept of critical thermal maximum. American Journal of Physiology. 235(5):R228-R236, 1978.

2. Ferris, E. B., M. A. Blankenhorn, H. W. Robinson and G. E. Cullen. Heatstroke: Clinical and chemical observations on 44 cases. Journal of Clinical Investigation. 17:249-262, 1938.

3. Hutchison, V. H. Critical thermal maxima in salamanders. Physiological Zoology. 34:92-125, 1961.

4. Pettigrew, R. T., J. M. Galt, C. M. Ludgate, D. B. Horn and A. N. Smith. Circulatory and biochemical effect of whole body hyperthermia. British Journal of Surgery. 61:727-730, 1974.

5. Shibolet, S., M. C. Lancaster and Y. Dannon. Heatstroke: A Review. Aviation, Space and Environmental Medicine. 47:280-301, 1976.

TABLE 1

Mean Values of Physiologic Responses in Hot Water Suit:

	INITIAL	BEGIN HOLD	BEGIN COOL	END
6 Normal Ss heated to 39.3 ± 0.2°C (USARIEM)				
Time (min)	0	60	135	150
T_{re} (°C)	36.9 ± 0.2	39.1 ± 0	39.5 ± 0	39.0 ± 0.1
T_{es} (°C)	36.5 ± 0.1	39.0 ± 0.2	38.8 ± 0.1	37.7 ± 0.1
HR (b/m)	74 ± 2	116 ± 4	108 ± 4	99 ± 6
Syst. (mmHg)	112 ± 5	138 ± 8	130 ± 16	121 ± 8
Diast.	68 ± 6	68 ± 5	62 ± 2	62 ± 1
Resp. (b/m)	13 ± 1	15 ± 2	18 ± 3	13 ± 2
5 Patients heated to 39.0 ± 0.2°C (NCI)				
Time (min)	0	60	135	150
T_{re} (°C)	37.4 ± 0.1	40.0 ± 0.3	40.0 ± 0.4	39.3 ± 0.4
T_{es} (°C)	37.2 ± 0.2	40.0 ± 0.2	40.1 ± 0.2	38.4 ± 0.2
HR (b/m)	96 ±13	138 ± 12	141 ± 12	132 ± 12
Syst. (mmHg)	123 ± 5	141 ± 15	138 ± 14	118 ± 8
Diast.	69 ± 4	67 ± 9	67 + 10	61 ± 5
Resp. (b/m)	15 ± 2	21 ± 3	23 ± 3	22 ± 3
5 Patients heated to 41.8 ± 0.2°C (NCI)				
Time (min)	0	150	210	245
T_{re} (°C)	373 ± 0.1	41.4 ± 0.1	41.2 ± 0.1	39.1 ± 0.4
T_{es} (°C)	37.1 ± 0.1	41.5 ± 0.1	41.6 ± 0.1	38.0 ± 0.3
HR (b/m)	96 ± 8	154 ± 15	163 ± 17	134 + 17
Syst. (mmHg)	119 ± 5	114 ± 11	121 ± 13	109 ± 8
Diast.	66 ± 5	58 ± 9	57 ± 7	64 ± 6
Resp. (b/m)	13 ± 1	23 ± 3	21 ± 1	16 ± 1

Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	028 Physiologic Correlates of Induced Severe Hyperthermia in Man
Study Title:	Predictive Modeling of Hyperthermia
Investigators:	Kent B. Pandolf, Ph.D., Leander A. Stroschein and Ralph F. Goldman, Ph.D.

Background:

Available biophysical data from copper manikin studies of a system (heated water circulating undergarment, insulating suit and temperature controller) and physiological data from 9 subjects exposed in this system to elevations of deep body temperatures to the $39.2 \pm 0.3^{\circ}C$ level, were used to develop a prediction model of interaction between the subjects and this heating system. The objective was to develop predicted responses with associated, normal, two-standard deviation variability for the various physiological parameters studied. These projected responses could then be extrapolated to suggest an anticipated "normal" response, and acceptable deviation, when patients at the National Cancer Institute became subjects for induction of $42^{\circ}C$ body core temperatures.

Progress:

The linear "curve" of best fit obtained from plotting metabolic rate (MR) vs. rectal temperature (T_{re}) is described by the equation MR (Watts) = 11.26 T_{re} ($^{\circ}C$) - 320. Correlation between MR and T_{re} was $r = 0.70$. There was considerable variation in response between subjects and this rise was not statistically significant. Projected time to achieve the $42^{\circ}C$ levels of core temperature were 3 to 4 hours for all subjects. Mean heart rate, blood pressure and, rates of T_{re} and esophageal temperature (T_{es}) rise for the three subjects unable to complete the study,were not significantly different at comparable temperatures than mean values from those completing the study. At equal temperatures, respiratory rates were significantly higher ($P < 0.05$) for those not completing the study when compared with the subjects completing the study, suggesting the desirability of a means to control hyperventilation.

These data will be incorporated into a prediction model concerning passive human hyperthermia. More importantly, the higher core temperatures and cardiovascular changes measured at the National Institutes of Health on volunteer patients with cancer will be accessible to USARIEM. These data will allow modeling of elevations in core temperature during "rest" to $T_{re} \simeq 42^{o}C$. The last phase in the completion of this work unit involves the predictive modeling of hyperthermia which is contingent upon the results from the volunteer patients. Both the acute physiological changes associated with induced hyperthermia and the acclimation responses with repeated exposures are valuable for modeling purposes. Unfortunately, the mortality rate associated with these volunteer cancer patients may result in a lengthy time period in order to achieve the latter objective (acclimation responses).

Publications:

Bynum, G. D., K. B. Pandolf, W. H. Schuette, R. F. Goldman, D. E. Lees, J. Whang-Peng, E. R. Atkinson and J. M. Bull. Induced hyperthermia in sedated humans and the concept of critical thermal maximum. American Journal of Physiology 235(5):R228-R236, 1978.

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OA 6142	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	001
b. CONTRIBUTING				
c. XXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U)Development and Characterization of Models of Cold Injury and Hypothermia (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 002300 Biochemistry;005900 Environmental Biology;012900 Physiology;003500 Clinical Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
70 07	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	1.4	34
	CURRENT 79	4.6	84

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

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20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* HAMLET, Murray P., D.V.M.

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SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME:

NAME: DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Cold Injury; (U) Frostbite; (U) Thermoregulation; (U) Osteocytes; (U) Cryobiology; (U) Fasciotomy

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Study factors involved in frostbite and other non-freezing injuries in both animals and man. Provide a rational basis for treatment and prevention of those injuries sustained by military operations.

24. (U)Attempts to produce radiographic bone changes seen in recuperation of frostbite victims will be included in an animal model. Hampster cheek pouch will be used to study the effect of compounds that inhibit platelet aggregation after freezing a portion of the pouch. The cheek pouch allows study of microvascular function through light microscopy and photomicroscopy.

25. (U)77 10 - 78 09 The fasciotomy and vasodilator paper demonstrating prolongation of vascular integrity and increased tissue salvage is accepted for publication. Radiometry for blood flow proved to be too cumbersome and had numerous engineering problems. No further work with radiometry is projected at this time. Finger cooling in air data is progressing and analysis continues. Radiographic lytic lesions, which are similar to those produced in man from mild frostbite have been reproduced in an animal model.

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*Available to contractors upon originator's approval

DD FORM 1498, 1 MAR 68 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	001 The Development and Characterization of Models of Cold Injury and Hypothermia
Study Title:	Characteristics of Human Finger Cooling in Air at $0^{o}C$
Investigators:	James J. Jaeger, CPT, MSC, James B. Sampson, Ph.D., Donald E. Roberts, Ph.D. and James E. McCarroll, MAJ, MSC

Background:

One of the missions of the Cold Research Program is to devise and evaluate measures which will enable an individual to prevent or delay the onset of cold injury. Since frostbite of the extremities, particularly the hands, is a common cold injury, it would be advantageous to have a model upon which the efficacy of various prophylactic interventions could be tested.

The literature on human peripheral circulation in the cold is quite extensive (1). However, only a few studies have attempted to examine the inter- and intra-individual variability of the hand temperature response to local cooling. Teichner (3) has observed large variations among individuals in the latency of cold-induced vasodilation (CIVD) and other parameters of the cooling hand in water. He reports that a large number of individuals fail to show CIVD at all. He classified individuals into slow, medium, and fast vasodilators and suggested the differences were a result of differences in arousal levels. Yoshimura and Iida (4,5) and Yoshimura et al. (6) have identified a number of sources of variation in the cooling pattern of a single finger immersed in ice water. These include age, sex, nationality, race, prior cold exposure, autonomic tone, and diet. All the studies cited above have used cold water to achieve hand and finger cooling. To the best of our knowledge, there is no comparable data on hands and fingers exposed to cold air. Since an air exposure has certain advantages over water immersion for the types of studies planned, it was necessary to evaluate human hand cooling curves in terms of various time and temperature characteristics and to determine inter- and intra-subject variability.

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Progress:

Because data should come from a large number of test subjects with as little experimental intervention as possible, it is anticipated that 50 test subjects will be needed. The data reported here represent information obtained from 14 subjects who have completed the full set of exposures to date. Subjects in groups of seven were seated around a large table in a cold chamber which was maintained at 0 ± 1^{o}C. Wind speed was approximately 0.15 meters per second. Subjects wore a standard military arctic uniform. Previous experimentation with this clothing ensemble has shown that there is no significant change in mean weighted skin temperature, rectal temperature or heart rate during a two-hour exposure to 0^{o}C air. Subjects sat with their arms supported at heart level by a nylon mesh net which allowed free circulation of air around the hands. After 15 minutes in the chamber, the right hand glove was removed from all subjects. For the next 120 minutes, the skin temperature of the thumb, middle finger and small finger was measured once a minute by a 30 gauge thermocouple placed 5 mm behind the nail bed.

Each subject was tested on seven separate occasions within a three-week period. The first week subjects were tested at the same time of day, Monday thru Friday. They were then retested on the following two Tuesdays.

Figure 1 illustrates the middle finger skin temperature response of three subjects. This plot indiates the range of finger temperature responses encountered. All three subjects showed an initial period of cooling immediately following removal of the glove at 15 minutes. Some subjects' fingers cooled very little beyond an initial 5 to 8^{o}C drop as seen for Subject 16. Most subjects demonstrated the pattern shown for Subject 10, which consists of a slow cooling phase followed by one or more episodes of skin warming. These events are the well known Lewis waves (2) otherwise known as cold induced vasodilation (CIVD). A CIVD event was arbitrarily defined as a rise in skin temperature of at least 2^{o}C which was sustained for two minutes or more. At the other extreme, a few subjects' fingers cooled continuously as illustrated by the plot for Subject 4. The temperature record for Subject 4 ends at 50 minutes because the temperature of his small finger had fallen to 4.5^{o}C. Subjects were removed from the cold chamber when any skin temperature reached this level. Although these three plots show the range of responses they do not convey the magnitude of the problem of between subject variability.

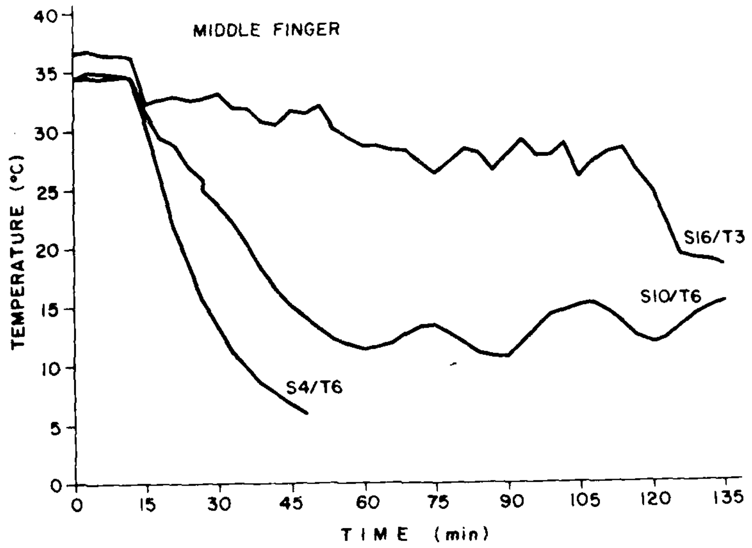

FIGURE 1. Skin temperature (°C) of the middle finger of three subjects versus time (min). "S" refers to subject number and "T" refers to trial number.

Figure 2 illustrates the cooling patterns of all 14 subjects for a single exposure plotted in the same axis. It is immediately obvious that between subject variability was considerable and must be dealt with in the design of the study. Fortunately, the within subject variability of cooling patterns was markedly less.

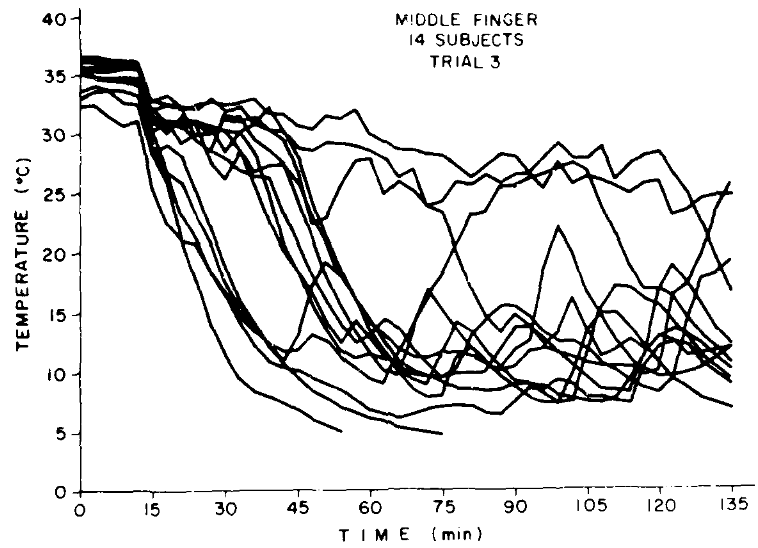

FIGURE 2. Skin temperature (^{O}C) of the middle finger of 14 subjects plotted individually as a function of time (min) for Trial 3.

Figure 3 shows the cooling patterns of a single subject for all seven exposures. The day to day variations in cooling patterns for the other 13 subjects were similar in magnitude. Of the seven cooling patterns shown in Figure 3, one illustrates an unusually large CIVD event. This large warming episode represents an extreme in the amplitude of CIVD events observed. The amplitudes of CIVD events varied between the minimum 2^{O}C rise and the 20^{O}C rise depicted in Figure 3. The amplitude and/or duration of CIVD events were not characteristic of individuals, fingers, or trials.

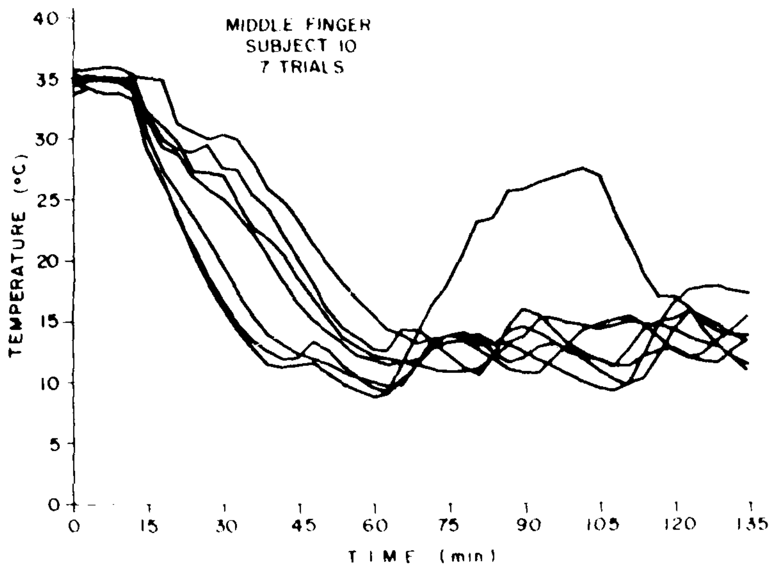

FIGURE 3. Skin temperature (^{o}C) of the middle finger of Subject 10 for seven trials plotted individually as a function of time (min).

In the past, various indices derived from skin temperature measurements have been used to characterize the entire finger cooling process (3,4). This is a useful approach since it allows for simple statistical comparison of a large number of these cooling curves. To the best of our knowledge, however, there has not been a systematic evaluation of these indices to test their reproducibility over time in the absence of experimental treatments.

In Figures 4, 5, 6, and 8 the more common descriptors of finger cooling are depicted in terms of their correlation between trials. In these figures, a particular parameter for the first trial is represented on the X axis while the same parameter as measured in the other six exposures is represented on the Y axis. To help visualize the trial by trial correlations, a line of best fit was drawn for each of the six comparisons.

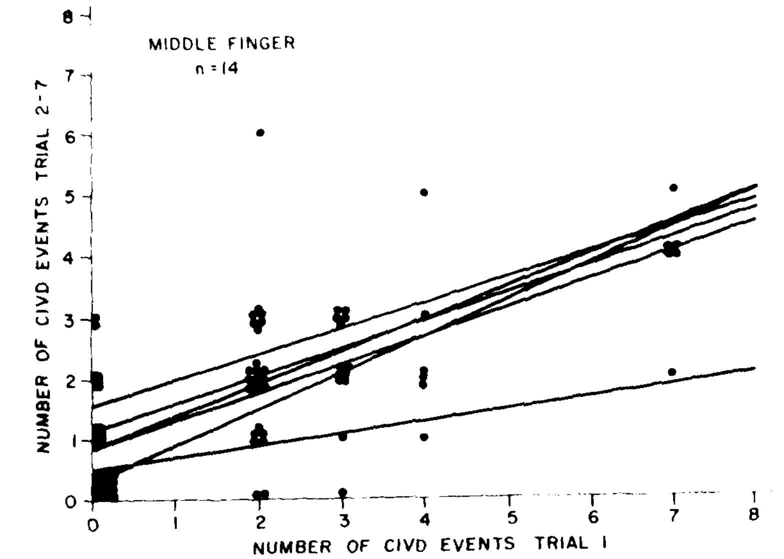

FIGURE 4. Number of CIVD events in Trials 2 thru 7 as a function of the number of CIVD events in Tone. 1. n = 14. Lines of best fit are shown for each of the six trial by trial comparisons.

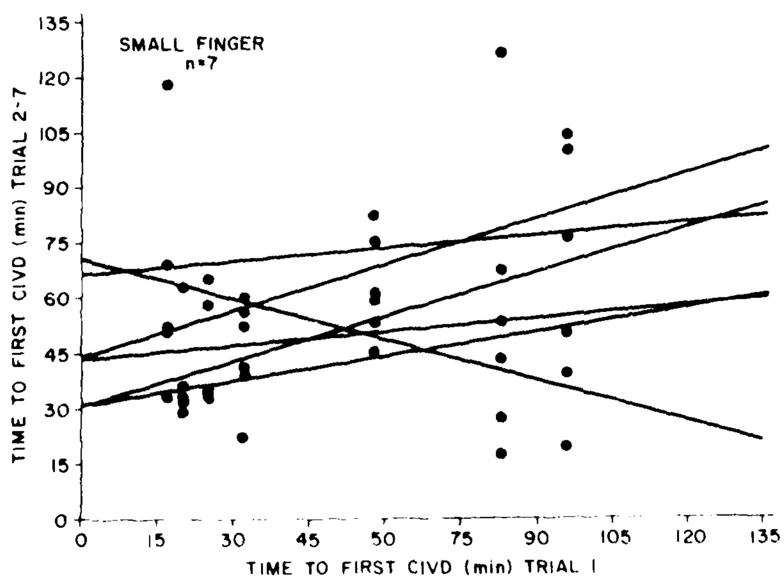

FIGURE 5. Time (min) to the first CIVD event in Trials 2 thru 7 as a function of the time to the first CIVD event in Trial 1. n = 7. Lines of best fit are shown for each of the six trial by trial comparisons.

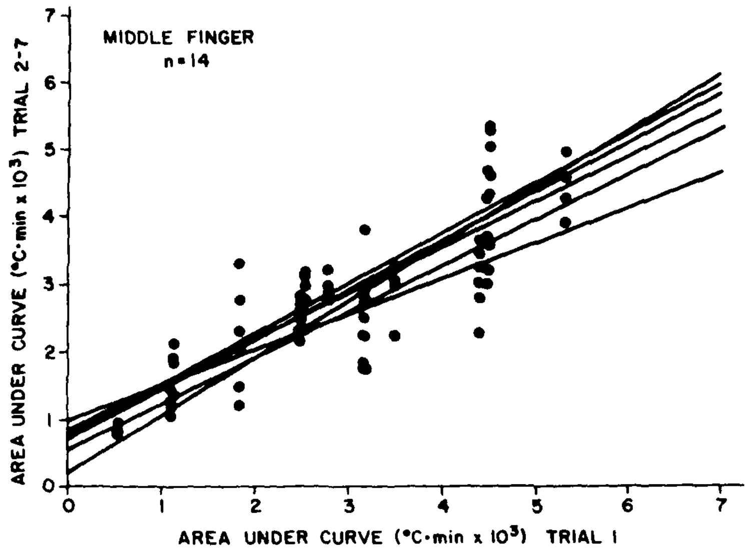

FIGURE 6. Mean skin temperature (°C) of the middle finger during Trials 2 thru 7 as a function of the mean skin temperature during Trial 1. n = 14. Lines of best fit are shown for each of the six trial by trial comparisons.

To illustrate the problem, Figure 7 shows the finger temperature response during Trial 3 for Subjects 3 and 4. Their mean finger temperatures were 12.5°C and 12.1°C respectively. On this basis, there is little to differentiate between the two subjects although it is obvious that their cooling patterns are quite different. To account for the varying exposure times the procedure of calculating the area under the temperature versus time curve was adopted. For this example, the resulting areas were approximately 2100 degree minutes for Subject 3 and 800 degree minutes for Subject 4. The 2.6 fold difference between these values enabled their cooling patterns to be categorized.

For the number of CIVD events for the middle finger, only three of the six correlation coefficients calculated for Trial 1 versus the other six trials were statistically significant at the .01 level (Fig. 4). This low degree of between trial reliability is reflected by the wide scatter of points on this plot. To guard against the possibility that Trial 1 was a unique exposure with unusually low correlation with other exposures, correlation coefficients for all other possible comparisons were calculated; that is, Trial 2 versus all others; Trial 3 versus all others, etc. Of the 21 correlation coefficients, thus calculated for this parameter, only 8 or 38% were significant. From this, it was concluded that the number of CIVD events observed during the standard cold hand exposure was not a reliable descriptor of an individual's cooling pattern.

To other parameters which have been used in the literature as descriptors of finger cooling are the temperature and the time at which the first CIVD event occurs after the start of a cold exposure. The plot shown in Figure 5 is for time of the first CIVD event but the situation it depicts is the same as that for the temperature of the first CIVD event. Again, only the Trial 1 versus Trial 2 thru 7 comparisons are depicted in this plot. The wide scatter of points on this plot illustrates the fact that there was not a single significant correlation coefficient among all possible trial by trial comparisons. From the data presented so far, it is obvious that any attempt to categorize individuals or test the effects of treatments on finger cooling by measuring aspects of CIVD activity is very difficult due to the high variability of CIVD events. A far more reliable parameter to describe the cooling process is simply mean temperature.

Figure 6 is the plot of the Trial 1 versus Trial 2 thru 7 values for mean temperature of the middle finger. All six correlation coefficients were significant at the .01 level. In fact, all 21 of the possible trial by trial correlation coefficients were significant. Although not especially elegant, the simple calculation of mean skin temperature during the exposure period appeared to be a reliable method of describing the finger cooling process.

However, for the experimental design used, calculation of mean temperature can lead to a misinterpretation of the data. Since the cold exposure of an individual was terminated when any skin temperature reached 4.5°C, not all subjects completed the two hour exposure.

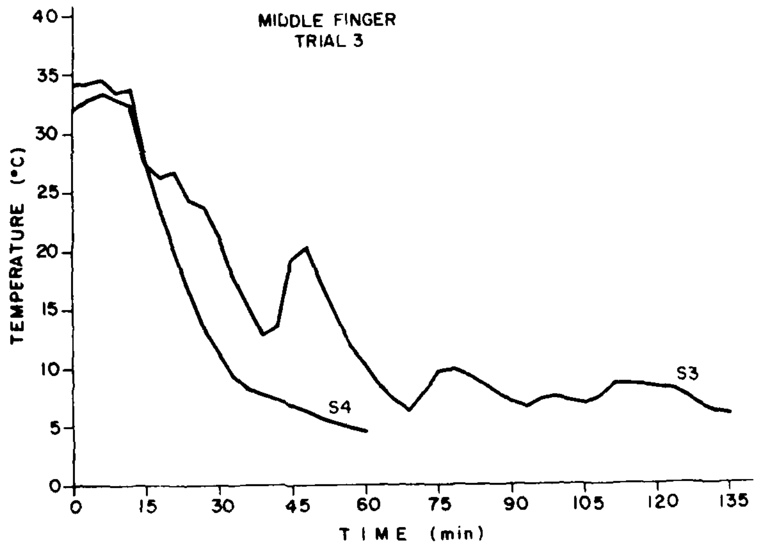

FIGURE 7. Skin temperature (°C) of the middle finger of two subjects versus time (min) for Trial 3. "S" refers to subject number.

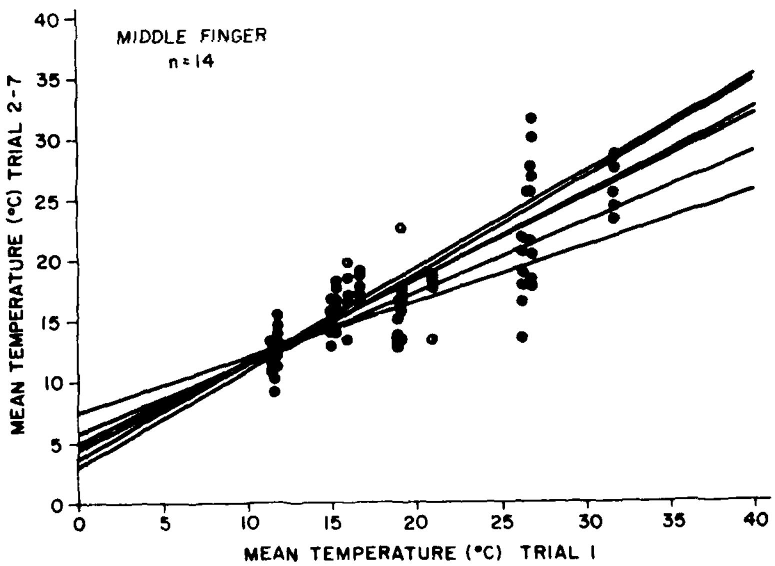

FIGURE 8. Area under the skin temperature versus time curve (°C min x 10^3) for the middle finger during Trials 2 thru 7 as a function of area under the curve for Trial 1. n = 14. Lines of best fit are shown for each of the six trial by trial comparisons.

When subjected to the same correlation analysis as the other parameters, the measurement of area under the cooling curve showed very good between-trial correlation with 100% of all possible trial by trial correlation coefficients being significant at the .01 level (Figure 8). This high degree of between-trial reliability also held for the thumb and small finger.

In summary, patterns of finger cooling in air exhibited marked between-subject variability but were reasonably reproducible for a given subject. In a repeated measures design, the parameters of mean temperature and area under the curve offer the highest degree of reliability when compared to parameters that describe various aspects of CIVD events. When the exposure times of subjects are not equal the measurement of the areas under the cooling curve allows discrimination between cooling patterns in cases where the measurement of mean temperature cannot.

In the previous study, two groups were tested at different times of the day. These two groups differed in their response to the cold stress. We could not rule out a group difference, so in order to test this, we decided to run a 24 h test.

Two groups of five subjects were instrumented with a harness containing sixteen thermocouples. Eight were used to obtain a mean weighted skin temperature and the remanding ones were located on each hand. Each subject wore a rectal thermocouple. The 24 h sequence was divided into 4 six hour blocks and each group was exposed to the cold stress during each time frame. Each exposure was repeated during the following week so that each subject was exposed eight times in two weeks, but twice in each time frame.

The temperature data was collected by means of a high speed numatron and transported to a DEC PDP-11 computer. All temperature data was also recorded on a multichannel tape recorder. This data is currently being analyzed.

This model for the air cooled hand has shown to be reliable and reproducible. Another comparison is planned to compare the response in the chamber with the response in a portable hand chamber which will enable larger samples in different places. Another planned project is the use of thermography to better understand heat loss in the model. Both the hand box model and thermography will be used to determine the response to cooling of women soldiers.

Presentations:

Jaeger, J. J., J. B. Sampson, D. E. Roberts and J. E. McCarroll. Characteristics of human finger cooling in air at $0^{o}C$. The Physiologist 20:47, 1977.

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(82002)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*: DA OA 6144	2. DATE OF SUMMARY*: 78 10 01	REPORT CONTROL SYMBOL: DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	N/A	N/L	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	002
b. CONTRIBUTING				
XXXXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U) Development and characterization of models to study acute mountain sickness and high altitude pulmonary edema in military operations (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 013400 Psychology; 012900 Physiology; 005900 Environmental Biology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
70 07	CONT	DA	In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	3	146
	CURRENT 79	6	177

19. RESPONSIBLE DOD ORGANIZATION

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SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: YOUNG, Andrew J., Ph.D., CPT, MSC

NAME: 955-2885 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U) Acute Mountain Sickness; (U) Fluid Compartments; (U) Radioactive Tracers; (U) Motor Activity

23. TECHNICAL OBJECTIVE.* 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Acute mountain sickness and high altitude pulmonary edema are debilitating disorders associated with the lowered oxygen present at high terrestrial elevations. Many of the physiological and biochemical parameters of these disorders cannot be studied in man due to the invasive nature of the measurements. The purpose of this work unit is to develop appropriate animal models to enable: (1) the elucidation of the physiological and biochemical adaptations which occur in response to the stress of high terrestrial elevations; and (2) the identification of new approaches for improving military effectiveness at high terrestrial elevations.

24. (U) Models will be developed and/or used for investigating: (1) physiological and biochemical responses to altitude; (2) control mechanisms operative in these responses; (3) etiology and symptomatology of acute mountain sickness and high altitude pulmonary edema and; (4) related functional deficits and disabilities.

25. (U) 77 10 - 78 09 Previous results using the rat as the model system indicated altitude-induced shifts of fluid into the intracellular compartments of various organs, specifically brain and lung, within the time frame associated with altitude-related disorders. As a prerequisite for investigating drug-induced changes in these fluid shifts, methods were developed for the estimation of the volume of total body and extracellular water in the intact rat using triated water and radioactive sulfate. Methods of quantitating spontaneous motor activity of unrestrained rats while at altitude are currently being developed in order to determine any behavioral changes which may occur in the same time frame as acute mountain sickness in humans.

*Available to contractors upon originator's approval

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress. Physical Fitness and Medical Factors in Military Performance
Work Unit:	002 Development and Characterization of Models to Study Acute Mountain Sickness and High Altitude Pulmonary Edema in Military Operations
Study Title:	Effect of Altitude on the Body Fluid Spaces of the Rat
Investigators:	Andrew J. Young, CPT, MSC, Ph.D., Allen Cymerman, Ph.D.; SSG Adrien R. Lussier and SP4 Mary K. Miles

Background:

During the first few days of exposure to altitudes above 2,500 meters, unacclimatized human subjects display physical and psychological symptoms that have been combined under the heading of acute mountain sickness (AMS). This illness is characterized by headache, anorexia, vomiting, lassitude, dizziness, weakness, irritability, impaired judgment, and inability to concentrate. The occurrence of AMS during field maneuvers or combat situations at high altitude has an obvious detrimental effect on military performance, since symptoms occur at a crucial time for successful mission accomplishment (6 hours to 6 days). Although the phenomenon of AMS is well described, the mechanism(s) responsible for the symptoms remain(s) obscure.

Several studies (1,2) have implicated changes in body fluid compartments with AMS symptomatology because of a similar temporal course. Within hours of exposure to high altitude, there is an increase in hematocrit which is due not to an increase in red cell mass but to a contraction of plasma volume (3,4). With minimal changes in body weight and no large alterations in total body water content, intravascular and interstitial water compartments are reduced after 48 hours of altitude exposure (1). Similarly, investigators have shown that the reduction in aldosterone excretion may be correlated with the presence of AMS symptoms (5). Using rats, Christensen et al. (6) have shown a change in brain wet-dry weight ratios during the first 24 hours of hypoxia which is indicative of an increase in brain water content. Thus, evidence is present which indicates that the intracellular movement of fluid during the initial stages of altitude exposure may be of paramount importance in the etiology of AMS. This project is concerned with the use of the rat for the development and characterization of an animal model system to investigate the importance of altitude-induced changes in fluid compartments. An increase in the water content of the brain and lung as well as an increase in red blood cell volume of the rat following altitude exposure has already been shown as part of this study. These observations are consistent with the hypothesis that a shift of fluid within compartments occurs upon acute altitude exposure and that the movement of water appears to be from extra- to intracellular space.

Progress:

During the current phase of this project, volumes of the fluid space compartments of the rat were measured. To this end, a modification of the method of Bauer et al. (7) was used. The method is based on the dilution principle which may be stated: if a known amount (M) of a substance is dissolved in an unknown volume (V) of fluid and the concentration (C) of the substance is then determined in a sample of the volume, then V is given by the relationship $C = M/V$ or restated $V = M/C$. The size of the extracellular fluid compartment (ECF) was estimated by the dilution of radioactive sulfate ($^{35}SO_4$), while the volume of total body water (TBW) was estimated by the dilution of tritium (^{3}H) labeled water. An estimate of the volume of intracellular water (ICF) could be calculated by the relationship:

$$TBW = ECF + ICF$$

Volume of dilution was determined in several groups of rats. Each group represented a different time interval between isotope administration and determination of volume of dilution. A mean value for the volume of dilution for each time period was calculated. This method allowed the time course of isotope mixing within the fluid compartment to be followed so that dilution volumes could be determined at the time when the isotopes were fully equilibrated within the fluid compartments. Determinations of these volumes were completed on rats at sea level and after 24 and 48 hours of exposure to a simulated altitude of 18,000 feet.

The results of these experiments are still being analyzed. However, results as shown in Table 1 do not agree with the hypothesis of a shift of water to the intracellular space. If the values are normalized to sea-level values (volumes at sea level equal 100%), then it seems that there is a loss of total body water upon exposure to altitude and, as shown, it appears that the loss is from the ICF. Methodological problems encountered in this phase of the study may account for the difference in conclusions. Presently, experiments are being conducted using a modified experimental design and technique which will greatly reduce the error of our measurements and enable a better estimate to be made of the compartment volumes.

TABLE 1

Volumes of Fluid Space Compartments after Altitude Exposure (18,000 ft)

Compartment	Volumes at Altitude as Percent of Sea Level	
	Time of Exposure	
	24 Hours	48 Hours
Total Body Water	63.4	98.5
Extracellular Fluid	98.5	88.5
Intracellular Fluid	30.6	83.7

Also during this phase, we have initiated work aimed at the quantification of the activity levels of the rat. A system has been designed and assembled which provides a measure of the spontaneous activity of a rat. This is accomplished by the measurement of disturbances in a small electrical field into which the animal's cage is placed. By the measurement of this activity with respect to time, we hope to be able to correlate behavioral and physiological changes (e.g., shifts in fluid space volume) occurring at the same time, upon exposure to altitude.

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(82005)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
DA OB 6145	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	005
b. CONTRIBUTING				
XXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)

(U) Models of Heat Disabilities: Preventive Measures (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS

016200 Stress Physiology; 005900 Environmental Biology; 003500 Clinical Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER: NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	5.4	274
	CURRENT 79	7.4	279

19. RESPONSIBLE DOD ORGANIZATION

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ASSOCIATE INVESTIGATORS

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NAME: FRANCESCONI, Ralph P., Ph.D. DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Heat Stress; (U)Heat Disabilities; (U)Body Temperature; (U)Tolerance; (U)Heat

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)The use of model systems to study the effectiveness of various measures designed to prevent, forestall or reduce the disabilities, injuries or performance decrements associated with military operations in the heat.

24. (U)A variety of suggested preventive measures e.g. prehydration, dietary supplementation and pharmacological agents will be evaluated in animal models for their effectiveness in forestalling or protecting from heat injury.

25. (U)77 10 - 78 09 A study designed to evaluate the efficacy of pretreatment with large doses of vitamin C to attenuate the pathological affects of heat injury demonstrated that it was ineffective. Rats previously exposed to heat were restressed at 41.5°C. Despite longer heating times, acclimated animals had reduced heating rates, lower body temperatures, and 1/3 of the heatstroke deaths. Thus, in rats prior heat exposure improves heat tolerance, as in man, and suggests a resistance to heatstroke. In a study using hyperthermic rats which were exercised to exhaustion, it was demonstrated that there was no depletion of high energy phosphate compounds in critical tissues. Additionally, it was concluded that efflux of tissue constituents (enzymes, metabolites, ions) is not occurring as a result of changes in membrane permeability.

*Available to contractors upon originator's approval

DD FORM 1498, 1 MAR 68 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	005 Models of Heat Disabilities: Preventive Measures
Study Title:	Heat/Exercise Injured Rats: Studies on Prevention and Mechanisms of Injury
Investigators:	Ralph P. Francesconi, Ph.D. and Milton Mager, Ph.D.

Background:

Recently, we have investigated the etiology, mechanisms, and physiological and clinical chemical effects of acute heat injury in laboratory animals. From these studies relevant information has been obtained on the pathophysiology and pathochemistry of heat injury. By exercising rats in a hot ambient environment (35°C) to critical rectal temperatures (42.5-43°C) and by monitoring closely thermoregulatory responses, blood chemistry changes, and tissue chemistry responses before, during, and following the incurrence of the hyperthermic injury, we have been able to estimate survival time, demonstrate the efficacy of fluid administration, and test the usefulness of pharmacological agents in forestalling the heat injury (1). These studies, in addition to our heat acclimatization experiments in humans (2,3), are designed ultimately to obtain information by which the physiological cost of work in the heat can be attentuated by pharmacological, hormonal, or alternative therapeutic intervention.

In more recent experiments we have observed the physiological and biochemical responses of animals from the time of incurrence of hyperthermic/exercise injury to, in some cases, the demise of the animal as a result of the injury. From analyses of blood samples taken immediately upon completion of the treadmill run, after intravenous administration of fluid, and at the time of final respirations, we have been able to monitor indices which are correlated to the extent of the hyperthermic injury. Thus, in rats treated prophylactically or therapeutically to attenuate the effects of heat injury, comparisons with controls of such variables as treadmill time, heating and cooling rates, survival times, clinical chemical correlates of heat injury, etc. permit useful assessments of the efficacy of the treatment regimens.

For example, there has occurred recently a renewed interest in an observation made originally by Henschel et. al. (4) concerning the effects of vitamin C supplements on the ability to work in hot environments. These workers demonstrated that in men undergoing heat acclimatization, those subjects taking supplementary daily dosages of vitamin C were able to work with a reduced core temperature (Tre) (0.4°C) only two days after the initiation of the vitamin C supplement. More recently, Strydom et. al. (5) demonstrated that men receiving 250 or 500 mg doses per day of vitamin C were likewise able to undertake an acclimatization program with reduced Tre and also reached optimal acclimatization in 5.7 days vs. 6.7 days for a control group. Similarly, there are several reports available concerning purely exercise responses in the absence of a heat load which imply the beneficial effects of pretreatment with vitamin C (6,7). However, we found that no prior research had addressed the question of potential beneficial effects of vitamin C when acute exhaustive exercise was combined with an intense ambient heat load. We reasoned that induction of heat injury in exercising rats and close monitoring of physiological and clinical chemical indices would afford an appropriate means to assess the salutary effects, if any, of vitamin C pretreatment.

Also, we elected to examine more closely the mechanisms by which heat/exercise induced injury causes efflux of tissue constituents into blood plasma. We had previously demonstrated that fluid administration to heat-injured rats can, in fact, repress the increments ordinarily occurring in plasma levels of creatine phosphokinase (CPK), potassium (K^+), and lactate. We hypothesized that the increases in the plasma levels of all three correlates of heat injury might be related to inadequate supplies of high-energy phosphate compounds resulting from the extreme fatigue/hyperthermia of the forced exercise in a hot environment. For example, it has been hypothesized (8) that cell membranes are permeable to large molecules such as enzymes (CPK) and that their retention is dependent upon adequate supplies of adenosine triphosphate (ATP). Similarly, Lambotte (9) has demonstrated that a moderate reduction in hepatic ATP levels induced by hypoxia resulted in a net loss of K^+ due to an increased cellular permeability for this ion. Also, Wilkening et. al. (10) noted that the rate of gluconeogenesis from lactate in isolated perfused rat liver was directly correlated with ATP content. Thus, we hypothesized that alterations in levels of high energy phosphate compounds in critical tissues of heat-injured rats were partially responsible for the fluctuations observed in plasma constituents at various time intervals after the incurrence of the heat injury. Further, an evaluation of the high energy phosphate levels of several tissues of heat injured rats would afford useful information on the degree of metabolic derangement and susceptibility of these tissues to heat injury. Finally, we sought to determine whether combined extreme hyperthermia/physical exhaustion are correlated with depletion of high energy phosphates in heat-injured rats and similarly whether their shocklike demise (11) is associated with hypoxic depletion of these energy-rich compounds.

In summary, we wished to test the efficacy of pharmacological prophylaxis in reducing the pathological responses of exhaustive exercise in the heat. Further, we wished to obtain additional information on the mechanisms of heat injury, susceptibility of critical tissues to heat injury, and means by which the pathophysiology of heat injury might be attenuated.

Progress:

To test the efficacy of vitamin C pretreatment in reducing the physiological cost of work in the heat, various dosages of vitamin C were both acutely and chronically administered to groups of rats. Following pretreatment with vitamin C, rats weighing from 250 g to 350 g were fitted with right jugular vein catheters, rectal thermistors, and tail-skin thermocouples. All rats were exercised on a treadmill at 9.14 m/min at an environmental temperature of $35^{o} \pm 0.5^{o}C$ thus assuring Tre of 42.5 to $43^{o}C$ and Tsk ranging up to $39^{o}C$. Upon cessation of the exercise, a 1.5 ml blood sample was taken for determination of clinical chemical indices of heat injury, and the animals were maintained (restrained, sedentary) for another 60 min. at $35^{o}C$ ambient at which time a second blood sample was removed. During the entire interval, rectal and skin temperatures were closely monitored so that alterations in thermoregulatory capacity might be noted. Figures 1-3 denote typical results for a group of 6 rats which had been treated daily with 50 mg/day of vitamin C for 9-12 days for total doses of 450-600 mg of vitamin C per rat. Controls were injected daily with equivalent volumes of physiological saline (1.5 ml). Figs. 1 and 2 demonstrate the thermoregulatory effects of prolonged pretreatment with vitamin C on rats running in the heat. Both figures clearly demonstrate that no beneficial effects accrued as a result of vitamin C pretreatment. All parameters measured including rates of rectal and skin temperature increse, cooling rates, maximal rectal and skin temperatures, etc. are nearly identical between the two groups.

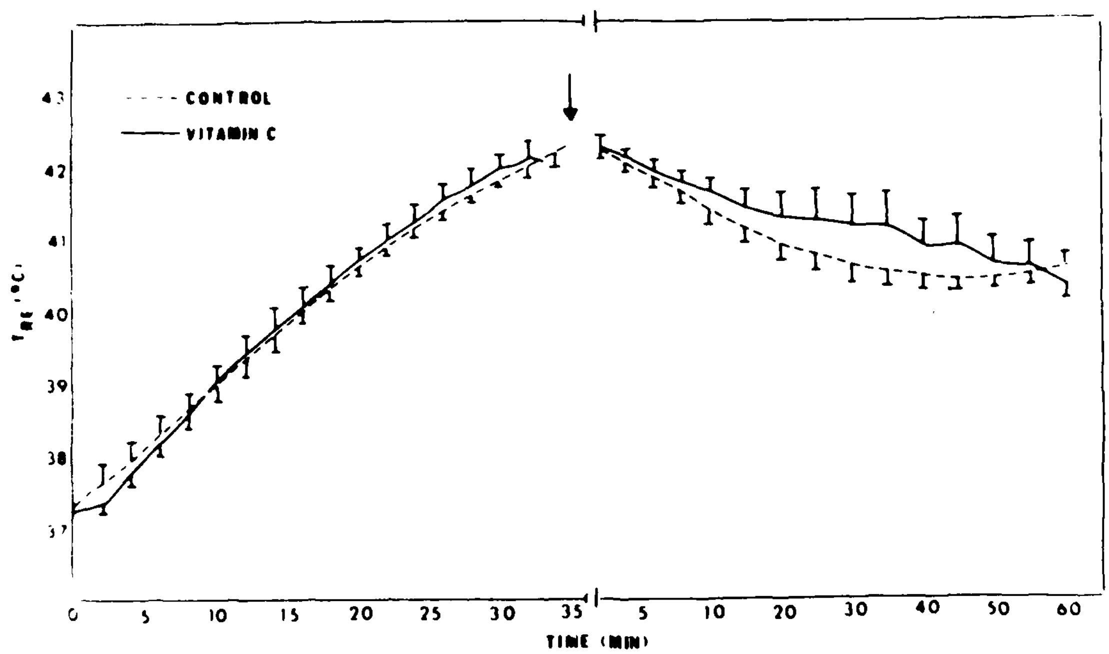

Fig. 1. Effects of vitamin C pretreatment on the rectal temperature responses of rats running on a treadmill (9.14 m/min) in the heat (35°C). For the first 35 min the rats were on the treadmill; the final 60 min represent cooling rates as the rats remained sedentary at the hot ambient temperature. Denoted in the figure are the mean values ± the standard error of the mean for 6 animals per group.

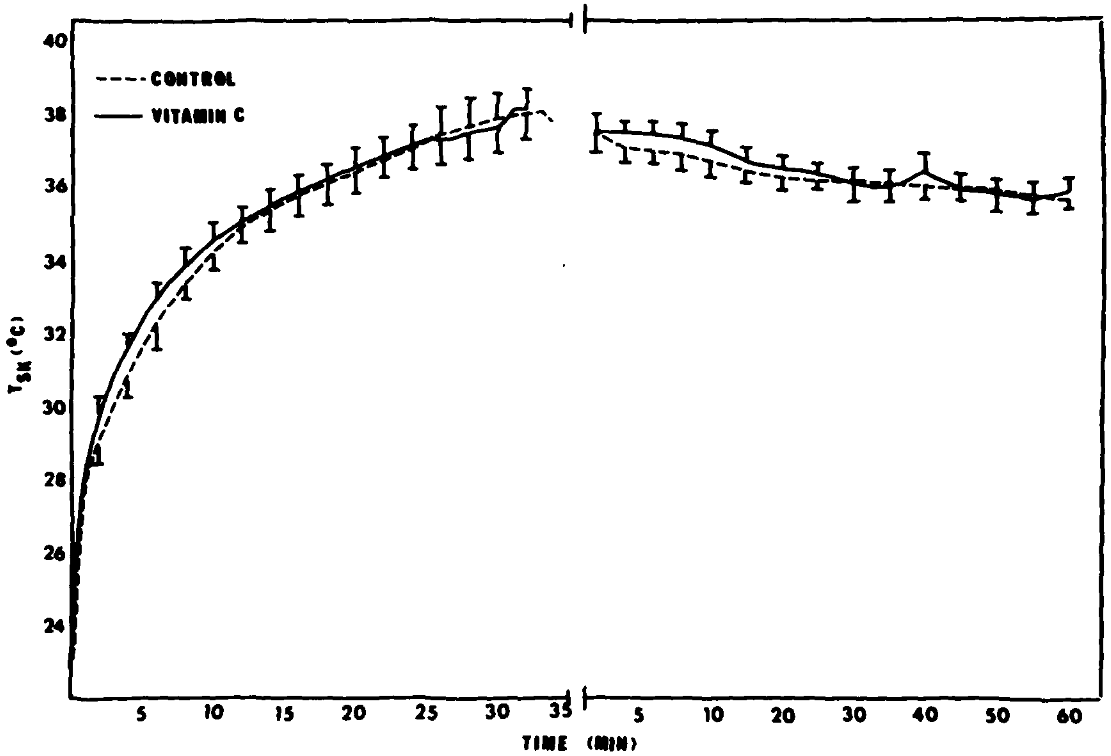

Fig. 2. Effects of vitamin C pretreatment on the skin temperature responses of rats exercising on a treadmill. All conditions are as noted in Fig. 1.

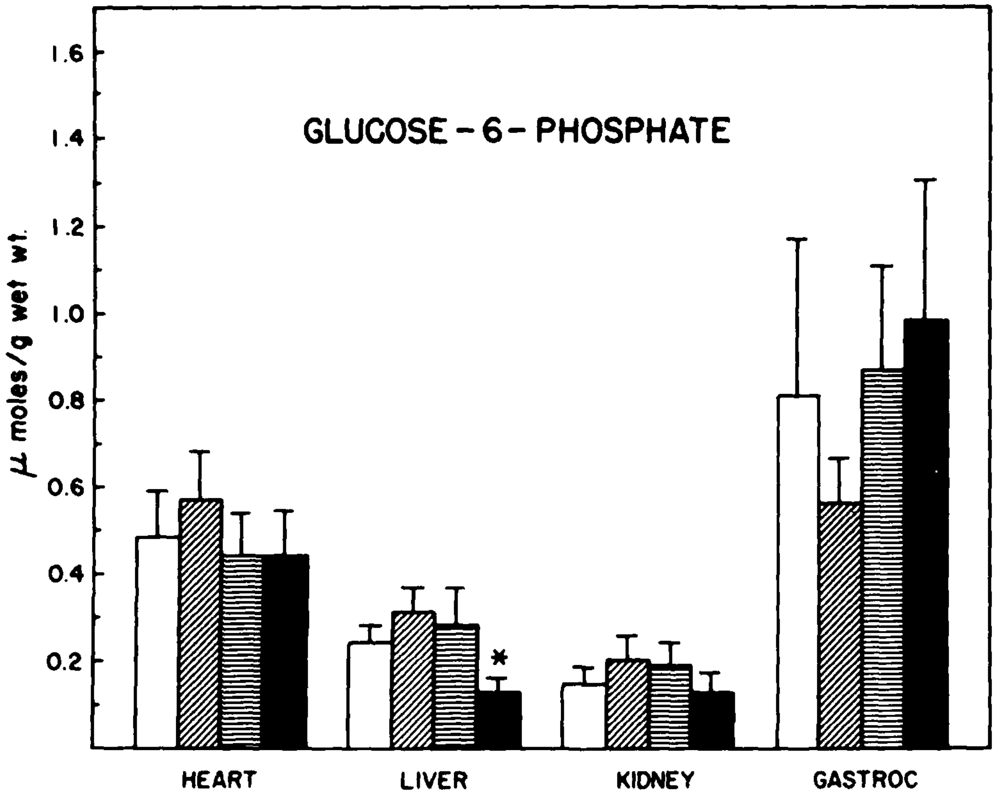

Fig. 3. Effects of hyperthermia/exhaustion on the glucose-6-phosphate levels of heart, liver, kidney and gastrocnemius muscle. The open bars represent data from sedentary controls while the diagonal-lined bars depicts data from hyperthermic rats immediately upon completion of the treadmill run. The horizontal-lined bars illustrate data from rats which were resuscitated with 1.5 ml physiological saline immediately upon completion of the treadmill run, and the solid bars depict data from animals which succumbed to the effects of the heat/exercise injury. The asterisk denotes data which are significantly different from controls ($p < .05$). Each bar represents the mean value ± S.E.M. for 9 animals per group.

To further examine the hypothesized beneficial effects of the vitamin C treatment regimen, two blood samples were taken from each rat. One sample (S_1) was taken immediately upon removal from the treadmill while the second (S_2) was taken 60 min following completion of the treadmill run. Comparisons were then made between the two groups for each sampling time of the clinical chemical indices of heat injury. It is apparent from the data that the vitamin C treated animals did not display any significant beneficial effects with respect to these indices of heat injury. In fact, mortality data (not included in the figure) indicate that the vitamin C treated animals were more severely affected by the heat injury. An indication of this is apparent in the lactic acid and potassium data, both of which we have reported as having prognostic value in determining the severity of heat injury.

In these and several other experiments utilizing vitamin C, we were unable to ascertain any physiologically beneficial effects of vitamin C pretreatment under these acute conditions.

In order to assess the extent of damage to critical tissues in heat-injured rats, we examined the high-energy phosphate content of heart, liver, kidney, and gastrocnemius muscle. In addition to the aforementioned reasons for selecting these compounds for close scrutiny, it should also be noted that these are the compounds which permit the transduction of chemical energy to heat and motion in living cells. Since carbohydrates and fats are oxidized in order to synthesize these high energy compounds, their levels in tissue can be reflective of a number of facets which are critical to proper cellular function: these include oxidative metabolism, electron-transport, glycogen and fat reserves, and enzyme levels. Thus, we hypothesized that in extremely hyperthermic and exhausted rats, levels of high-energy phosphate compounds could be useful in describing the etiology and mechanism of the heat injury as well as the resuscitative therapeutic regimens.

Thus, rats were exercised under the conditions previously described, and four treatment groups were established. In addition to a sedentary, control group, a second group of animals was sacrificed immediately upon completion of the treadmill run; thus, these animals were sacrificed at exhaustion with Tre of at least 42.5°C. A third group of animals was removed from the environmental chamber (35°C) to a moderate ambient temperature (22°C) and infused over a period of 40 min with 1.5 ml of physiological saline. We had previously demonstrated (1) the beneficial effects of this fluid therapy. Twenty minutes following completion of the infusion (60 min following completion of the treadmill run) these rats were sacrificed. A fourth and final group of animals was closely observed following completion of the treadmill run at an ambient temperature of 35°C.

When these rats were entering their terminal phase as a result of the heat injury (unconsciousness, abdominal respirations, convulsions), they were sacrificed. Upon sacrifice, heart, liver, kidney, and gastrocnemius muscle were quickly extricated from animals in each of the four groups. These tissues were rapidly frozen, and stored deep frozen for subsequent analysis of tissue constituents.

The results of these studies, which were somewhat surprising in several respects, are summarized in Figs. 3-5.

Initially, in the heart, kidney, left lateral lobe of the liver, and gastrocnemius muscle taken from animals immediately upon temination of the treadmill run, levels of glucose-6-phosphate (G-6-P), adenosine triphosphate (ATP), and creatine phosphate (CP) were unchanged when compared with sedentary controls. We had anticipated that the combination of fatigue/hyperthermia might have caused decrements in levels of high energy phosphates in critical tissues. In animals which had been resuscitated by infusion of isotonic saline into a jugular catheter, levels of CP were significantly elevated in gastrocnemius muscle (Fig. 5). In animals which were unconscious and succumbing to the effects of hyperthermic injury, levels of hepatic G-6-P and ATP were significantly reduced (Figs. 3,4). Several interesting conclusions are possible from the results of these studies: hyperthermic exhaustion does not occur as a result of metabolic deficiencies resulting in depletion of high energy compounds in critical tissues; of the tissues studies liver appears to be the most severely affected by the extreme hyperthermia; resuscitation by fluid administration results in excessive repletion of creatine phosphate in leg muscle; efflux of tissue constituents upon completion of the treadmill run does not occur as a result of membrane permeability changes secondary to a depletion of high energy phosphates in critical tissues.

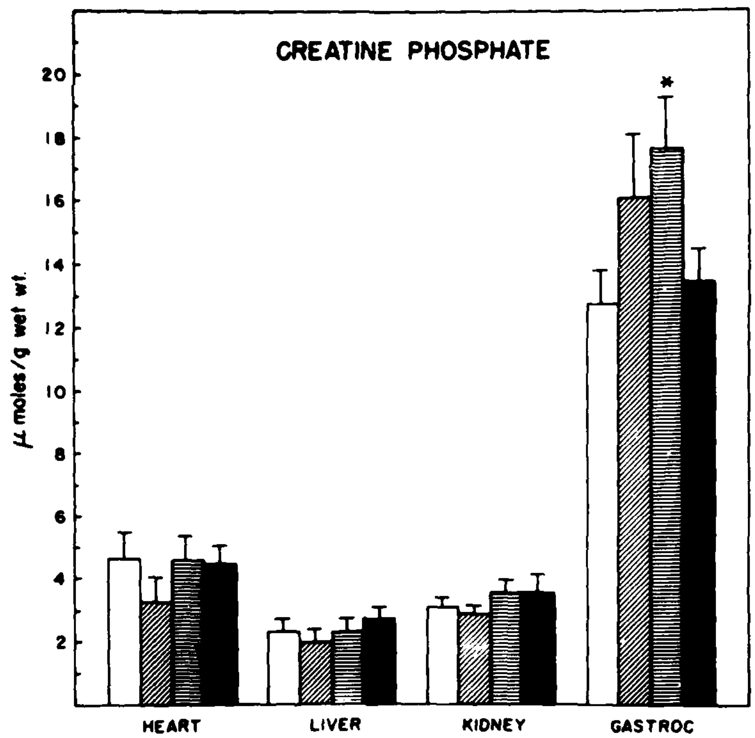

Fig. 4. Effects of hyperthermia/exhaustion on adenosine triphosphate levels in selected tissues of control and experimental rats. The asterisk represents significant differences from control levels ($p < .02$). All other conditions are as noted in Fig. 3.

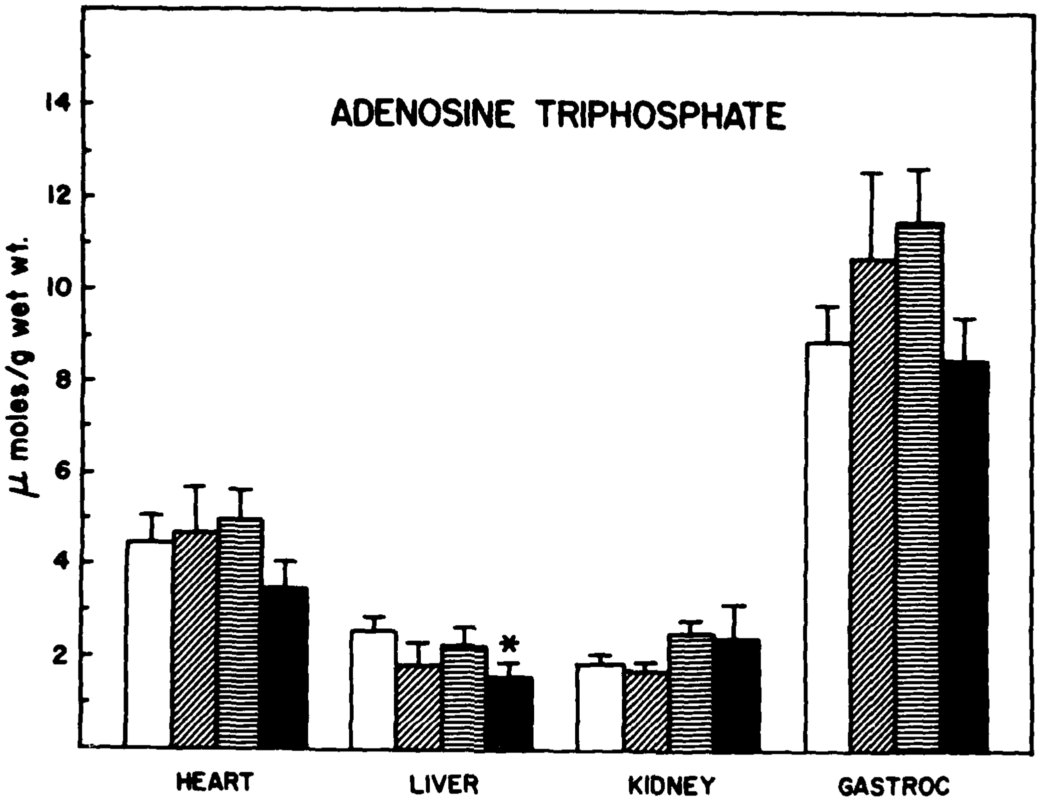

Fig. 5. Effects of hyperthermia/exhaustion on the creatine phosphate levels in selected tissues of control and experimental rats. The asterisk denotes significant differences from control levels ($p < .025$). All other conditions are as noted in Fig. 3.

Future Plans:

Research involving the pathophysiology and pathochemistry of heat injury will be continued to obtain information pertinent to the effective diagnosis, prevention, and treatment of heat injuries. Research aimed at reducing the physiological cost of heavy exercise in severe heat will also receive further attention because such information will permit increased physical performance with reduced risk of heat exhaustion or heat stroke.

Presentations:

Francesconi, Ralph P. and Milton Mager. Heat injured rats: Pathochemical correlates and survival time. Presented at the Annual Meeting of the Federation of American Societies for Experimental Biology, Atlantic City, New Jersey, 1978. (Fed. Proc. 37, 428, 1978).

Publications:

Francesconi, R. P. and M. Mager. Heat injured rats: Pathochemical indices and survival time. J. Appl. Physiol. 45:1-6, 1978.

LITERATURE CITED

1. Francesconi, R. P. and M. Mager. Heat injured rats: pathochemical indices and survival time. J. Appl. Physiol. 45:1-6, 1978.

2. Francesconi, R. P., J. T. Maher, G. D. Bynum and J. W. Mason. Recurrent heat exposure: enzymatic responses in resting and exercising men. J. Appl. Physiol. 43:308-311, 1977.

3. Francesconi, R. P., J. T. Maher, G. D. Bynum and J. W. Mason. Hormonal responses of sedentary and exercising men to recurrent heat exposure. Aviation, Space, Environ. Med. 49:1102-1106, 1978.

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TABLE 1

Effects of Vitamin C Pretreatment on the Clinical Chemical Indices of Heat Injury in Exercised Rats

	CREATINE PHOSPHOKINASE IU/L		LACTIC ACID MG/DL		BLOOD UREA NITROGEN MG/DL		CREATININE MG/DL		POTASSIUM MEQ/L		HEMATOCRIT PERCENT RBC	
	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
VITAMIN C TREATED												
$\bar{X}$	192.4	207.2	40.6	59.7	19.7	26.7	.82	1.04	7.2	10.2	41.4	45.8
SD_x	77.2	41.0	22.2	36.1	3.3	2.6	.13	.17	1.2	3.2	1.5	5.8
SE_x	34.5	18.3	9.9	16.1	1.6	1.1	.06	.07	.6	1.4	.7	2.6
CONTROL												
$\bar{X}$	301.2	265.5	30.6	35.3	18.9	25.4	.86	1.25	6.8	7.0	41.8	43.3
SD_x	266.8	138.7	15.2	10.8	5.2	4.0	.11	.17	1.4	2.3	3.8	4.4
SE_x	119.3	69	6.8	5.4	2.3	2.0	.05	.09	.6	1.1	1.7	2.2
T	.87	.91	.83	1.29	.45	.62	.51	1.84	.53	1.69	.22	.72
P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	005 Models of Heat Disabilities: Preventive Measures
Study Title:	The Role of Heat Acclimatization in Preventing Heat Stroke Mortality
Investigators:	Roger W. Hubbard, Ph.D., Wilbert Bowers, Ph.D. and Milton Mager, Ph.D.

Background:

The environmental stress imposed on the soldier by high ambient temperatures is translated into a physiological strain primarily on his cardiovascular system which is responsible for the transfer of excess heat from the body core to the skin. Recent evidence derived from our rat heatstroke model (1,2,3,4) indicates that under environmental conditions designed to produce sustained elevations in the body temperature at rest (sedentary hyperthermia), both heatstroke injury and death could result. The incidence of heatstroke mortality, as measured by the number of animals that fail to survive 24 h following a hyperthermia episode, is related to both the time and intensity of body core temperature. Similar results were obtained for the incidence of cellular injury defined as serum transaminase activity (SGPT and SGOT) exceeding 1000 IU/L. In contrast, exertion-induced hyperthermia produced a significantly higher incidence of cellular injury and heatstroke death at lower core temperatures than hyperthermia alone. One hypothetical explanation for this result is the possibility that exhaustive physical exercise, by worsening circulatory collapse and metabolic acidosis, predisposes tissue to hyperthermic injury. In this regard, we have recently reported that in the rat prehydration and volume replacement during acute, sedentary hyperthermia was remarkably successful in reducing heatstroke mortality within 24 h, post experimentation (5). These results raise the question to what degree this protection could be induced by acclimatization procedures thought to increase circulating plasma volume.

Over two hundred years ago, Lind (6) emphasized that habituation or natural acclimatization to hot environments reduced the risk of heat injury. In the early

1960's, researchers from this laboratory reported that many of the benefits of natural acclimatization could be achieved artifically by short (100 min), daily exposures to exercise in the heat (7). The resultant physiological changes or adaptations to high ambient temperatures are often referred to as "indices" of heat acclimatization and include, in response to successive exposures, a progressive reduction of core temperature and pulse rate with a concomitant increase in the amount of sweat produced. For obvious reasons, the benefits of this human acclimatization process in preventing or forestalling severe heat injury have not been experimentally defined. By developing a rat heat stroke model, and at the same time, by defining the many similarities between human and animal heat injury syndromes (1,2,3,4), we are now in a position to more credibly define the degree to which an artificial acclimatization process can prevent or forestall serious heat disorders.

<u>Progress:</u>

Prior to combining the stresses of both heat and physical exercise, a preliminary investigation was conducted to measure the acclimatization response of 34 fed unanesthetized laboratory rats weighing approximately 500g. The experimental animals (n=21) were restrained for five successive days in an environmental chamber at 41.5°C ambient until a t core of 40.4°C was achieved. Controls (n=13) were treated similarly, but were restrained at 26°C ambient without resultant hyperthermia. Following a 24 h fast, designed to reduce any subtle hormonal or nutritional differences between animals, all rats were restrained at 41.5°C ambient until a hyperthermic exposure equivalent to an LD75 (59 deg-min) was achieved. At this point, rats were removed from the heat and were monitored at 26°C ambient while resting in plastic cages lined with wood shavings. After recovery animals were returned to their cages (26°C) and allowed water but no food for 24 h. All rats alive after 24 h were counted as survivors.

The results are shown in Table 1. The prior heat exposure of the experimental group resulted in a significant reduction in the core heating rate when re-exposed to 41.5°C ambient. As a consequence, the heating time to reach a hyperthermic area equivalent to an LD75 was significantly prolonged. In spite of the longer exposure at 41.5°C, the maximum core temperature of the experimental group was significantly lower than that of the controls (42.0 ± 0.4 vs 42.5 ± 0.4). Since the experimental animals, despite longer exposure, had a substantially lower rate of heatstroke mortality (33 vs 85%), future research on the use of the laboratory rat as a model for the heat acclimatization process and its role in reducing the risk of heatstroke appears promising.

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TABLE I

HEAT STRESS/ACCLIMATIZATION

	n	Total Area[1]	Max T_c	% Mort.	Heating Time	Heating Rate	Cooling Rate	E.O.H. H.R.	E.O.H. HCT.	E.O.H. PROT.
Experimentals	21	57.3 ±8.0 LD 75.9	42.0 ±0.4 LD 2.5	7/21 33%	82 ± 30	0.06 ±.02	0.11 ±.03	512 ± 56	47 ± 4	7.5 ± 0.7
Controls	13	57.1 ±9.1 LD 75.0	42.5* ±0.4 LD 62.0	11/13 85%	61* ±18	0.09* ±.03	0.10 ±.02	527 ± 55	49 ± 1	7.2 ± 0.5

[1] Core temperature was measured at 2 to 6 minute intervals and thermal area was calculated when core temperature exceeded 40.4°C using the formula thermal area (deg.min) ≈ ∑ time interval (2 to 6 min) x 1/2 °C above 40.4°C at start of interval + °C above 40.4°C at end of interval.

* $p < 0.5$ for student t test between the mean ± S.D. and the mean immediately above it.

(82009)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY		1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
		DA OB 6120	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	009
b. CONTRIBUTING				
XXXXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)

(U)Biological Processes that Limit Heavy Physical Work Ability of the Soldier (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS

012900 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
70 07	CONT	DA	C. In-House

17. CONTRACT GRANT

a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER: NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	1.8	26
	CURRENT 79	10	247

19. RESPONSIBLE DOD ORGANIZATION

NAME: USA RSCH INST OF ENV MED

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TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME: VOGEL, James A., Ph.D.

TELEPHONE: 955-2800

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: PATTON, John F., Ph.D.

NAME: 955-2879 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)High Intensity Exercise; (U)Anaerobic Work Capacity; (U)Anaerobic Metabolism; (U)Muscle Contraction

23. TECHNICAL OBJECTIVE. 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)The combat soldier often depends upon his ability to perform sustained and sometimes severe levels of muscular exertion. The objectives of this research are to a) identify and characterize those biological processes that influence his capacity to perform heavy work, thereby providing a rational basis for improving the soldier's performance; and b) identify the physiological and biochemical processes that occur during physical training both at the whole body and muscle level, thereby providing a rational basis for improving physical training programs.

24. (U)Specific areas of study will include: (1) Anaerobic metabolism during high intensity exercise; (2) Measures of anaerobic power/fitness; (3) Develop training methods for anaerobic fitness; and (4) Biochemical and morphologic changes in skeletal muscle during training of various intensities and frequency.

25. (U)77 10 - 78 09 A specialized high intensity bicycle ergometer has been constructed for the purpose of measuring anaerobic power capacity of human subjects. Operational check-out and calibration is underway. Data collection will begin on 1 October 1978.

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*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	009 Biological Processes that Limit Heavy Physical Work Ability of the Soldier
Study Title:	Anaerobic Power Production as a Component of Physical Fitness
Investigators:	Howard G. Knuttgen, Ph.D. and James A. Vogel, Ph.D. with the Technical Assistance of Michael J. Sacco

Background:

Physiological responses and adaptations to muscular exercise have been extensively studied during the past half century. Exercise itself has been studied as an important phase of human performance while various forms of exercise have been employed in the study of basic physiological mechanisms. Considerable attention has been given to maximal voluntary contraction (MVC) of muscle groups and the development of strength. Also, numerous investigations of large muscle activity that could be supported completely by aerobic metabolism have been published, including such activities as cycling, walking, running, and cranking. The exercise intensities studied in these activities rarely involve forces of contraction of the individual muscles involved in excess of 30% of MVC.

It has not been possible to study the full range of intensities of large muscle activity in humans because of the unavailability of ergometers that: (a) can provide resistances adequate to cover all exercise intensities of which a person is capable and (b) possess the feature of power production for the study of exercise both with concentric and eccentric muscle contractions.

Concentric contraction exercise in human exercise performance is characterized as involving mostly shortening contractions of the active musculature, movement of the skeletal parts to which the muscles are attached closer together, and production of external work on an ergometer. Exercise with predominantly eccentric contractions involves most of the active musculature being subjected to forcible stretch, the bony attachments of the muscles being moved further apart, and work being performed by the ergometer on the subject.

Ergometers presently available for the study of human performance in cycling or cranking can produce conditions of exercise involving repetitive contractions approximating up to 20-30% of the MVC in the concentric condition of the muscle groups involved.

The objectives of this study are: (1) the design and construction of a new ergometer with special capabilities; (2) the establishment of ergometer test-retest reliability for a full range of exercise intensities; and (3) the development of a theoretical model on which to base further study of capacities for anaerobic power production and high intensity exercise.

Progress:

The ergometer that was developed was designed to enable research involving exercise with both concentric and eccentric contractions at a full range of exercise, including the very highest intensities of which humans are capable under either condition. The type of exercise selected was that of leg cycling with the option of having the subject either seated on a saddle above the pedals (as in bicycling) or seated in an armchair behind the pedals and crankshaft (see Figure 1). The pedal crankshaft (A) of the ergometer is driven by an electric motor (B). Exercise is performed with the legs as the subject either causes the motor to run at a higher rpm than the motor attempts to establish (for concentric contraction exercise) or by resisting the motor and causing it to run at a lower rpm (for eccentric contraction exercise). The power necessary to alter the rpm by a predetermined amount is established prior to an experiment and provides the exercise intensity for either condition.

The drive system employed is an ES-200ARG (WER Industrial, Grand Island, NY) and includes a static DC regenerative motor control (model ES220RG) and a D.C. shunt-field drive motor with a capacity for 3730 W (5 horsepower).

For a concentric exercise experiment, a forward mode and decelerate mode are employed. The selector for speed/torque is set initially for speed and the control system maintains the motor (and pedal axel) at the speed indicated on the speed potentiometer. The subject is provided with an audible metronome run in time with the pedal axel (e.g., 60 rpm) and/or a meter displaying the actual rpm. The subject's feet are fastened to the pedals and the motor started. The subject initially follows the pedals around passively at the established rpm with no attempt at active cycling.

The torque potentiometer would be set at the level of power eventually desired for the concentric exercise. When the speed/torque switch is changed to torque mode, the control causes the motor to decelerate to exactly 10% of the original speed. The subject is required to commence exercise at this same instant by cycling in time with the metronome so as to maintain the original speed exactly. In order to do this, the subject must produce the amount of power present on the torque potentiometer.

For an eccentric exercise experiment, reverse mode and accelerate mode are selected. The pedals are driven in the direction of the subject as they complete the upper arc of each rotation. When the change from speed to torque mode is made, the control causes the motor to accelerate to 10% faster than the initial speed. The subject resists the acceleration, maintains the initial speed by cycling to the metronome, and receives the power level preset on the torque potentiometer.

The practical limits for the speed the ergometer can establish for the subject as pedal axel rpm in both concentric and eccentric exercise are 10-120 rpm. The limits to power level are at 10-1,500 W. Experiments to provide both mechanical and biological calibration of the ergometer are presently in progress. For mechanical calibration, functional resistance is provided over the flywheel by a belt attached to an electronic force transducer. Biological calibration is being provided by the comparison of physiological responses of human subjects on the new ergometer with data obtained from experiments performed with ergometers in common laboratory use.

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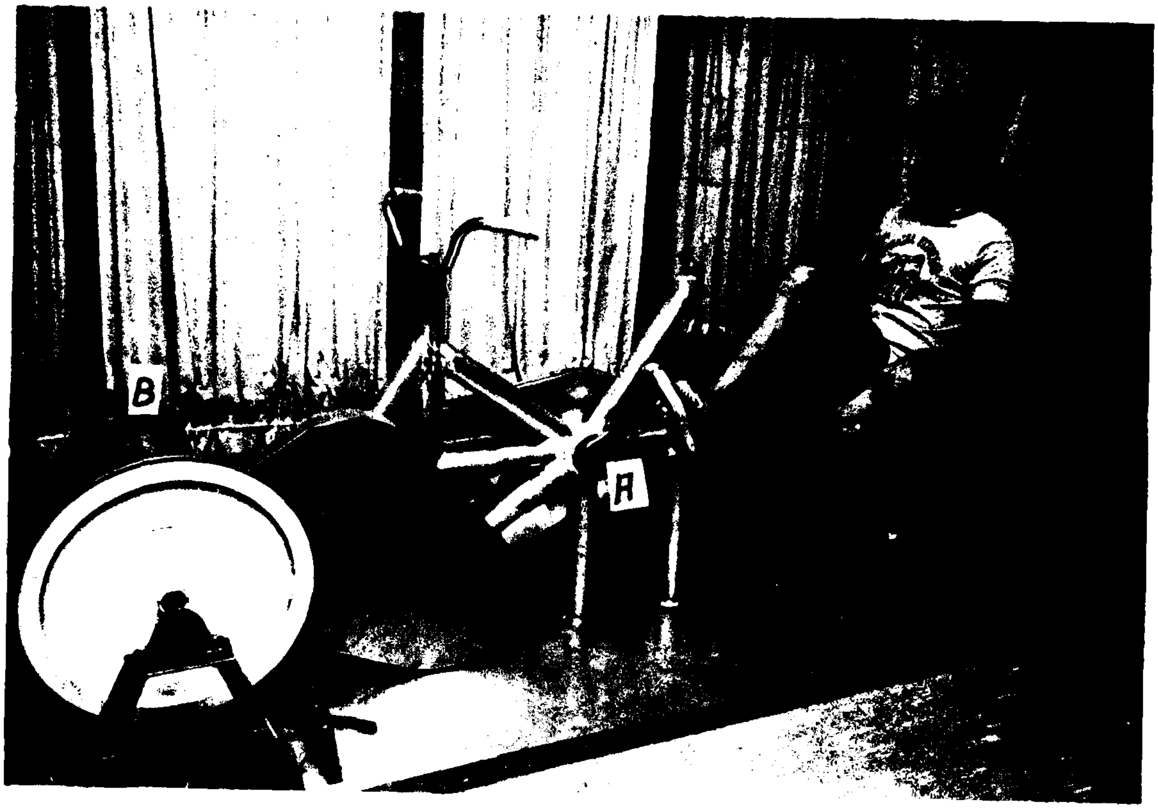

Figure 1. High intensity (anaerobic) capacity bicycle ergometer

(82011)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OC 6122	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	N/A	N/L	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	011
b. CONTRIBUTING				
XXXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)*
(U) Assessment of the Impact of the Environment on Military Performance (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
013400 Psychology; 005900 Environmental Biology; 002300 Biochemistry;012900 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 11	CONT	DA	

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	3.8	231
	CURRENT 79	8	259

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
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RESPONSIBLE INDIVIDUAL
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TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* KOBRICK, John L., Ph.D.
TELEPHONE: 955-2855
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: FINE, Bernard J., Ph.D., 955-2874
NAME: STOKES, James W., LTC, MC, 955-2822 DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Human Performance in Heat;(U)Human Performance in Cold;(U)Human Performance at Altitude;(U)Sustained Human Performance

23. TECHNICAL OBJECTIVE.* 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Prior to the development of frank casualties in situations involving extreme environments, prodromal symptoms occur which lead to performance deficiencies. The objective of this project is to develop a methodology to identify and analyze the principal military task components and personal characteristics of individual soldiers which are particularly influenced by exposure to extremes of heat, cold, and altitude, and by difficult and/or extended operations, and thereby affect the efficiency of functioning military systems.

24. (U) The methodology embodies high face validity - use of real military systems; actual military equipment and procedures; precise definition and measurement of tasks; systematic manipulation of environmental exposures and operational conditions; and, predictive validity - ability to generalize findings to actual Army operational field situations.

25. (U) 77 10 - 78 09 Data analysis is underway with a completed study of heat-humidity exposure (105^{o}F, 40% RH, E.T. 88^{o}) on selected artillery fire direction center tasks (fire mission calculations, message decoding, map target plotting, range calculation) following a 15-hour simulated rapid translocation flight. Data collection has been completed in a study of effects of illumination levels on color discrimination sensitivity. Methodology is being developed for laboratory simulation and measurements of aspects of performance of the artillery forward observer, including target detection, identification, and location, range and deflection estimation, and adjusting fire.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

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Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	011 Assessment of the Impact of the Environment on Military Performance
Study Title:	Development of Methodology for and Analysis of Selected Cognitive and Perceptual Tasks by the Artillery Forward Observer
Investigators:	Bernard J. Fine, Ph.D. and John L. Kobrick, Ph.D.

Background:

The most important source of guidance information for the artillery fire direction center (FDC) regarding present and potential targets is the artillery forward observer (FO). The FO establishes direct visual contact with a target, relays information about its nature and position to the FDC, and estimates corrections about the placement of successive artillery rounds until the mission ends.

Fine and Kobrick (4) have shown that FDC task elements can be adversely affected by environmental stressors. The FO may be even more vulnerable to such stressors since he is more directly exposed. Since FDC accuracy is critically dependent on information supplied by the FO, environmentally-induced errors in FO performance can have disastrous consequences. The purpose of this study is to develop a methodology to determine critical perceptual and cognitive factors involved in FO performance, and to study related effects of exposure to a hot-wet environment.

The duties of the FO, which are usually performed in a free-ranging open system, present a number of problems for simulation within the laboratory setting required for accurate control of environmental stress factors. This requirement necessitates the development of unique instrumentation and methodology. The FO performs very complex procedures involving target detection and identification, communication, distance estimation, geographic orientation, map usage, and the integration of complicated strategic and tactical concepts. Since all of the tasks performed by the FO could not be included in one study, the following tasks were selected for investigation, based on their seeming importance, and the feasibility of simulating them under laboratory conditions within the practical limits of available state-of-the-art devices.

Progress:

Methodologies have been conceptualized, and are being developed for administration and analysis of each of the selected FO tasks listed below. Regarding target detection-identification and distance estimation, the FO operates by direct visual contact with the terrain, and must identify targets against complex backgrounds. Very little research has been done to relate factors in the visual search process to individual differences in perceptual ability, particularly as they are influenced by environmental factors. The limited research points to interactions between individual differences and environment. For example, Fine and Kobrick (3) found significant relationships between field dependence-independence and visual target detection at sea level and at altitude, and Fine and Witherspoon (5) found apparent effects of heat on target detection.

The FO must also be able to accurately estimate distance to the target both from his own position and from the visible impact points of artillery rounds. Distance judgment is a complex process consisting of absolute and relative judgment (8). No studies have been done to examine individual differences in distance judgment as influenced by environmental stress.

In this study, the FO will monitor a large projection screen using binoculars, the combination of which provides a very realistic viewing scene. A semi-wooded landscape containing a fairly large number of buildings will be projected on the screen. From this view, the FO will plot certain reference points and his own position on a sector map of the area, and will determine distances from his position to various landmarks or buildings. He will also monitor the screen for potential targets, which will periodically appear on the screen. Instrumentation has been designed and is under development to present stereoscopic terrain scenes which can be precisely alternated and overlapped so as to fade in and fade out selected targets without a discernible alteration of the scene. The FO will identify each target, plot its location, determine the range, and will call in to a simulated FDC for a shot at the estimated location, using appropriate FO procedures. Following an interval of travel time for the round, a simulated hit indicated by a light flash will be projected on the screen at the location on the scene called by the FO. The light flash will be accurately adjustable by an optical system for vertical and horizontal position on the screen and for proportionate size to correspond to its equivalent real-world size and distance. The FO will continue to correct successive rounds until the target is hit (shot landing within 50 meters). The FO's calculations, messages, and search patterns will be recorded for analysis.

With respect to target detection and recognition at low ambient illumination, since many military operations are conducted at twilight or at night to minimize detection, the FO must be able to detect and recognize enemy targets at low illumination levels. Although hypoxia is known to impair dark adaptation (10,11,12), the data are based on detection of light flashes. Effects of environmental stress on resolution and judgment of complex meaningful military targets is unknown. The present task will determine the threshold luminance function for detection and recognition of selected military targets as a function of viewing distance.

The subjects will view a series of projected slides of military target objects (vehicles and personnel) such that the images subtended at the retina will duplicate real-life image sizes for three viewing distances (60, 90, 120 yards). Each subject will adjust the image brightness by manipulating a variable density filter to achieve the threshold brightness for detection and for recognition for each target and viewing distance condition.

An additional FO task is compensatory tracking. Current infantry-based weapon systems (TOW, Dragon, Stinger, Copperhead, HELLFIRE) are based on the concept of an observer maintaining visual contact with a target and directing a missile to it after launch from a rear area. The influence of environmental stress exposure on the compensatory tracking performance involved in such missile guidance has not been studied. In this task, the observer will monitor an irregular sinusoidally-moving target on a CRT screen, and will make adjustments using a joystick control to attempt to keep the target on the center reticle lines of the screen. Following training to an asymptotic level of performance, two-minute trials will be conducted on each subject intermittently throughout the day during both normal and environmental stress conditions. Both the input signal and the subjects' compensatory adjustments will be recorded separately but time-related on tape, and later computer-analyzed for horizontal and vertical error components, and for phase differences.

Another required FO task is color discrimination. The ability to distinguish between shades of color is involved in many of the activities performed by the FO. Map reading requires sensitive distinctions between shades of pastels which are used to designate areas. Contour lines are printed in tan and brown, rather than black. This may result in reduced functional legibility at low light levels, when tactical enemy operations are likely to occur. Another problem for the FO is to distinguish camouflaged objects, which are concealed basically by reduction of their outlines and contrast by manipulation of shades of color. Detection of camouflaged objects should be similarly reduced at low light levels. Selective sensitivity for hues is well understood (7). Yellow (530 mu) is most visible at high to moderate illumination, and hue sensitivity shifts toward the blue wave lengths of the visible spectrum as illumination is reduced. However, there is very little information on effects of environmental stress on color sensitivity across a range of ambient illumination. Kobrick (9) showed reduced color sensitivity zones in the visual field during hypoxia exposure. Others have demonstrated reductions in color saturation thresholds (13), and reductions in color sensation threshold (6), due also to hypoxia exposure. Fine (2) has shown highly significant and replicable differences between field-independent and field-dependent persons in discriminating colors at sea level.

Subjects will be tested repeatedly on the Munsell-Farnsworth 100-Hue Color Discrimination Test, which is widely used in the paint and textile industries to select dyers, color batch testers, tinters, etc. The test will be administered not only at customarily used lighting conditions (100 watts, incandescent), but also under reduced illumination (60, 40, 25 watts, incandescent).

A very important requirement for the FO is vigilance. He must remain alert for extended periods of time during lulls in combat. Considerable reductions in alertness over time have been shown for normal ambient conditions but little has been done to study it under heat or hypoxia exposure. During a two-hour vigilance task, Fine (1) found that field-dependent introverts made significantly more errors of omission than did field-independent introverts or extraverts of either type. Four subjects fell asleep during the tasks; all were field-dependent introverts. The same task will be used in the present study to replicate the findings, and to investigate the effects of heat and altitude stress. Subjects will monitor a display of symbols representing friendly and hostile objects, which will appear on a 24" CRT in 12-second bursts, separated by 1-sec. blank intervals. Each display will either be identical to the previous one, a rearrangement of previous symbols into a new configuration, an unknown new symbol embedded in a previous configuration, or an unknown symbol in a new configuration. The unknown will appear at random interals ranging from 1 sec. to over 3 min. The task will be divided into 6 identical 20-min. segments, during each of which the unknown will appear 12 times. The task will be to monitor the display continuously and to press a button each time an unknown is detected. Response times will be recorded, and errors of omission and commission tallied. Methodology is being developed for computer-controlled presentation of the stimuli and recording of the responses.

Finally, perceptual-motor coordination will be evaluated. Eye-hand coordination is a complex sensory interaction which is a basic component of a great many activities performed by soldiers. It is a major factor in operation of laser-mediated infantry-based weapon systems which involve rear-echelon fired guided missiles. Individual differences in this ability are very large and research evidence suggests that heat and altitude exposures could produce highly significant impairments in the performance of some individuals. In this study, targets will be employed which move at random and at various speeds. Three tasks will be used in which the subject will attempt to hit moving targets with a hand-held control device which can position, aim, and fire electronically represented projectiles on a video screen. The subjects will perform individually, competing against their own scores.

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Program Elements:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	*011 Assessment of the Impact of the Environment on* Military Performance
Study Title:	Effects of Simulated Rapid Translocation and Heat Exposure on Artillery Fire Direction Center Tasks
Investigators:	Bernard J. Fine, Ph.D. and John L. Kobrick, Ph.D.

Background:

This study evolved from research previously reported under the title "The Separate Effects of Altitude and Heat on Sustained Performance of Simulated Artillery Fire Direction Center Tasks." It extends the previous work into the area of rapid translocation.

The effect on human behavior of rapid translocation over long distances and several time zones has been a source of serious concern since the advent of high-speed air travel. Significant physiological changes and disruptions of circadian rhythms have been documented in animal research (4), and with humans (5,6,7,8,10,11). Psychological and performance changes have also been reported, although only a few such studies have been done. Klein, et al. (10) showed that the flying efficiency of experienced pilots in supersonic flight simulation tests was significantly reduced (8.5%) following an actual eastward flight to Europe from the U.S. A similar westward trip produced only slight impairment. Performance disruption consisted mainly of deviation off course and reduced ability to respond to sudden changes in flight patterns. The authors attributed the performance impairments to "greater fatigue due to an unfavorable flight schedule and the more severe sleep loss connected with eastward travelling."

These results disagree with three studies by Hauty and Adams (5,6,7) who found no changes in simple reaction time, simple decision-making or critical flicker fusion threshold following translocation in any direction. However, Klein, et al., attributed this to the "low demand character" (too easy) of the Hauty and Adams tasks.

Klein, Wegman and Hunt (11) found performance decrements (6-10%) in several psychomotor tasks following eastbound flight from the U.S. to Germany. In general, the more complex tasks showed greater disruption than did the simple ones, and eastward travel produced the greatest impairments. Disturbances in physiological circadian rhythms were accompanying factors.

There is general agreement that travel across a minimum of four time zones is required to produce the impairments observed. Fatigue produced by the travel conditions and the disruption of customary sleep patterns are considered to be the principal causative factors.

The effects noted above may be a serious practical problem in military situations where airborne or Special Forces personnel will be expected to be operational directly after a long-distance airlift to a tactical situation. If the tactical situation is located in an extreme natural environment (e.g., heat, cold, high altitude), combined effects of translocation and environmental stress may produce even greater impairments in performance than would the environment alone.

Although a number of military and government agencies have been interested in the translocation problem, there has been little or no objective investigation of these effects on actual military performance (9). One of the major problems in this research has been the lack of a reliable methodology for quantitatively measuring valid military performance tasks. Another problem is the difficulty of maintaining controlled environmental testing conditions. Without these capabilities, the quantification of impairments in military performance relative to typical (normal) baseline performance cannot be achieved, nor can the separate effects of translocation and environmental stress be identified. The performance model which we have developed based on artillery Fire Direction Center (FDC) tasks achieves these requirements and, also, has been shown to be sensitive to the effects of environmental exposure, such as would be experienced in a tactical operation (1). Most important, the model will allow quantitative assessment of the resulting performance impairments which may occur. The study described here is an attempt to use the model in a simulation of rapid translocation from a temperate climate to a hot-dry climate. It focuses on the immediate effects rather than on the changes in circadian rhythms which occur somewhat later, and on the fatigue effects, rather than on schedule changes induced by changing time zones.

Progress:

The design of the study involved four groups of six subjects each. Each group, separately, was given two weeks of intensive training on three selected FDC-type tasks; (1) fire missions, involving the reception and notation of range, elevation, and adjustment data relevant to hypothetical targets, and the calculation of site, a factor involved in vertical alignment of the guns, requiring the use of a graphical site table, a slide rule device used by FDC personnel; (2) reception, notation and decoding of map grid coordinates using an Army code wheel device; (3) reception, notation and decoding of encoded military-type messages using a typical Army operations code book. The subjects were also trained in and practiced on map target plotting and measurement of battery-to-target range using the artillery's range-deflection protractor. A number of personality and other "individual difference" measures were administered during the training phase.

All four tasks were then performed on four consecutive days under both control and stress conditions. The schedule provided for counterbalancing the simulated air translocation experience with an equivalent control condition involving residence in a dormitory. Groups 1 and 3 experienced the heat stress-plus-translocation condition prior to the heat stress-plus-dormitory condition. Groups 2 and 4 were exposed to the stressors in the reverse order. All groups were tested on the day before each stress exposure under control (normal) conditions. The design did not permit evaluation of a translocation effect apart from heat stress, since the primary purpose of the study was to determine the extent to which the additional stress of translocation affected performance in the heat.

The translocation phase was simulated by the use of a small environmental chamber, at sea level, which was stripped of all conveniences. A wooden bench was the only seating provided. Ss slept on the bare metal floor, in their uniforms. They were provided with one blanket and no pillows. Toilet facilities were available in the chamber. Food was provided as would be obtained on a military aircraft. Flight noise was simulated by quadraphonic play-back of a tape recording of the noise spectrum generated inside the cargo deck of a C-130 aircraft while the aircraft was in operation, including take-off, inflight and landing noise. The duration of the "flight" was 15 hours. The loudness level of the flight noise was 88 $\pm$ 2 db, measured at the speakers.

When the aircraft "landed" at the end of the flight, the Ss immediately entered an adjacent chamber set at 105°F, 40% R.H. (effective temperature = 88°F) and began to perform their artillery-related tasks.

They were exposed to the stress condition for seven hours and performed the FDC tasks during hour 1,3,5 and 7. The fourth hour was for lunch. During the second and sixth hours of each day, the Ss were tested individually for about 20 minutes each on several "basic" psychological dimensions thought to be related to important military tasks. These dimensions included reaction time, abstract thinking, and time estimation.

No significant differences were found between the heat or heat-plus-translocation conditions and their respective control conditions. It was apparent from comparisons with previous studies that, despite the high dry-bulb temperature (105°F), the hot environment was not stressful enough to produce significant decrements within the seven hour exposure period.

We have previously noted, in comparing our two previous studies which used the FDC tasks model, that humidity appeared to be a very critical factor in causing performance decrements within a seven hour exposure period. The first study (95°F, 88% R.H., ET 92°) resulted in much larger performance decrements than the second study (97°F, 73% R.H., ET 89.5°) although both were well over the ET of 86 noted by Grether (3) as being a cut-off point above which performance decrements occur in the heat. The present study had an ET of 88, also above the cut-off point noted above. The research literature is equivocal regarding the effect of humidity on performance, however. Our studies seem to implicate it to a much greater extent than heretofore demonstrated.

The addition of the simulated translocation stress to the heat stress did not result in any significant increase in performance decrements. We hypothesize that despite the seemingly difficult conditions of sleeping and resting on a steel floor, with minimal amenities, most subjects probably obtained a longer night's sleep than they typically get when on their own. Many subjects were observed going to "bed" at 1800 hours, after the evening meal, and slept through until the following morning. Future studies would do well to deprive Ss of rest and sleep for a period of time prior to the translocation, much as troops would be deprived if they were actually preparing for a departure 24 hours in the future. Decreased cabin pressure (usually equivalent to about 8000 ft) with resulting mild hypoxia and very low relative humidity could also be provided in the simulation.

Because there were no over-all statistically significant decrements in group performance does not mean that the stressors were ineffective on all subjects. As we have previously observed, the key to ultimately understanding the effect of stress on performance lies in understanding how different types of individuals respond to stress. Group averages are meaningless in terms of predicting a given individual's performance and frequently mask the fact that one-half of the Ss get worse and the other half improves in any given experiment.

In the Code Book task of the present study, for example, the distribution of error changes from control to heat condition is shown below for the 20 Ss (a + indicates an increase in the number of errors from control to heat condition):

+19	+12	+3	- 6
+18	+10	+2	- 7
+17	+ 7	0	- 9
+14	+ 5	0	-10
+13	+ 5	-2	-19

These figures yield a non-significant group average change of +3.6 errors from control to heat condition. Yet it is obvious from the above individual scores, that about 1/3 of the subjects show substantially larger increases in errors and about 1/3 actually showed improved performance. If one compares the performance of the upper vs the lower third of the above distribution, the top third showed an average improvement of 7.57 fewer errors in the heat, whereas the bottom third showed a decrement indicated by an average increase of 14.7 errors in the heat. The differences between the two thirds is highly significant by t-test ($t = 8.38$) and p-value associated with the difference is at $< .0001$ level. While the above statistical technique is not entirely a valid one, it is presented to show the magnitude of the difference between the extremes of the distribution and to reiterate our point that a group average sheds little light on the performance of the members of the group.

This type of finding is not unusual. It is our opinion that it happens in most research and that the concern for group averages nearly always masks the typically wide range of individual responses and leads to errorneous conclusions (2). It is this type of result, noted repeatedly in experiment after experiment, that motivates us to focus on individual differences in performance.

However, such an endeavor is extremely difficult in studies such as ours. Because of the small number of subjects used, a reasonable sample of different types of people is almost impossible to obtain in each study. Consequently, we are attempting to accumulate individual difference data across studies so as to build up a sufficiently large data base to enable valid comparisons to be made. This procedure is complicated by the fact that the conditions under which the studies are run change from study to study making direct comparisons of performance impossible.

From knowledge gained to date, we are now in a position to standardize our heat exposures over several studies in order to make the accumulation of data, by individual, possible. We are also starting a data analysis which will look at relative performance across the first three studies in an effort to determine those individual difference factors which appear to be involved, even though direct comparisons are not permissible.

Presentations:

Fine, B. J. and J. L. Kobrick. Human performance under climatic stress and the fallacy of the "average" soldier: potentially serious implications for military operations in extreme climates. Army Science Conference, West Point, NY, 1978.

Publications:

Fine, B. J. and J. L. Kobrick. Effects of altitude and heat on complex cognitive tasks. Human Factors. 20:115-122, 1978.

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1. Fine, B. J. and J. L. Kobrick. Effects of altitude and heat on complex cognitive tasks. Human Factors. 20:115-122, 1978.

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Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	011 Assessment of the Impact of the Environment on Military Performance
Study Title:	The Effect of Repeated Measurements and Reduced Illumination on Performance of the Farnsworth-Munsell 100 Hue Test
Investigators:	Bernard J. Fine, Ph.D. and John L. Kobrick, Ph.D.

Background:

The Farnsworth-Munsell 100-Hue Test (3) is one of the most widely used tests of color vision. It was designed to separate persons of normal color vision into classes of superior, average and low color discrimination ability and to measure zones of color confusion of color defective persons. The test is widely used in color control laboratories by manufacturers of dyes, plastics, textiles and paints as a color standard and to test personnel for various jobs requiring precise color judgment. It also is used clinically to aid in diagnosis of defective color vision, to monitor the progress of certain medical treatments which can affect color vision and to test for side effects of drugs. The military services use the test at times for screening of personnel for various jobs.

According to the instructions, the test typically is administered once, although it may be given twice for purposes of reliability. In clinical applications, however, it is sometimes necessary to administer the test repeatedly, as when monitoring a patient's progress with medication known to affect color vision over time.

Very little is known about the effect of repeated exposure to the test or responses to it. With this type of sensory measure, particularly in situations where the respondents are not informed of their scores, there has been little reason to suspect that a person's performance might change substantially over repeated trials.

However, Fine and Kobrick (5) administered the test ten times to a number of soldiers in an environmental stress study, in order to assess the effects of heat and altitude on color discrimination, and found a very substantial improvement in performance over the first five of six trials which were conducted under non-stressful conditions. In addition, they found that the improvement over the first four trials was due primarily to field-independent subjects. This result was consistent with that obtained in an earlier study by Fine (4) who found extremely large differences in color discrimination ability between subjects selected as extreme on the dimension of field-dependence-independence. (Field-dependence-independence is a personality dimension reflecting an individual's ability to perform perceptual tasks requiring abstract thinking.) In Fine's study, the test was administered only twice, but improvement was noted from first to second administration and was substantially accounted for by the field-independent subjects.

This apparent learning effect and its interaction with field-dependence have important implications for any application of the test requiring repeated administrations. In experiments on the effects of stress on color discrimination ability, with which we are involved, the stress effects may be negated by continued learning (improvement) of the subjects with each administration of the test, and the interaction between learning and field-dependence may introduce certain biases into the results. In clinical applications, the effectiveness of the test in monitoring changes in color vision over extended periods of time may be questionable, unless the test is given a sufficient number of times before treatment so that the patient can reach an asymptotic level of "control" performance.

In addition to the learning aspects, the study focuses on the effect of reduced illumination on color discrimination. This is an essential pre-test area since we plan to study stress-induced changes in color discrimination-related performance, e.g., map reading and target detection-identification, under varying degrees of illumination (dawn, mid-day, dusk). It is of great importance to determine beforehand the degree to which color discrimination and learning are affected by known decreases in illumination.

Progress:

The Hidden Shapes Test (1), the Maudsley Personality Inventory (2) and a personal history questionnaire were administered to 24 Ss at Fort Devens, MA. It had been planned to administer the tests to a much larger group, but due to a number of circumstances involving the commitment of troops to other activities and to a general lack of volunteers, only 24 Ss were available. The original design of the study called for selection of 12 field-dependent and 12 field-independent Ss from the initial volunteer group on the basis of the tests mentioned above. Since only 24 Ss volunteered, it was decided to proceed with them and to recruit additional Ss afterward, if needed, to fill out the field-dependent requirements.

Of the 24 Ss, 20 were able to proceed through the entire study. However, of the 20, only 2 were classifiable as field-independent. Efforts are now underway to recruit additional subjects to complete the design.

The design calls for each subject to be tested twice per day for five successive days. The two daily trails are successive with a five minute break between trials and take place at the same time each day, usually in the morning. The first five trials are conducted with 100 watts illumination. The sixth, seventh and ninth trials are conducted with either 25, 40 or 60 watts illumination, the order varying from subject to subject. The eighth and tenth trials are with 100 watt illumination, which is supplied through a Macbeth Easel Lamp (ADE-10) and a Corning Daylight Roundel Filter.

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(82012)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
	DA OD 6149	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	012
b. CONTRIBUTING				
c. XXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)

(U)Assessment of the Impact of Environmental Stressors on Systemic Hypotension (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS

012900 Physiology; 012600 Pharmacology; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER: NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	3.9	128
	CURRENT 79	2	25

19. RESPONSIBLE DOD ORGANIZATION

NAME: USA RSCH INST OF ENV MED

ADDRESS: Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

21. GENERAL USE

Foreign Intelligence Not Considered

20. PERFORMING ORGANIZATION

NAME: USA RSCH INST OF ENV MED

ADDRESS: Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME: HAMLET, Murray P., D.V.M.

TELEPHONE: 955-2865

SOCIAL SECURITY ACCOUNT NUMBER

ASSOCIATE INVESTIGATORS

NAME: ROBERTS, Donald E., Ph.D.

NAME: 955-2863 DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Altitude; (U)Hypoxia; (U)Heat; (U)Cold; (U)Disabilities; (U)Systemic Hypotension; (U)Treatment; (U)Hypothermia

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)The phase of systemic hypotension (shock) which receives the most investigative effort is the normovolemic period following volume replacement. If preceded by sufficient stress during the hypotensive phase the normovolemic phase progresses to "irreversible shock" and death. Current military concepts limit the initial stress to primary wound trauma. The degree to which environmental stressors (altitude, cold, heat) interact with traumatic injury and induce or accelerage irreversible shock has not been explored. Trauma of a usual non fatal nature may precipitate systemic hypotension given the environmental stressors under which combat troops fight and are evacuated. The purpose of this work unit is to expand our knowledge of the interaction of environmental stressors on the development and progression of shock.

24. (U)A hemorrhagic model of systemic hypotension will be developed and standardized in an animal model which will permit an investigation of the multitude of factors associated with "shock." The environmental stressors of altitude, cold, and heat will be applied to the animal model prior to and or during hemorrhagic shock to determine their impact on the post normovolemic phase. The information will be used in developing guidance for the prevention and treatment of shock in harsh environments.

25. (U)77 10 - 78 09 Selection of a suitable animal model for hypovolemic shock in heat and cold has proven to be more difficult than expected. The splenectimized dog is perhaps the most suitable. Questions on thermal regulation, absence of sweating need to be resolved. Anesthesia procedures also complicate the selection of a suitable model. Cooling rates during initial hypovolemia complicate anesthesia. Continuation of this work unit awaits assignment of investigators.

* Available to contractors upon originator's approval

DD FORM 1498, 1 MAR 68 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 012 Assessment of the Impact of Environmental Stressors on Systemic Hypotension

Study Title: The Effects of Systemic Hypotension and Hypothermia on the Cardiorespiratory Functions of the Swine

Investigators: Donald E. Roberts, Ph.D. and Ronald E. Jackson, MAJ, MC

Background:

Systemic hypotension (shock), whether hemorrhagic or neurogenic, is not an uncommon complication of combat or peacetime trauma. If promptly diagnosed and properly treated, the individual may be treated and returned to activity. If not treated, the individual may progress to a chronic hospitalization and/or death. Systemic hypotension may be complicated by existing environmental factors. High altitude operations place an individual in an hypoxic environment which may complicate the medical status of an individual with systemic hypotension. The peripheral vasodilation which accompanies the responses to a hot environment would be in opposition to the peripheral vasoconstriction necessary for the body's response to systemic hypotension. However, in cold environments, peripheral vasoconstriction may be potentiated by that which occurs as a result of shock and result in an increase in peripheral tissue cold injury. Also, decreased blood volume resulting from hemorrhage may result in an increased rate and depth of hypothermia. Initial efforts have been directed toward developing an appropriate animal shock model in which the effect of cold on the response to shock can be determined.

Progress:

Review of the literature indicates that the animal of choice is the swine. During the coming year preliminary work on the development of the animal model will proceed, and subsequently, the effects of hypothermia on systemic hypotension will be evaluated. Preliminary work planned for this year will include problems with anesthesia and respiratory function before acceptance of the swine model.

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
				DA OB 6143	78 10 01	DD DR&E(AR)636
3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS / 9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO / A. WORK UNIT

10. NO./CODES	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	013
b. CONTRIBUTING				
c. XXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)

(U) Models of Heat Disability: Predisposing Factors (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS

016200 Stress Physiology; 013400 Psychology; 003500 Clinical Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER: NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	3.8	165
	CURRENT 79	4.5	134

19. RESPONSIBLE DOD ORGANIZATION

NAME: USA RSCH INST OF ENV MED

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SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: HUBBARD, Roger, Ph.D.

NAME: FRANCESCONI, Ralph P., Ph.D. DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Heat Stress; (U)Heat Disabilities; (U)Body Temperature; (U)Military Disabilities

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The use of model systems to study the effects of predisposing factors on the incidence and severity of disabilities, injuries and performance decrements associated with military operations in the heat.

24. (U)Models will be used to document and elucidate the role of obesity, dehydration, alcohol, drugs etc. in predisposing animals to heat illness.

25. (U)77 10 - 78 09 303 untrained and unacclimatized rats were run to exhaustion at either 5°, 20°, 23-26°, or 30°C to determine the effects of ambient temperature on the incidence of heat exhaustion and fatal heatstroke. An increase from 5° to 30°C: (1) reduced run time to exhaustion by 48% and the range by 79%; (2) increased heat exhaustion from 16 to 92% and fatal heatstroke from 0 to 68%. These results support the hypothesis that with increasing heat loads, the poorest performers become more representative of the group and their susceptibility to heat illness. An additional experiment was designed to assess the value of preinduced hypothermia (33°C) in forestalling the pathological effects of exhaustive exercise in the heat. It was observed that the initially hypothermic animals were able to run significantly longer on the treadmill but, following completion of the run, cooling rates were significantly reduced. These results indicate that pre-induced hypothermia can prolong the time to hyperthermic exhaustion, thus increasing physical performance in the heat.

*Available to contractors upon originator's approval

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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 013 Models of Heat Disabilities: Predisposing Factors

Study Title: Heat Exhaustion and Heat Stroke: Predisposing Factors

Investigators: Roger W. Hubbard, Ph.D., Milton Mager, Ph.D. and Wilbert Bowers, Ph.D.

Background:

Historically, there have been two opposing views regarding the pathophysiology of heatstroke and their origins can be traced to the observations of Andral (2), Wood (23), Osler (18), Haldane (8), Adolph and Fulton (1), Fantus (5), and Drinker (4) during the 100 year period between 1838 and 1936. The classical concept is generally attributed to Malamud et. al. (17) who suggested that heat induced direct thermal injury to a target issue, i.e. the thermoregulatory centers of the brain, which resulted in a failure of sweating and thermoregulatory control and shock. This hypothesis was at variance with the earlier proposal of Adolph and Fulton (1), who believed heatstroke to be the result of circulatory failure also leading to shock.

The widely held belief in the Malamud hypothesis has resulted in the common practice to define the term 'heastroke' as a heat disorder accompanied by the classical triad of coma or convulsions, generalized anhidrosis and fever over 106^{o}F (16). Over the years, however, many experienced practioners have expressed dissatisfaction with one or more of these diagnostic criteria. For example, in 1919 Hearne (9) stated that suppression of sweating was the cause of heatstroke among British Troops in Mesopotamia; however, Willcox observed 6816 heat casualties and 555 heat deaths in the same area but did not regard anhidrosis as the primary cause of heat hyperpyrexia (22). In 1956, Austin and Berry (3) reported on 100 cases of heatstroke "selected" from over 1000 heat victims of three summer heat waves. All of them met the criterion of a hot, dry skin but even in this select population there were 39 cases whose body temperatures did not exceed 106^{o}C. More recently, there have been numerous Israeli reports of heatstroke accompanied by profuse sweating (19,20,21). Instead of being an uncommon variant or occurrence, these observations may reflect both the Israeli military practice of drinking by command in the absence of thirst as well as the role of physical effort in precipitating heatstroke. For example, Shibolet et. al. (19) reported that 28 of 29 cases of heatstroke observed at the time of collapse were sweating actively, if not profusely. Thus, it is evident that although a patient may collapse with severe exertion-induced hyperthermia, sweating may be present or return enroute to the hospital. If this were the case, he may be both cool and rational upon admittance, inspite of having sustained severe heat injury. These conflicting observations have been used by investigators in this area to synthesize a more general concept that heatstroke develops when excessive body temperature itself becomes a noxious agent. This concept, by deemphasizing the role of anhidrosis and by reemphasizing the importance of hyperthermia, per se, is useful to the heatstroke researcher but raises questions for the practitioner. For example, if reliance on the classical symptoms leads to underdiagnosis, then there is still difficulty in defining exactly when body temperatue is "too high", what degrees and duration of hyperthermia produces injury, and, by inference, what are the associated risks (21).

Thus, despite the change in emphasis, the foregoing concept was still consistent with Malamud's hypothesis that heatstroke pathophysiology was the result of direct thermal injury to tissue. The earlier experiments from this laboratory (11,15) confirmed this hypothesis to the extent that mortality in 24 h increased with either increased core temperature or an integrated measure of the time and intensity of core heating. Recent investigations (10,12,13,14), however, have provided additional insights, and demonstrate that exercise to exhaustion substantially lowers the threshold for both heatstroke injury and mortality at low comparable thermal loads. These results are consistent with Adolph and Fulton's hypothesis (1), and adapted by us (13), that exhaustive physical effort, by worsening circulatory collapse and metabolic acidosis, predisposes tissue to hyperthermic injury. Thus, a new hypothesis combining the essential features of both direct thermal injury and cardiovascular origins of heatstroke pathophysiology may be necessary.

Progress:

In an attempt to draw examples of this hypothetical effect of exercise on heatstoke mortality from the existing human literature, we have recalculated data from two series of heatstroke cases where both core temperature on hospital admission and subsequent mortality were available (6,7). The report by Gauss and Meyer (7) in 1917 on 158 cases of heatstroke from Cook County, Chicago indicates that 96% were males, 80% were 30 to 50 years old, and over 65% were manual laborers. In contrast, Ferris et. al. (6) described 44 cases of heatstroke occurring in Cincinnati during two severe heat waves in 1936; in this series, 61% were males, 73% were over 50 years old and only 9 (20%) were doing work which at most required moderate exercise at the time of or preceding their collapse. The majority of these patients presented clinical evidence of degenerative vascular disease. If hyperthermia alone were the predominant cause of heatstroke mortality, then one might have expected a slightly higher mortality at equivalent core temperatures in the older population with indications of cardiovascular disease. As shown in Fig. 1, this was not the case. Approximately 30% of the heatstroke deaths occurred in younger and presumably healthier laborers with temperatures on admission below 106°F (41.1°C). In contrast, there were no deaths at temperatures below 107°F in the older, sedentary population. These results appear in reasonable agreement with both the rat model and with those of Malamud on military recruits where 22% of heatstroke fatalities were characterized by temperatures below 106°F (41.1°C) on admission.

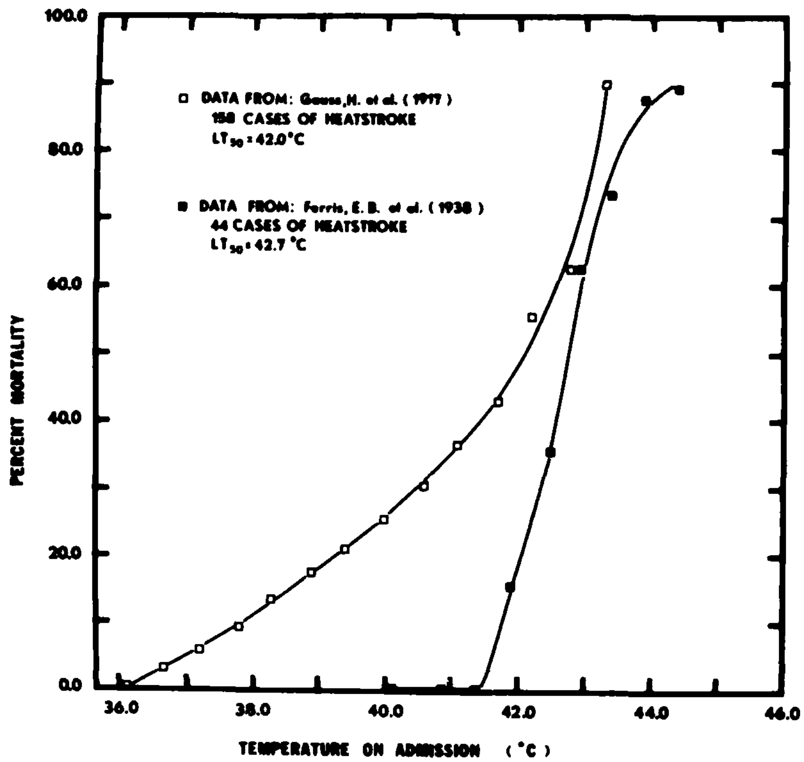

Fig. 1. Dose-response curves of percent mortality versus temperature on admission in human heat stroke patients. Data was recalculated by the method of Reed and Muench from the sources indicated in the insert.

In Israel, it is a common military practice to have an entire unit rest, if possible, if or when one of its members suffers heat exhaustion (Shibolet, personal communication). This doctrine is based on two implicit assumptions: 1) that during physical activity in the heat, the performance of various individuals becomes more similar or predictable, and 2) that rest, per se, may be the final defense against an epidemic of heatstroke so a weak link hypothesis is justified. In order to test these assumptions, we have compared group performances of 325 untrained and unacclimatized rats run to exhaustion at either 5^{o}, 20^{o}, or $23\text{-}26^{o}C$. As shown in Fig. 2, an increase in ambient temperature from 5^{o} to $26^{o}C$: 1) reduced mean run time to exhaustion by 38.3% and the range of individual performances by 53.8%; and 2) increased the incidence of heat exhaustion (core temperature $40.4^{o}C$) from 10.4% to 100% and fatal heatstroke in 24 h from 0 to 75.2%.

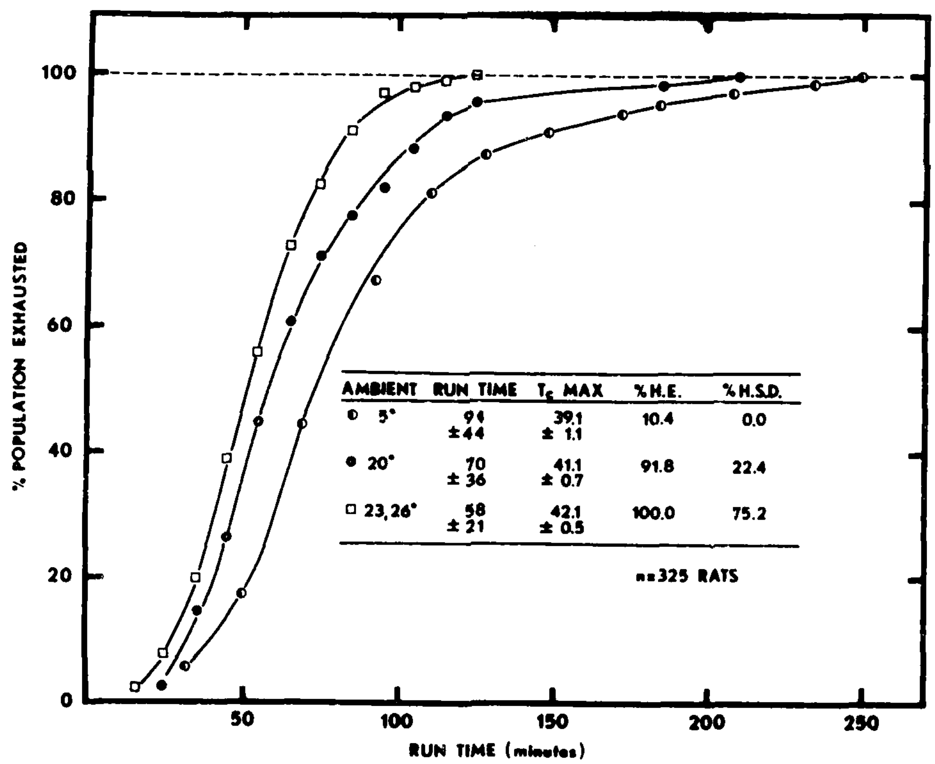

Fig. 2. Dose-response curves of percent population exhausted versus run time to exhaustion at different ambient temperatures. See insert for further data.

The incidence of both heat exhaustion and heat stroke fatalities in relation to run time to exhaustion is demonstrated in Fig. 3. The bell-shaped distribution of both heat exhaustions and heat stroke fatalities seen at 23-26°C ambient again emphasizes the existence of both heat sensitive and heat resistant individuals within any given population tested. Moreover, based on the incidence of heat stroke throughout the entire range of exhaustion times, it appears that total prevention of heatstroke is unlikely, if not impossible, once exhaustion has occurred throughout the test population at risk in the heat.

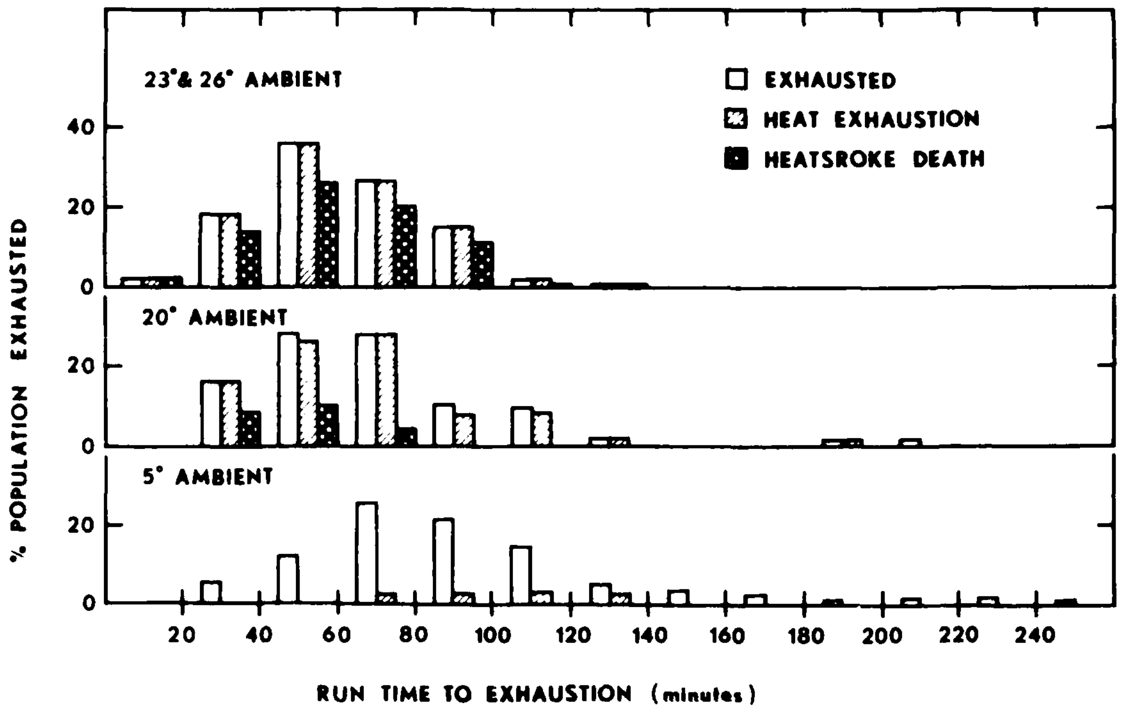

Fig. 3. Histograms of the incidence of both heat exhaustion and heat stroke fatalities in 24 h in relation to run time to exhaustion at different ambient temperatures. Heat exhaustion arbitrarily defined as a t core > 40.4°C.

In order to visualize and test the validity of the 'weak link' concept, we have replotted the foregoing data in the form of a projection (Fig. 4). The mean core temperature of the first 5% of each population exhausted is plotted along the abscissa, i.e. the core temperature of the first 5% exhausted at 5°C, then 20°C etc. The subsequently established heat injury and performance data for the entire population is then plotted against this core temperature data obtained from the 'weakest links' - i.e. the first 5% of each population to exhaust. For example, in the test group running at 20°C, if the first 5% of the population exhausts with a t core of 40.6 ± 0.2°C, then the population as a whole (if not rested) will ultimately exhaust with a t core of 41.7 ± 0.7°C, at a run time of 70 ± 36 min and will suffer an incidence of 91.8% heat exhaustion and 22.4% heat stroke fatalities. In contrast, in the test group running at 23-26°C, if the first 5% of the population exhausts with a t core of 41.7 ± 0.4°C, then the population as a whole (if not rested) will exhaust with a t core of 42.1 ± 0.6°C, at a reduced run time of 58 ± 21 min and will suffer an incidence of 100% heat exhaustion and 75.2% heat stroke fatalities. Taken in the context of our previous findings that exhaustive physical effort substantially lowers the threshold for both heat injury and heat stroke mortality, these results should reinforce the concept that when one or more individuals of a given population succumb to the effects of heat and work then: 1) the entire population should be rested or 2) the remainder of the population, if kept working, will run a high risk of subsequent heat injury and heat stroke fatality.

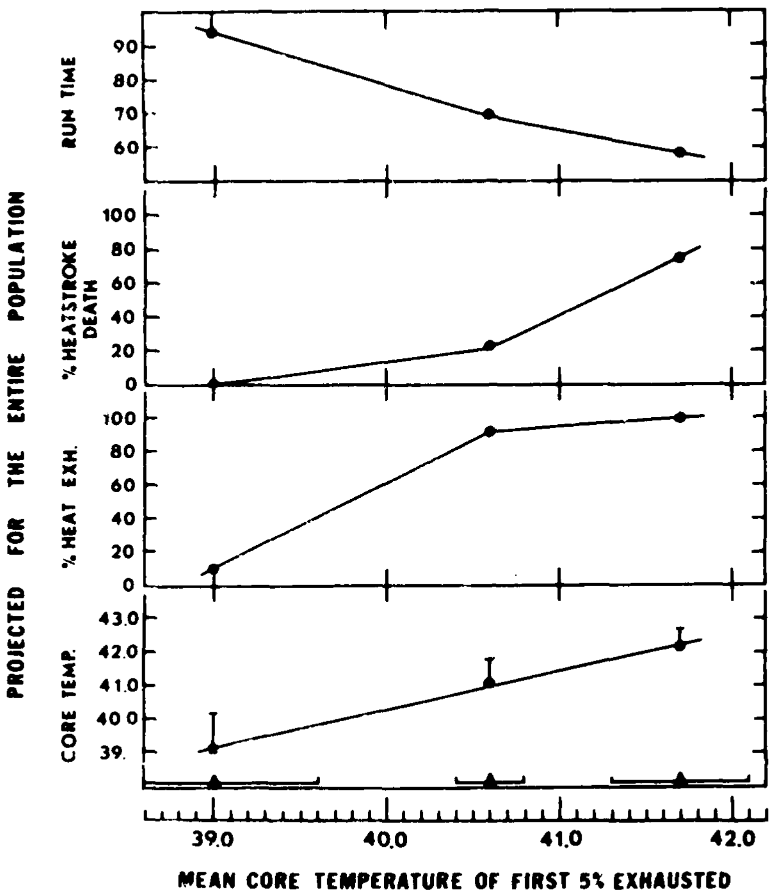

Fig. 4. Heat injury and performance data for entire groups exhausted at different ambient temperatures versus mean core temperatures of the first 5% of each group to exhaust. See text for details.

Future Plans:

These results clearly indicate that a lack of rest during exhaustive physical exercise in the heat lowers the threshold for both heat injury and heat stroke mortality. Since in this design both stressors (heat and exhaustive exercise) occur simultaneously, future research will determine to what degree prior exhaustion predisposes to heat injury, i.e. physical exercise followed by heat stress. These future investigations should provide additional insights into the value of night vs daylight operations in hot climates.

Presentations:

1. Hubbard, R. W., R. E. L. Criss, L. P. Elliott and I. V. Sils. Use of serum enzymes to differentiate in the rat between heat and/or work induced disorders. American Physiological Society Annual Fall Meeting, Hollywood, Florida, October 9-14, 1977.

2. Mager, M., R. W. Hubbard, W. T. Matthew, C. Kelly, G. Sheldon and J. W. Ratteree. Biophysical and clinical chemical indices of potential fatalities in a rat heatstroke model. American Physiological Society Annual Fall Meeting, Hollywood, Florida, October 9-14, 1977.

3. Hubbard, R. W. Effects of exercise in the heat on predisposition to heatstroke. Special symposium, American College of Sports Medicine, Annual Meeting, Washington, D.C., May 24-27, 1978.

Publications:

1. Hubbard, R. W. Effects of exercise in the heat on predisposition to heatstroke. Medicine and Science in Sports. In press.

2. Hubbard, R. W., W. D. Bowers, W. T. Matthew, F. C. Curtis, R. E. L. Criss, G. M. Sheldon and J. W. Ratteree. Rat model of acute heatstroke mortality. J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 42:809-816, 1977.

3. Hubbard, R. W., R. E. L. Criss, L. P. Elliott, C. Kelly, W. T. Matthew, W. D. Bowers, I. Leav and M. Mager. The diagnostic significance of selected serum enzymes in a rat heatstroke model. J. Appl. Physiol. Respirat. Environ. Exercise Physiol. In press.

4. Hubbard, R. W., W. T. Matthew, R. E. L. Criss, C. Kelly, I. Sils, M. Mager, W. D. Bowers and D. Wolfe. Role of physical effort in the etiology of rat heatstroke injury and mortality. J. Appl. Physiol. Respirat. Environ. Exercise Physiol. 45(3):463-468, 1978.

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10. Hubbard, R. W. Effects of exercise in the heat on predisposition to heatstroke. Medicine and Science in Sports. In press.

11. Hubbard, R. W., W. D. Bowers, Jr. and M. Mager. A study of physiological, pathological and biochemical changes in rats with heat-and/or work-induced disorders. Israel. J. Med. Sci. 12:844-886, 1976.

12. Hubbard, R. W., W. D. Bowers, W. T. Matthew, F. C. Curtis, R. E. L. Criss, G. M. Sheldon and J. W. Ratteree. Rat model of acute heatstroke mortality. J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 42:809-816, 1977.

13. Hubbard, R. W., R. E. L. Criss, L. P. Elliott, C. Kelly, W. T. Matthew, W. D. Bowers, I. Leav and M. Mager. The diagnostic significance of selected serum enzymes in rat heatstroke model. J. Appl. Physiol. Respirat. Environ. Exercise Physiol. In press.

14. Hubbard, R. W., W. T. Matthew, R. E. L. Criss, C. Kelly, I. Sils, M. Mager, W. D. Bowers and D. Wolfe. Role of physical effort in the etiology of rat heatstroke injury and mortality. J. Appl. Physiol. Respirat. Environ. Exercise. Physiol. 45(3):463-468, 1978.

15. Hubbard, R. W., W. T. Matthew, J. D. Linduska, F. C. Curtis, W. D. Bowers, I. Leav and M. Mager. The laboratory rat as a model for hyperthermic syndromes in humans. Am. J. Physiol. 231:1119-1123, 1976.

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Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	013 Models of Heat Disability: Predisposing Factors
Study Title:	Preinduced Hypothermia: Effects on Physical Performance in the Heat
Investigators:	Ralph P. Francesconi, Ph.D. and Milton Mager, Ph.D.

Background:

A variety of factors have been identified which may predispose individuals to the pathological effects of acute heat stress. Among these are obesity, poor physical condition, alcohol consumption, dehydration, low-grade infection, and lack of acclimatization. Alternatively, relatively few recent studies have been concerned with identifying factors which may permit increased levels of work in the heat at reduced physiological cost. We hypothesized that pharmacological intervention which results in whole-body hypothermia may produce beneficial effects when administered prior to subjecting the animal to an exhaustive run in a hot environment.

Progress:

The literature is replete with studies demonstrating the hypothermic effects on sedentary animals of a variety of compounds including amino acids (1), monoamines (2), metabolic inhibitors (3), calcium (4), and narcotics (5). However, it is significant to note that no studies have been performed on the effects of preinduced hypothermia on the ability to work in the heat. For example, we hypothesized that an initial Tre of 33°C (vs. control 37-38°C) would permit increased exercise time to hyperthermic exhaustion (42.5-43°C). Also, we were interested in potential beneficial post-run effects of initial hypothermia on such parameters as cooling rates, survivability, etc.

To test this hypothesis catheterized rats were administered small dosages of chlorpromazine intravenously, and then placed into a cold chamber (4°C) while skin and rectal temperatures were closely monitored. The combination of the chlorpromazine (100-150 ug) and cold ambient conditions produced hypothermia (33°C) usually within 30-45 min. Following the induction of this hypothermic state, rats were again exercised on the treadmill in the heat. The following figures demonstrate the results of a typical experiment utilizing chlorpromazine-induced, hypothermic rats. Figs. 1 and 2 demonstrate graphically the thermoregulatory responses of 2 groups (n=6 per group) of rats while Table 1 quantitates these results.

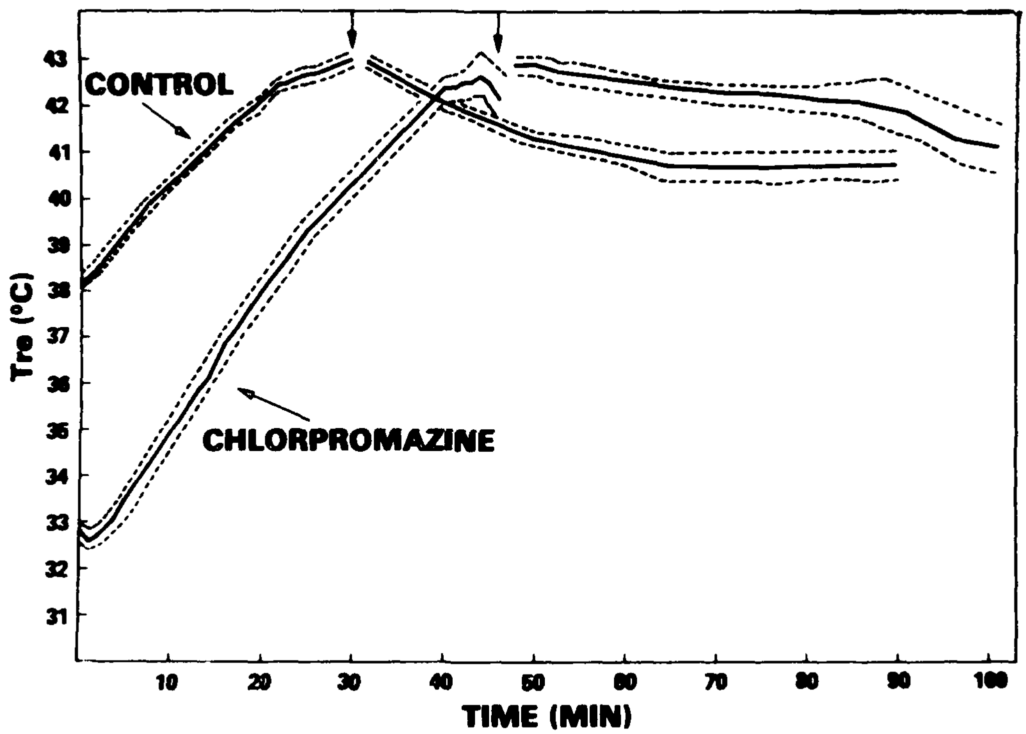

Fig. 1. Effects of chlorpromazine-induced hypothermia on the rectal temperature responses of rats exercising in the heat. The solid line represents the mean Tre for an n of 6 rats per group while the dotted line depicts the range of standard errors of the mean. The solid arrows denote the end of the treadmill run for both groups of rats. Following completion of the runs the rats remained sedentary in the heat chamber for 60 min while Tre was continually monitored.

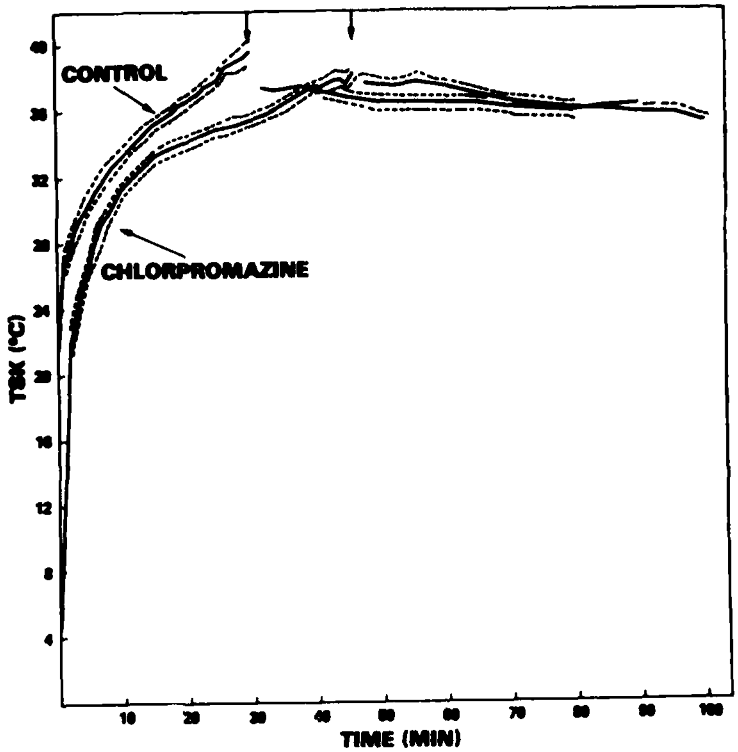

Fig. 2. Effects of chlorpromazine-induced hypothermia on the skin temperature responses of rats performing treadmill exercise in the heat. All conditions are as described under Figure 1.

The results of these experiments of the effects of pre-induced hypothermia on the ability to exercise in the heat present several interesting conclusions. For example, it can be observed that the initial hypothermic state of the chlorpromazine treated animals permitted a longer interval on the treadmill until the point of hyperthermic exhaustion was reached. Thus, in terms of total work done or physical performance, it can be deduced that the initial hypothermic state had beneficial effects in these experiments. However, consideration of the thermoregulatory data presents alternative conclusions. It can be observed in Table 1 that initial hypothermia had no significant effects on the maximal Tre and Tsk achieved by both groups of animals while the rate of Tre increase was significantly greater for the chlorpromazine treated animals. However, the rate of increase of skin temperature was greater in the control or saline-treated group. One of the most interesting observations concerns the cooling rate after completion of the treadmill run. Saline-treated rats demonstrate decrements in Tre which reflect a cooling rate of more than double that of the chlorpromazine treated animals. This is a significant observation which could mean that chlorpromazine, while inducing hypothermia in the cold, interferes with the ability to lose body heat in a hot environment (skin vasodilation in the rat). An alternative explanation might be that the longer time on the treadmill has increased the physiological cost to the chlorpromazine treated animals and compromised their thermoregulatory capacity. This point could be resolved by studying rats made hypothermic by alternative methods or simply studying the thermoregulatory effects of chlorpromazine when administered to animals in hot environments.

Therefore, chlorpromazine-induced hypothermia was effective in prolonging the time to hyperthermic exhaustion thus increasing exercise performance in the heat; however, thermoregulatory data indicated that the drug may have compromised the animals' ability to dissipate heat after the treadmill run. In this regard it may be useful to continue similar experiments in animals made hypothermic by alternative methods.

Future Plans:

Results of the present experiments give impetus to further tests of the potential beneficial effects of hypothermia on the ability to work in the heat.

Presentations:

Francesconi, Ralph P. and John T. Maher. Perceptual advantages of heat acclimatization. Presented at the Fall Meetings of the American Physiological Society, Hollywood Beach, Florida, 1977.

Publications:

Francesconi, R. P., J. T. Maher, J. W. Mason and G. D. Bynum. Hormonal responses of sedentary and exercising men to recurrent heat exposure. Aviation, Space, and Environmental Medicine. 49:1102-1106, 1978.

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TABLE 1

Summary of the Effects of Chlorpromazine-Induced Hypothermia on the Thermoregulatory Responses of Rats exercising in the Heat

	TIME ON TREADMILL (MINUTES)	RECTAL TEMPERATURE MAXIMUM (°C)	SKIN TEMPERATURE MAXIMUM (°C)	Δ Tre/ MIN ON TREADMILL (°C)	Δ Tsk/ MIN ON TREADMILL (°C)	Δ Tre/ MIN COOLING POST-TREADMILL (°C)	Δ Tsk/ MIN COOLING POST-TREADMILL (°C)
CHLORPROMAZINE TREATED							
$\bar{X}$	43.17	42.74	37.91	.231	.426	.017	.043
SD_x	2.23	.39	1.00	.014	.056	.014	.029
SE_x	.91	.16	.41	.006	.023	.006	.011
CONTROL NaCl							
$\bar{X}$	25.80	42.91	37.76	.182	.628	.04	.033
SD_x	3.19	.20	1.22	.017	.028	.011	.015
SE_x	1.43	.09	.54	.008	.012	.005	.005
T VALUE	10.62	.86	.22	5.10	7.32	2.88	1.10
P	<.001	NS	NS	<.001	<.001	<.02	NS

(82014)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OC 6124	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	014
b. CONTRIBUTING				
c. XXXXXXING	CARDS 114F			

11. TITLE (Precede with Security Classification Code)*

Cell Culture Modeling of Cellular Disabilities Associated with Environmental Extremes(22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

005900 Environmental Biology; 010100 Microbiology; 002300 Biochemistry

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
77 10	CONT	DA	C. In-House

17. CONTRACT GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE d. AMOUNT:

e. KIND OF AWARD f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	4.4	73
	CURRENT 79	3.5	27

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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NAME:* USA RSCH INST OF ENV MED

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

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21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U) Tissue Culture; (U) Endothelial Cells: (U) Hypothermia; (U) Frostbite; (U) Ultrastructure

23. TECHNICAL OBJECTIVE.* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) In vivo studies have concluded that an intact vascular system is necessary to prevent necrosis of frozen tissue. More specifically, the fate of endothelial cells lining the vascular system appears to be important to the eventual prognosis. This study proposes to develop an in vitro tissue culture model suitable for studying cold induced endothelial cell damage. This will hopefully result in an in vitro human endothelial cell model with direct application to human frostbite in vivo.

24. (U) Calf aorta endothelial cells will be grown in vitro. Some cells will be grown at 37°C as controls while others will be exposed to various above- and below-freezing temperatures for various time periods. Ultrastructure damage will be monitored via two types of electron microscopy, light microscopy and release of cellular enzymes.

25. (U)77 10 - 78 09 Calf aorta endothelial cells have been cultured in vitro successfully and are currently being subjected to above- and below-freezing temperatures. Electron microscopic examination seems to indicate appreciable damage occurs largely following a freeze-thaw injury. Enzyme release data further substantiates this and appreciable amounts of LDH enzyme are found only after freeze-thaw and not at super-cooled temperatures. Future work will utilize this model to study the mechanism of hemostasis that occurs in frostbite. More specifically, the role of platelet aggregation as it relates to isolated endothelial cells will be studied independently of other variables known to cause platelet aggregation. This will help to elucidate the role of damaged endothelium as the initiator of platelet aggregation, independent of collagen and other in vivo factors known to cause platelet aggregation.

*Available to contractors upon originator's approval

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Program Element:	6.11.02A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	014 Cell Culture Modeling of Cellular Disabilities Associated with Environmental Extremes
Study Title:	Development of an In Vitro Endothelial Cell Model as It Applies to Cold Induced Ultrastructural Changes
Investigators:	Lynn R. Trusal, CPT, MSC, Ph.D. and Murray P. Hamlet, D.V.M.

Background:

The importance of an intact vascular system to tissue survival following frostbite injury has been demonstrated (3,5). It is also known that endothelial cells lining the vascular system are non-thrombogenic unless the cells are removed, exposing the subendothelium. Freeze-thaw damage to blood vessels is known to initiate clotting mechanisms leading to hemostasis and possible loss of limbs by tissue necrosis (4). Thus, ultrastructural damage to endothelial cells lining the blood vessels appears to be the initial event leading to hemostasis following an in vivo freeze-thaw injury. Because platelet aggregates are the blood stream's first line of defense from hemorrhage, their role in post-frostbite hemostasis needs study. This should help to elucidate the role of the platelets in the particular clotting mechanism activated by freeze-thaw damage.

Progress:

An in vitro endothelial cell model has been devleoped and is currently being utilized to study the specific types of ultrastructural damage caused by both above and below freezing temperatures. Calf aortas serve as the source of endothelial cells, which are obtained by collagenase perfusion of the luminal surface of the aorta and seeded in vitro utilizing a complete tissue culture medium. Plastic Leighton tubes with coverslips have proven particularly useful as culture vessels; because they allow water submersion at different temperatures, can be processed for examination by four types of microscopy and monitored for release of cellular enzymes. More specifically, damage to the cells is determined by a combination of light microscopy, scanning electron microscopy, transmission electron microscopy and release of cellular enzymes as measured by UV spectrophotometry.

Most previous research indicates that in vitro cultured endothelial cells respond similarly to in vivo endothelial cells located on the blood vessel wall. Similar parameters include ultrastructure, Factor VIII antigen and synthesis of basement membrane collagen (2). To increase the in vivo to in vitro comparison, the bovine endothelial cells are grown in confluent, non-mitotic monolayers and processed in this manner through Epon embedding for electron microscopy.

The in vitro endothelial cell model is being used to study the effects of both supercooled (i.e. -5°C) and freezing temperatures (-10°, -15° and -20°C) on endothelial cell ultrastructure. Because available in vivo evidence indicates that endothelium is not damaged when exposed to a supercooled temperature in the absence of freezing, we were initially interested in evaluating the ultrastructure of supercooled endothelial cells in vitro (1). We chose (-5°C) because it is below the centigrade freezing point of water (O°C) and yet above the point where supercooled cultures would freeze instantly if disturbed (i.e. -10° to -12°C) for processing. We then chose to examine the time points of 1,2,3,5,10, 20 and 40 minutes at (-5°C). Following exposure, cultures were immediately removed and processed for light and electron microscopy. Media from the Leighton tubes containing the cells was then assayed for the presence of lactic dehydrogenase (LDH), glutamic oxaloacetic transaminase (GOT), creatine phosphokinase (CPK), glutamic pyruvic transaminase (GPT) and Na^+ and K^+ ions. Analysis of cellular enzyme and ion release from endothelial cell cultures maintained at (-5°C) for up to 40 minutes showed no significant release of these cellular constituents. This may or may not be related to the cellular density or the UV spectrophotometric method used. Electron microscopy results are still being conducted and can not be commented on at this time.

We then chose to examine the effects of various above and below freezing temperatures on the ultrastructure of the endothelial cells. Cultures were exposed at O°C, -5°C, -10°C, -15°C and -20°C while controls were maintained at 37°C. Once again, cellular release of GPT, CPK, GOT, Na^+ and K^+ was not significant compared to controls. Release of LDH was significantly increased at -15° and -20°C. This indicated that only following a freeze-thaw state (approx. -12°C) was there enough LDH released to be measured by UV Spectrophotometry. Because LDH is localized in the cytoplasm, release of this enzyme is indicative of extensive cellular disruption. This conclusion is supported by the transmission electron micrographs of both control and experimental cultures. Cultures exposed to $0^{o}C$ thru $-5^{o}C$ which were not frozen demonstrated intact cellular and nuclear membranes, normal chromatin distribution, and intact mitochondria with normal cristae appearance. Endothelial cells frozen at $-15^{o}C$ exhibited extensive cellular disruption including broken cellular membranes, abnormal condensation of nuclear chromatin, fragmentation of the nuclear membrane and some mitochondria with thickened and disrupted internal membranes.

Thus, data analyzed so far indicate freeze-thaw must occur for significant ultrastructural damage to occur. It is currently unknown whether or not extended time periods at supercooled temperatures will lead to ultrastructural disruption. The existing enzyme results would indicate this is probably true. (It is also known what ultrastructure effects result from various durations below freezing). Both these aspects are currently under investigation.

Future Plans:

The initial purpose for studying freeze-thaw damage to endothelial cells in vitro was to isolate the cells so that they could be studied independently of systemic factors. This allows better control of variables, and permits the use of drugs whose effects may be studied independent of other interactions. Following the development of an index of cellular damage as it relates to both temperature and duration of exposure, we will continue to utilize the in vitro model to study the role of the hemostatic mechanism in vitro. More specifically, the role of platelet aggregation as it relates to damaged (freeze-thaw) endothelium will be studied. For example, it is known that numerous agents can initiate platelet aggregation. They include collagen, basement membrane, serotonin, epinephrine and ADP (2). Such aggregation is usually initiated by removal of endothelium and exposure of the subendothelium containing collagen and basement membrane. It is unknown whether or not freeze-thaw damaged endothelial cells will cause platelet aggregation in the absence of collagen and other systemic factors. Such studies are possible in an in vitro system. It will also be possible to study anti-platelet agents in vitro and the use of known aggregating agents. Thus, it will be possible to better understand the initial events in post-frostbite hemostasis and examine ways to alter its occurrence or severity.

Presentations:

Trusal, L. R. and C. J. Baker. Development of a suitable in vitro system to study freeze-thaw damage to endothelial cells in monolayer culture. In Vitro 14:378, 1978.

Publications:

Trusal, L. R. and C. J. Baker. Processing of endothelial cell monolayers grown on plastic substrates for transmission and scanning electron microscopy. (Submitted to Stain Technology).

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(83041)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OB 6141	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	H. Terminated	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	041
b. CONTRIBUTING				
c. XXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)*

(U) Prophylaxis of Cold Injury and Cold-Induced Manual Performance Decrement (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 002300 Biochemistry; 002600 Biology; 003500 Clinical Medicine; 005900 Environmental Biology; 012600 Pharmacology; 012900 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING		
	CURRENT 78	3.8	73

19. RESPONSIBLE DOD ORGANIZATION

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NAME: 955-2865 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U) Cold Injury Prevention; (U) Peripheral Blood Flow; (U) Facial Rewarming; (U) Cold Induced Vasodilation; (U) Biofeedback; (U) Reactive Hype.emia

23. TECHNICAL OBJECTIVE.* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The relative loss of fighting manpower was greater for cold injury in the Korean conflict than for malaria in the Vietnam conflict. Five integrated strategies are proposed by this work unit which may logically protect soldiers from the cold and improve manual performance: reactive hyperemia (tourniquot release, forced exercise, facial warming, psychological conditioning, and pretreatment with Vitamin C.

24. (U) The effect of isometric and isotonic exercises on skin temperature and other physiologic parameters in the cold will be used to study the effect on peripheral skin temperature. Twenty-four subjects will be tested in a cold environmental chamber -5°C wearing full arctic uniforms, and having one hand exposed. Volunteers will be tested on high and low of their maximum voluntary contraction rate on isometric and isotonic hand exercising hand apparatus. Responses under different temperatures will be recorded. Finger blood flow will be evaluated with impedance plethysmography and mercury strain gauge techniques. Hand temperatures in different environmental chambers will be evaluated after utilizing a radiant belt heating of the forehead for various time intervals. The ability of the individual to vasodilate in response to heating the forehead will be studied.

25. (U) 77 10 - 78 09 The reactive hyperemia portion has been postponed pending development of an accurate method of measuring peripheral blood flow. Facial warming and forced exercise studies have been completed and final reports written and submitted for publication. Data collection has begun on psychological conditioning for hand cooling. Pretreatment with Vitamin C is postponed pending assignment of investigator.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 041 Prophylaxis of Cold Injury and Cold-Induced Manual Performance Decrement

Study Title: Evaluation of Facial Warming to Improve Peripheral Cold Response

Investigator: Joel J. Berberich, CPT, MSC, Ph.D.

Background:

Historically the loss of fighting manpower and the strain placed on military and medical logistics and support due to cold injury have been significant. The military significance of optimizing performance in cold weather is manifest. Accordingly, such strategies that provide additional heat to the extremities would be useful accomplishments.

The technique of inducing indirect peripheral vasodilation by warming the face has been described by Bader and Macht (1,2). These investigators found facial warming to be far more effective than chest or limb warming in inducing vasodilation of the hands. A rise in hand skin temperature of 10°C was the average gain when subjects were exposed to ambient temperature of 15°C. Facial warming essentially restored hand temperature to normal levels. In this study an infrared lamp (250 W) was used to warm the entire face so as to maintain a skin temperature of 42°C for an 80-90 minute period. Unfortunately, this study was restricted to only two subjects exposed to unrealistically warm environments.

Additional evidence supports the concept of specific physiological responses to facial warming. Thermal irradiation of the face has elicited far greater physiological thermoregulatory responses for the cat (3) and for men (4,5) when directly compared to irradiation of other parts of the body. Similarly, greater sensitivity to facial irradiation was found for psychophysiological warmth perception in man (6).

We sought to determine whether or not facial warming elicited hand warming in cold environments. It was decided at the outset to limit facial warming to the forehead since the heat input required would be minimized and the possible utility for the soldier maximized.

Progress:

Ten volunteers were exposed to +25°C, O°C, and -25°C environments dressed in appropriate clothing. For cold exposures, their hands were either bare (O°C) or lightly gloved (-25°C). The subjects were exposed twice to each environment: once with and once without facial warming. The center of the forehead was warmed to 42°C for 30-45 minutes during the exposure with an incandescent light. Rectal temperature and 34 skin temperatures were continuously measured using copper-constantan thermocouples (4 each hand, 4 each foot, 8 trunk and activity sites for mean temperature and 8 facial sites). Heart rate was also measured. The hypothesis was tested by comparing extremity (hand and foot) temperatures for each subject for the facial warming and non-facial warming exposures.

The average of three finger temperatures is expessed as the area under a curve of temperature against time for both hands. Areas under the curve were compared for minutes 1-44 and 45-105 of exposure to O°C. The hands were bare from minutes 15-105; the facial warming extended from 45-90 minutes.

The right and left finger average temperatures at O°C and right and left toe averages were not different for any time period for facial warming versus control.

At 23°C, no significant differences were found for both finger averages and both toe averages except for the 45-60 min. period, which was the start of facial warming, when both average temperatures for facial warming were significantly lower than that for control.

The one previous study evaluating peripheral responses to facial warming at 15°C and 23°C demonstrated significant peripheral warming (2,4). Differences between the present study and that study may account for the failure to obtain peripheral warming with FW: more subjects (10 vs. 2), limited and localized face warming site (60 vs. 300 cm^2); shorter warming period (45 vs 90 minutes). The previous approach was not thought to be practical (especially militarily), so we opted for these differences. The apparent vasoconstriction following facial warming in the present study is the opposite response to that previously found and is paradoxical.

Unlike previous studies, this study evaluated facial warming in ambient temperatures where its use would be reasonable. The results, at least with modality of warming utilized, do not support facial warming as a prophylaxis for reduced risk of cold injury and maintenance of manual dexterity in the cold.

LITERATURE CITED

1. Bader, M. E. and M. B. Macht. Indirect peripheral vasodilation produced by the warming of various body areas. J. Appl. Physiol. 1:215-225, 1948.

2. Macht, B. B. and M. E. Bader. Indirect peripheral vasodilation produced by the warming of various body areas. Environmental Protection Series Report No. 132. Quartermaster Climatic Research Laboratory, Lawrence, MA, 18 p., 1948.

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(83042)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
				DA OB 6144	78 10 01	DD DR&E AR 636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	042
b. CONTRIBUTING				
c. XXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)

(U) Models of Heat Disabilities: Treatment and Diagnosis (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS

005900 Environmental Biology; 003500 Clinical Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT GRANT

a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER: NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	6.5	254
	CURRENT 79	13.6	270

19. RESPONSIBLE DOD ORGANIZATION

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21. GENERAL USE

Foreign Intelligence Not Considered

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NAME: FRANCESCONI, Ralph P., Ph.D. DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Disabilities; (U)Military Heat Stress; (U)Pathology Model; (U)Physiology; (U)Biochemistry; (U)Behavior; (U)Tolerance; (U)Heat

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)The use of model systems to develop new or modified forms of treatments or diagnosis for the various disabilities, injuries and performance decrements associated with military operations in the heat.

24. (U)A variety of agents will be evaluated for their efficacy in reducing core temperature, decreasing the pathological effects of hyperthermia, increasing performance, or alleviating the symptomatology of heat illness among humans or animals acutely exposed to high environmental temperatures or work regimens. Additionally, a variety of clinical and physiological parameters will be evaluated for their usefulness in the early diagnosis of heat illnesses, and to characterize in animals and humans those who have experienced or are susceptible to heat related injury.

25. (U)77 10 - 78 09 The pathophysiology of fatal heatstroke is still unknown, and it would be desirable to determine which serum constituents changed prior to death. From a variety of studies, the data from a large group of untreated fatalities (n=62) were analyzed for both pre-heat and terminal values. This group had a maximum core temperature of $42.6 \pm 0.3^{\circ}C$, a hyperthermic area of 65 ± 23 degree-minutes, and a survival time of 0.47 ± 0.26 hr. The following indices, uncorrected for change in plasma volume, increased significantly: HCT (48 ± 3 to 57 ± 6); serum protein (7.1 ± 0.4 to 7.9 ± 0.8); SGOT (31 ± 42 to 100 ± 136); SGPT (31 ± 42 to 100 ± 136); CPK (211 ± 247 to 663 ± 620); K (6.5 ± 1.2 to 11.8 ± 2.5); and lactate (40 ± 13 to 53 ± 1). Both plasma volume (minus 28%) and glucose (118 ± 20 to 85 ± 33) Decreased significantly. These data should provide the control levels for evaluating the effectiveness of potential treatments or reduced thermal loads.

*Available to contractors upon originator's approval

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	042 Models of Heat Disabilities: Treatment and Diagnosis
Study Title:	Pathochemical Indices of Heatstroke Mortality
Investigators:	Roger W. Hubbard, Ph.D., Wilbert Bowers, Ph.D. and Milton Mager, Ph.D.

Background:

It is well known that acute heatstroke can occur under a variety of circumstances ranging from heavy physical exercise on relatively cool days to sedentary exposure to high ambient temperatures (10). The situation is further complicated by a variety of conditions known to predispose to heatstroke including: dehydration; lack of training, acclimatization, or adequate rest; alcohol or drug consumption; or prior or existing illness (13). Although this list is by no means complete, it does suggest why diagnosis is often difficult and why the pathophysiology of fatal heatstroke is still uncertain.

Historically, there have been two opposing views regarding the pathophysiology of heatstroke. The classical concept is generally attributed to Malamud et. al. (11) who suggested that heat induced direct thermal injury to a target tissue, i.e. the thermoregulatory centers of the brain, which resulted in a failure of sweating and thermoregulatory control and shock. This hypothesis was at variance with the earlier proposal of Adolph and Fulton (1), who believed heatstroke to be the result of circulatory failure also leading to shock. With either hypothesis, shock was the critical end point.

Shock, from whatever cause, is a failure of adequate perfusion of vital organs which usually results in some degree of tissue anaerobiosis and the accumulation of lactic acid. Therefore, arterial blood lactate levels have a prognostic significance and as such are the most reliable indicator of irreversible shock in human beings (2). Similarly, it has been reported that arterial pH is low and serum lactic acid is high in heatstroke (11,12). Thus, in heatstroke it is assumed that the cell is subjected to three simultaneous insults including: a) poor local circulation or ischemia, b) metabolic or hypoxic acidosis and c) direct thermal injury. Recent investigations (4,5,7) from this laboratory have demonstrated that exercise to exhaustion substantially lowers the threshold for both heatstroke injury (as measured by the release of certain cell enzymes) and mortality at low comparable thermal loads. These findings are, therefore, consistent with the hypothesis that exhaustive physical effort, by worsening circulatory collapse and metabolic acidosis, predisposes tissue to hyperthermic injury.

The foregoing analysis provides, at least to some degree, a theoretical basis for defining and evaluating certain clinical findings in heatstroke for their diagnostic or prognostic significance. The substances of interest include: 1) blood lactate and to what degree its change in concentration reflects prior exercise, acute hyperthermia and/or glucose availability. For example, hypoglycemia has been encountered occasionally in heatstroke but its pathogenesis is still uncertain. The contribution of central glucopenia to heatstroke coma is likewise unknown. 2) serum enzymes such as SGPT, SGOT and CPK are known to increase dramatically in heatstroke (6,8,12) and, thus, are valuable both diagnostically and prognostically. However, the transaminases (SGPT, SGOT) require 24 to 48 h to reach peak elevations and, unfortunately, death occurs within the first 24h in a large percentage of cases (11). 3) Potassium, as the major intracellular cation, is released into the circulation and reaches extreme levels during progressive lethal hyperthermia in rats (3). It is uncertain to what degree changes in serum potassium reflect changes in blood pH, membrane damage or intracellular energy depletion.

Thus, in summary, although direct thermal stimulation of carbohydrate metabolism has not been ruled out, the rise in lactate levels with hyperthermia probably reflects tissue ischemia. On the other hand, increased serum concentrations of intracellular substances such as potassium and transaminase enzymes suggest damage to cell membranes. It is assumed that the greater the deviation from normal values, then the greater is the likelihood of severe injury and death. However, prior to conducting experiments on the value of either preventive measures or treatments, it is necessary to establish how rapidly these indices change under heat stress conditions known to produce severe heat injury and subsequent mortality. For this reason, data was consolidated from a variety of our prior rat studies to produce a large group of untreated fatalities for whom both pre-heat and agonal clinical chemical assays existed for each individual.

Progress:

The animals used in this evaluation were represented by the following five experimental groups (Table 1).

TABLE 1

Experimental Groups

Group #	n	Exercise	Exhausted	Exercise Ambient	% Total
		(kgm•m)	no	(°C)	
1)	2	----	no	----	3.2
2)	12	9	no	5°	19.3
3)	15	9	no	20°	24.2
4)	8	9	no	26°	12.9
5)	25	46 $\pm$ 22	yes	5°	40.3

As shown in the table above, 40% (group 5) were run to exhaustion, 56% (groups 2-4) performed limited exercise and 3% (group 1) performed no prior exercise at all. Physical exercise was achieved by treadmill running at 11 m/min up a 6° incline. All rats were then exposed to 41.5°C ambient while restrained in an environmental chamber. The total group (n=62) had a maximum mean core temperature following heat exposure of 42.6 $\pm$ 0.3°C ($\bar{x} \pm$ S.D.), a hyperthermic area of 65 $\pm$ 23 degree•minutes, and a survival time of 0.47 $\pm$ 0.23 h. Since the differences between groups (2 + 3 + 4 vs 5), although significant, were quantitatively small but qualitatively similar, the results were combined as shown in Table 2. The change in hematocrit between pre-heat and agonal samples was used to predict the change in the other substances due to hemoconcentration. Since the mean survival time for these rats was approximately 30 min, the hourly rate of change can be estimated directly from the table. Plasma protein was observed to increase significantly following hyperthermia but significantly less than would be predicted

Table 2

Pathochemical Indices of Heatstroke Mortality

Conditions		HCT	Plasma Protein	Blood Lactate	Serum Glucose	Serum K^+	Serum Na^+	Serum SGOT	Serum SGPT	Serum CPK
		(%)	(g/dl)	(mg %)	(mg %)	(meq/L)	(meq/L)	(IU/L)	(IU/L)	(IU/L)
Pre-Heat	$\bar{x}$	48	7.1	40	118	6.5	142	99	31	211
	S.D.	± 3	± 0.4	± 13	± 20	± 1.2	± 4	± 114	± 42	± 247
	(n)	(60)	(60)	(60)	(60)	(55)	(55)	(60)	(60)	(60)
Agonal Observed	$\bar{x}$	57*	7.9*	53*	85*	11.8*	144*	311*	100*	663*
	S.D.	± 6	± 0.8	± 1	± 33	± 2.5	± 3	± 212	± 136	± 620
	(n)	(62)	(62)	(62)	(62)	(62)	(62)	(62)	(62)	(62)
Agonal Predicted ɸ	$\bar{x}$	—	9.3*+	54+	165*+	9.2*+	200*+	138*	44*	285*
	S.D		± 2.3	± 18	± 49	± 2.8	± 45	± 154	± 61	± 304
	(n)		(60)	(60)	(60)	(55)	(55)	(60)	(60)	(60)

* Mean significantly different ($p<.002$) from mean immediately above it.

\+ Predicted values significantly different ($p<.002$) from pre-heat values.

ɸ Calculated according to the formula of Van Beaumont (Aerospace Med. 45(2):176-181, 1974).

by the degree of hemoconcentration. This suggests a net loss of protein from the intravascular compartment due to either increased hydrostatic pressure or capillary permeability. The pre-heat lactate concentrations (40 $\pm$ 13) were elevated by the prior exercise but the observed increase in the agonal samples were not significantly different from that predicted by dehydration alone. The lack of net lactate accumulation during hyperthermia raises many interesting questions regarding its production and/or utilization and whether it accurately reflects tissue hypoxia during heatstroke. By the same token, the significant decline in serum glucose (heretofore unreported for hyperthermic rats) is more noteworthy when contrasted with its predicted value (85 vs 165) due to hemoconcentration. These results taken in the context of no net lactate accumulation might suggest impaired glucose production. The highly significant increase in serum potassium, above that predicted by dehydration, was not unexpected and probably reflects cell membrane damage. This assumption is supported by the three fold increases seen in serum enzyme concentrations. Hyperkalemia without a corresponding increase in serum sodium was noticed previously by Frankel (3) in severely hyperthermic rats and, conceivably, is a cause of death due to cardiac toxicity. These results suggest the use of I.V. dextrose and insulin as a possible heatstroke therapy to reduce serum potassium by raising plasma volume, glucose and insulin levels. Since serum sodium levels appeared tightly controlled and did not approach predicted values, there must have been a net loss of extracellular sodium due to some combination of renal excretion, salivation or Na^+/K^+ exchange across damaged cell membranes.

In summary, although not completely analyzed, these results should provide the data required to a) formulate further research protocols, b) serve as an untreated control group for severe, untreated heatstroke and c) provide further insight into the concept of using rate of change rather than levels of key pathochemical substances as prognostic indicators.

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION* DA OB 6146	2. DATE OF SUMMARY* 78 10 01	REPORT CONTROL SYMBOL DD-DR&E(AR)636
3. DATE PREV SUM'RY 77 10 01	4. KIND OF SUMMARY D. Change	5. SUMMARY SCTY* U	6. WORK SECURITY* U	7. REGRADING* NA	8a. DISB'N INSTR'N NL	8b. SPECIFIC DATA-CONTRACTOR ACCESS [X] YES [ ] NO / 9. LEVEL OF SUM A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	043
b. CONTRIBUTING				
c. CXXXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)*
(U)Physical Fitness Level Requirements and Evaluation for the US Army(22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
012900 Physiology; 012500 Personnel Training & Evaluation

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

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b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	15.3	108
	CURRENT 79	15	207

19. RESPONSIBLE DOD ORGANIZATION
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NAME: DA

21. GENERAL USE
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22. KEYWORDS (Precede EACH with Security Classification Code) (U)Job Fitness Requirements; (U)Physical Fitness Standards; (U) Energy Cost; (U) Military Occupational Specialties; (U) Muscle Strength

23. TECHNICAL OBJECTIVE.* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) A sound physical fitness training program in the Army should include a scientific matching of fitness standards to specific job requirements. New enlistees should also be screened for physical fitness and classified acocrding to physical capacity for job eligibility.

24. (U) Specific studies will include: (1) Determination of fitness requirements (aerobic, anaerobic strength) for each job grouping; (2) Develop a physical fitness battery suitable for screneing new accessions at Armed Forces Entrance Examination Stations and MOS qualification; and (3) Survey levels of fitness where appropriate to insure adequacy and appropriateness of training programs.

25. (U) 77 10 - 78 09 (1) The first phase of a combined effort with TRADOC to revise the Army's physical training program has been completed. This portion included new standards and training exercise packages for all "Baseline" category soldiers, i.e., soldiers with non-physically demanding MOSs. These standards were based on physiological cost measures of five "common soldiering tasks". (2) In response to DCSPER tasking to develop and evaluate a test battery for fitness screening at AFEES, a study was carried out on 1500 new accessions. The battery that best predicted completion of BT and physical performance success included an exercise HR test of stamina, isometric strength of legs and arm/shoulders, percent body fat and behavioral assessment of psychosomatic complaints and coping response.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	043 Physical Fitness Level Requirements and Evaluation for the US Army
Study Title:	Physiological Costs and Training Responses of the Echo (Baseline) MOS Program
Investigators:	John F. Patton III, Ph.D., James A. Vogel, Ph.D., William L. Daniels, CPT, MSC, Ph.D., Dennis M. Kowal, CPT, MSC, Ph.D., Dan S. Sharp, CPT, MC, M.D. and Robert P. Mello. M.A.

Background:

Under a tasking from the Army Deputy Chief of Staff for Personnel, this Institute is collaborating with the Army Training and Doctrine Command (TRADOC) to revise the Army's physical fitness standards and training program (Figure 1). The basis for this new program is the establishment of fitness standards based upon job requirements, regardless of gender or age.

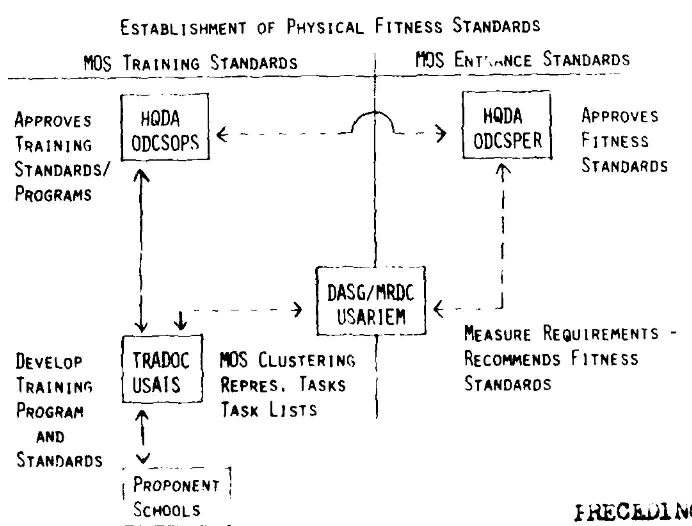

Figure 1:	DA organizational concept for responsibility to establish MOS and entrance standards for physical fitness

The establishment of these standards follows the steps described in Figure 2. The first two steps have been completed and the clustering of MOSs has resulted in the following classification:

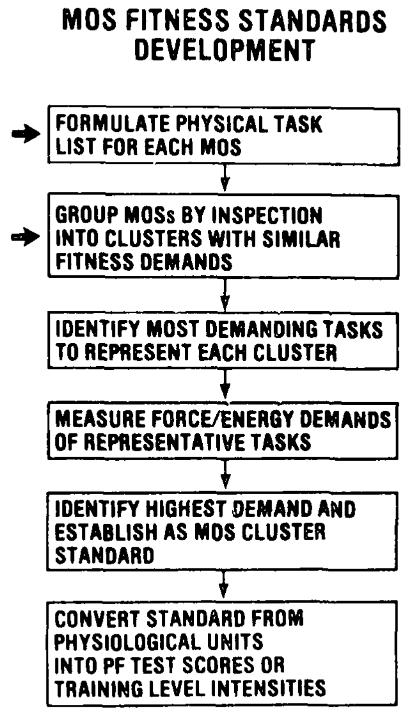

Figure 2: Steps to establish MOS physical fitness standards

TABLE 1

Clustering MOSs According to Aerobic Power and Strength

Cluster Designation	Grouped by Aerobic Power	Strength
Alpha	High	High
Bravo	Medium	High
Charlie	Low	High
Delta	Low	Medium
Echo (Baseline)	Low	Low

The arbitrary ratings were based on the following criteria:

TABLE 2

MOS Clustering Criteria

Category	Muscle Strength (kg) Weight to be Lifted	Aerobic Demand (Kcal/min)
Low	< 30	< 7.5
Medium	30-40	7.5-11.25
High	> 40	> 11.25

The next step in determining fitness requirements is the identification of representative physical tasks for each cluster. The minimum physical fitness requirement will then be based on the greatest energy demand measured among all the representative tasks of that cluster. These requirements will first be expressed as capacities in the physiological terms that they were measured, e.g., maximal oxygen uptake and maximal muscle strength. However, since testing for MOS in practice is carried out as performance tests (mile run, sit-ups and push-ups), regression analysis will be used to convert physiological data to performance standards.

This entire process has now been completed for the first cluster known as Echo or Baseline. This cluster represents all those MOS that require the minimum level of physical fitness. These MOS are generally "sedentary" in nature and are not dependent upon a specific level of physical fitness to meet job demands. This cluster had no physical tasks on which to base a fitness requirement. TRADOC, however, decided that the requirement will be based on a group of five tasks called "common soldiering tasks". These tasks have been established as a necessary minimum for all soldiers irrespective of MOS. They are:

1. 8 km march in 2 hours.
2. One-man emplacement dig in 45 min.
3. Lift and carry 50 lbs bag 50 m, 8 times in 10 min.
4. Low and high crawl for 75 m in 90 sec.
5. Rush 75 m with 2 intermediate stops of 2 secs each in 25 secs.

Progress:

A research study designed to measure the energy demand of the common soldiering tasks and to thus determine performance standards for the Echo (Baseline) cluster was carried out between January and April 1978. The study employed both male and female recruits at the Ft. Jackson Training Center.

The fitness requirements for the Baseline cluster in terms of minimum scores for the new three-event physical fitness test (mile run, push-ups, sit-ups) were derived in two ways: a) regression analysis equating fitness test scores to common soldiering task scores; b) actual energy cost measures of selected common soldiering tasks (CST).

a. Regression Analysis

Multiple regression analysis was performed on the physical fitness test event data and the CST data obtained from a sample of 1200 male and female recruits during the final week of Basic Training. Tables 3, 4 and 5 present the correlation and regression analysis for the mile-run, sit-ups and push-ups, respectively. The standard for each event was calculated using the standard for the CST event in the regression equation and adding two standard errors of the estimate (SEE) to represent a range that 95% of the population could attain.

The time for the one-mile run had the highest correlation with the rush event (Table 3) resulting in a standard of 612 sec or 10.2 min. The CST which correlated the highest with sit-ups (Table 4) was the crawl event ($r = 0.24$) which resulted in a standard of 16. The highest correlation for push-ups (Table 5) was with the crawl event ($r = 0.58$) which when used in a regression equation showed a need to perform 11 in order to achieve the standard.

Table 3
Correlation and Regression Analysis Between One-Mile Run Time and Common Soldiering Tasks (CST).

CST(STD)	Multiple r	Regression Equation	SEE	Y + SEE
Rush (25 sec)	0.60	Y = 236 + 10(25)	62*	612*
Lift and Carry (10 min)	0.57	Y = 72 + 7(10)	56	254
8 km March (120 min)	0.58	Y = 113 + 3(120)	57	587
Dig (45 min)	0.38	Y = 75 + 6(45)	56	457

SEE = Standard error of estimate.
* mile run time (secs)

Table 4
Correlation and Regression Analysis Between Sit-ups and Selected Common Soldiering Tasks (CST)

CST(STD)	Multiple r	Regression Equation	SEE	Y - 2SEE
Dig (45 min)	0.13	Y = 50 - .054(45)	11.5*	25*
Lift and Carry (10 min)	0.21	Y = 50 - .053(10)	11.5	26
Crawl (90 sec)	0.24	Y = 45 - .067(90)	11.5	16

SEE - Standard error of estimate
* Number of sit-ups

Table 5

Correlation and Regression Analysis Between Push-ups and Selected Common Soldiering Tasks (CST).

CST(STD)	Multiple r	Regression Equation	SEE	Y 2SEE
Dig (45min)	0.38	Y = 50 [illegible] .16(45)	10*	23*
Lift and Carry (10 min)	0.45	Y = 50 [illegible] .14(10)	10	29
Crawl (90 sec)	0.58	Y = 47 − .18(90)	20	11

SEE Standard error of estimate
* Number of push-ups

b. Energy Cost Analysis

The CST possessing a significant aerobic component e.g., 8 km march, dig emplacement and lift and carry were measured to determine their energy cost. This was carried out in both men and women using portable Max Planck respirometers (2). The oxygen uptake in l/min was converted to Kcal/min by assuming 5 Kcal for each liter of oxygen consumed. Table 6 presents the energy cost data for the three CST measured.

TABLE 6

Energy Cost of Common Soldiering Tasks (Mean ± SE)

Event	KCal/min Male	KCal/min Female
8 km March	9.[illegible] ± 0.5(16)	6.1 ± 0.5(11)
Dig Emplacement	8.[illegible] ± 0.5(12)	5.3 ± 0.3(12)
Lift and Carry	11.5 ± 0.9(12)	7.9 ± 0.3(11)

Number of subjects in parentheses.

The energy cost of the lift and carry was the highest, so data from this event was used to determine the aerobic requirement or one mile run time for the Echo cluster.

By combining the male and female data (n = 23) for the lift and carry, a relationship was established between oxygen uptake (l/min) and performance time (min) for this event (Figure 3). From this data it can be seen that the standard of 10 min. is equivalent to an oxygen uptake of 1.25 l/min. This is equivalent to 6.25 Kcal/min (5 Kcal per liter of oxygen). If one assumes that this rate should not exceed 70% of ones maximal work intensity (3), then this energy expenditure is equivalent to a maximal work capacity of 9 Kcal/min. This, in turn, is known to be equivalent to a one-mile run time of approximately 10.5 minutes (3).

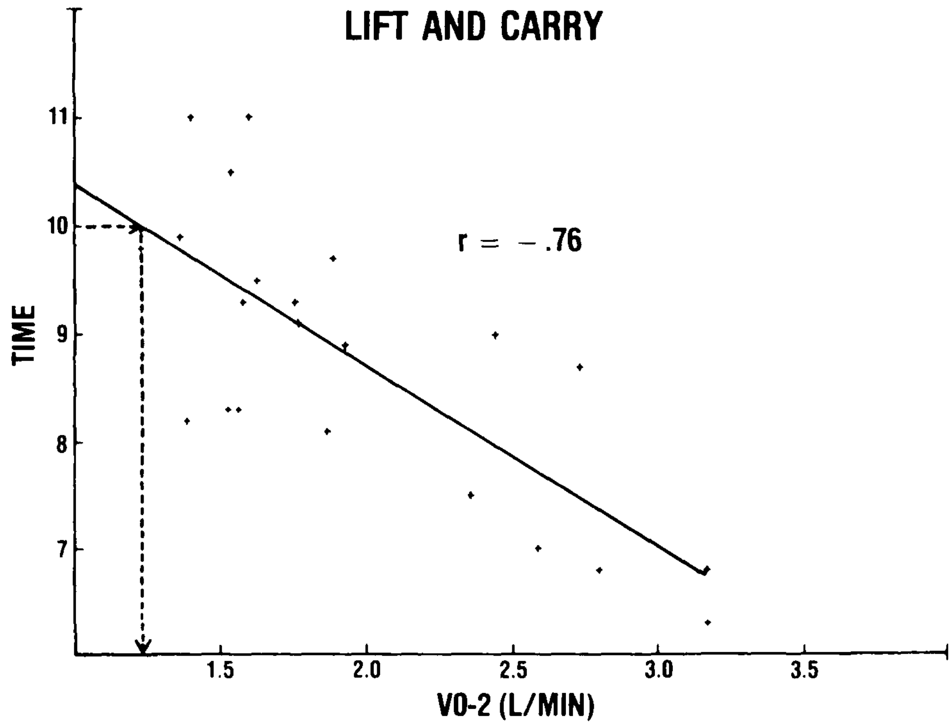

Figure 3: Relationship between oxygen uptake (l/min) and performance time (min) for the lift and carry

c. Establishment of Fitness Standards

The standard for the one-mile run using energy cost analysis compared favorably with the one-mile run standard calculated using regression analysis. Therefore, based on the data collected at Ft. Jackson, this Institute recommended to TRADOC that the standards of the three-event PT test be as follows:

TABLE 7

Test Event	Standard
One-mile Run	10.2 minutes
Push-ups	11 reps in 2 mins.
Sit-ups	16 reps in 2 mins.

It should be pointed out that while standards have been recommended for the 3-event PT test, it is questionable whether these standards pose an appropriate physical challenge to the majority of male recruits. Indeed, the emphasis for achievement is to be placed on training progression level intensity for the program designed by TRADOC for the Echo Cluster.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	043 Physical Fitness Level Requirements and Evaluations for the US Army
Study Title:	Evaluation of a Physical Fitness Test Battery for Armed Forces Entry Examination Stations
Investigators:	Dennis M. Kowal, CPT, MSC, Ph.D., James A. Vogel, Ph.D., Dan Sharp, CPT, MC, James E. Wright, CPT, MSC, Joseph J. Knapik, Specialist 6, M.S., John F. Patton, Ph.D. and William L. Daniels, CPT, MSC, Ph.D.

Background:

The Armed Forces are considering supplementing the present entry medical examination with an evaluation of physical fitness (stamina and muscle strength) at the entrance examination station. This has been precipitated by several considerations: (1) the findings of the GAO that personnel are being assigned to MOSs in which they could not physically perform, (2) the recent expansion of women into jobs previously held by men, and (3) the high attrition rate during basic training due to physical inability to perform during training. These considerations have necessitated the development of a test battery by which potential enlistees could be screened for entry into service and evaluated for the jobs in terms of their physical capacity, prior to entry into the service.

Our laboratory was tasked by the Army Deputy Chief of Staff for Personnel to ".... develop, for pilot testing, a battery of physical fitness tests suitable for screening new accessions for MOS classification during the AFEES medical examination."

Progress:

Due to administrative problems at AFEE stations, the study was carried out at the Ft. Jackson Training Center using recruits in Basic Training (BT). The study design is outlined in Figure 1. The physical fitness test battery (PFTB) as it might be administered in the AFEES was given to new recruits during fill week prior to the commencement of any physical training. The battery was re-administered again to the same recruits at the end of BT and at the end of AIT. Criterion measures, or performance variables established by the infantry school at Fort Benning, GA included the three event Army Basic Physical Fitness Test (BPFT) and performance on the Common Soldiering Tasks (CST). These tasks have all had minimum performance standards established that all soldiers must be able to achieve, regardless of age, sex or job speciality. However, for our purposes, the actual performance on each event was measured.

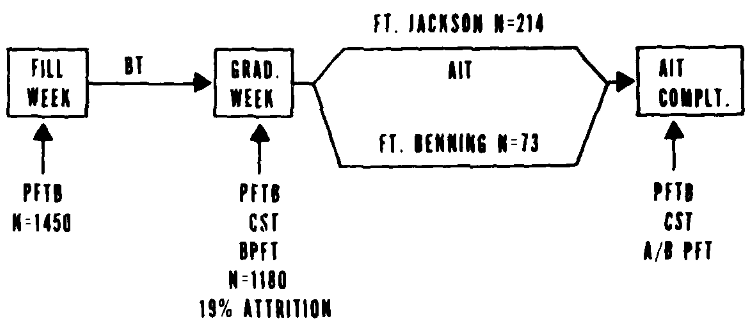

Figure 1. Experimental design of study conducted at Ft. Jackson, South Carolina in 1978. Physical fitness test battery (PFTB) was carried out before and after basic training (BT) and after advanced individual training (AIT).

The CST and their respective standards were: (a) road march 8 km in two hours; (b) dig emplacement 4 x 2 x 3 feet in 45 minutes; (c) lift and carry 50 lb bag 50 meters - repeat eight times in 10 minutes; (d) low crawl 35 meters and high crawl 35 meters in 90 seconds; and (e) rush 75 meters with two intermediate stops of two seconds each, within 25 seconds. Only 1160 out of an initial 1480 subjects completed both pre and post-basic training measurements. The other 320 were not available for post basic testing testing due primarily to injury or illness, administrative discharge, recall by reserve or National Guard unit, etc.

The PFTB proposed for AFEES was developed based on the following considerations:

a. simple and inexpensive equipment and procedures

b. brief to administer

c. requires little space

d. not excessively stressful or unsafe

e. sufficient resolution to separate fitness levels into categories for MOS assignment

f. include major fitness factors

The test battery included measures of stamina, or aerobic power, strength of several major muscle groups, e.g. leg, trunk, arms and upper torso, body composition, as well as measures of health opinions (HOS) and response to life problems (RTLP).

Aerobic power (stamina or cardiorespiratory fitness) is optimally determined in the laboratory by the measurement of maximal oxygen uptake ($\dot{V}O_2$ max). In the field setting or in population studies, $\dot{V}O_2$ max can be predicted by heart rate measurement during stationary cycling or stepping or by timed runs over a measured distance. The latter is impractical in the AFEES setting as is the cost of procuring cycle ergometers. Thus, a stepping test was selected.

Crucial to any heart rate predictive exercise test is the accurate recording of heart rate during the exercise. Stepping can cause a good deal of motion artifact on the ordinary electrocardiograph. To avoid this problem, we have worked with a commercial supplier (Gulf-Western) of a hospital heart rate monitor (cardiotachometer and digital display) to modify the electronic circuitry so as to optimally screen out artifacts. The monitor uses three point electrocardiograph leads placed at the shoulders and lateral chest wall.

A three load continuous stepping test was chosen. The test consisted of stepping at a rate of 25 steps per minute at three or four possible step heights: 10, 20, 30 or 40 cm. The loads selected were based on the stature of the individual. Stepping continued for three minutes at each level proceeding immediately to the next level without rest. During the course of the study a subsample was directly assessed for $\dot{V}O_2$ max using an interrupted treadmill test to develop a predictive equation for the stepping test.

The maximal strength capacity of a particular muscle group is best assessed by a measure of the peak isometric or static force that can be briefly exerted. Such a procedure minimizes the problem of motivation and is quite safe and reproducible. For an AFEES application, we designed equipment that is precise, compact and relatively inexpensive to measure maximal static strength. The design was based on equipment originally designed by Asmussen and modified by Hermansen for similar purposes in the Norwegian Army. However, the AFEES design incorporated all measurements within a single device and utilized an inexpensive cable tensiometer (Pacific Scientific Corp.).

Strength of leg extensors was determined by testing the quadriceps femoris muscle. The subject sat securely fastened in the chair of the apparatus with knees bent at 90° and grasped handles on the seat edge for additional stability. Upon command, he exerted maximal outward force for 3-4 seconds on a bar situated in the arch of the feet, the bar being connected in the rear to a cable tensiometer transducer.

The strength of the upper torso (arm and shoulder flexors) was assessed with the subject securely fastened with a lap belt in a sitting position. The upper arms were parallel to the floor and form a 90° angle when they grasped an elevated overhead bar connected to the tensiometer. The subject pulled downward maximally for 3-4 seconds.

The strength of the mid-trunk (back) extensors were assessed with the subject in the standing position with shoulders strapped to a stabilizing bar connected to the tensiometer. The subject was instructed to bend back against the shoulder harness while supporting the pelvic girdle against a plate, maximally for 3-4 seconds.

In addition to standard height and body weight measures, percent body fat was estimated by measuring four skin folds and applying them to a body density equation for the calculation of body fat. Harpendin calipers were employed.

The Health Opinions Survey (HOS) which assesses the psychosomatic predisposition of individuals and the Response to Life Problems (RTLP) which evaluates a person's ability to cope with environmental stress were used to provide a motivational parameter for the prediction of performance during basic training.

Physical performance on the CST and the Army BPFT were the primary validation measurement for the test battery. The completion of basic training was another major criterion measure that was considered. Trainees were dichotomized on the basis of completion of basic training or recycling (Disposition 1 or 2 respectively) or discharged from the service for medical or administration reasons (Disposition 3 or 4 respectively).

Table 1 summarizes the pre- and post-training values for the 1160 men and women who completed basic training. The significant pre-post differences document the effects of basic training on physical conditioning and performance reported in previous research from this laboratory. Likewise, the substantial differences between men and women were apparent.

In order to predict the aerobic power or fitness from the step test and other available measures, a multiple regression model was used. It produced an equation that combined body fat, leg strength and the heart rate response at the highest work load for men and women. The resulting correlation was significant R = .88. This provided an excellent estimation of aerobic fitness that may be useful for the AFEES application. The predicted $\dot{V}O_2$ max values pre and post training are presented in Table 2 for men and women respectively.

TABLE 1

Mean and SD of Test Parameters for Male and Female Subjects

Pre- and Post-Basic Training

Variable	MALES (n=993) Pre	MALES (n=993) Post	FEMALES (n=393) Pre	FEMALES (n=393) Post
Weight (kg)	70.8 ± 10.6	71.6 ± 8.7*	59.1 ± 7.0	61.3 ± 6.7*
Height (cm)	174.3 ± 6.6		162.5 ± 6.8	
% Body Fat	16.2 ± 5.1	14.5 ± 3.7*	27.9 ± 4.7	26.5 ± 3.6*
LBM (kg)	58.8 ± 6.8	60.7 ± 6.9*	42.4 ± 4.6	44.9 ± 4.2*
Step Test HR				
HR2	125.1 ± 14.6	120.6 ± 10.3*	123.1 ± 13.9	115.6 ± 12.0*
HR3	145.7 ± 16.4	139.3 ± 10.8*	144.6 ± 15.4	134.1 ± 11.9*
HR4	165.4 ± 15.3	157.5 ± 24.7*	165.7 ± 15.0	152.6 ± 11.5*
VO_2max (ml/kg min)	50.6 ± 4.6	51.9 ± 3.9*	37.0 ± 3.6	38.9 ± 3.7*
HR_{max} (bpm)	191.9 ± 6.0	187.2 ± 6.4*	190.5 ± 7.8	183.9 ± 9.0*
Strength (kg)				
Legs	143.1 ± 38.3	158.4 ± 41.1*	93.4 ± 30.0	106.5 ± 31.1*
Trunk	72.6 ± 18.2	79.0 ± 16.5*	47.6 ± 12.6	56.6 ± 10.5*
Upper Body	97.7 ± 18.1	102.1 ± 16.2*	55.2 ± 11.7	60.9 ± 9.6*
1 Mile Run (sec)	486.5 ± 69.6	447.5 ± 60.6*	685.6 ± 103.8	569.6 ± 66.8*
Push Ups	29.6 ± 10.9	28.6 ± 10.6	10.8 ± 7.8	10.4 ± 7.8*
Situps	32.2 ± 10.7	38.4 ± 11.4*	22.9 ± 10.8	31.7 ± 11.5*
8km March (min)		62.4 ± 7.7		74.1 ± 8.1
Lift/Carry (sec)		464.6 ± 78.9		555.9 ± 62.3
Dig (min)		32.9 ± 10.7		45.3 ± 12.3
Lo-Hi Crawl (sec)		88.9 ± 22.1		164.0 ± 50.0
75m Dash (sec)		22.1 ± 2.6		29.4 ± 4.9
Psychosomatic Complaints (HOS)	29.5 ± 6.5	26.8 ± 6.9	31.5 ± 6.1	29.6 ± 5.5
Coping Response (RTLP)	36.9 ± 6.6	37.1 ± 6.3	37.4 ± 6.2	36.6 ± 6.1

*$p \leq .01$

TABLE 2

Aerobic Power (Predicted $\dot{V}O_2$ Max)

(ml/kg • min)

	MEN	WOMEN	% Δ
PRE-BT	48.5	38.7	20
POST-BT	50.9	41.3	19
% Δ	2	3	

TABLE 3

Prediction of Criterion Measures Using

Test Battery Measures

CRITERION	PREDICTED BY	R
Mile Run	Leg strength + Ex_{hr}	.61
Push-ups	Upper body and trunk strength	.59
Sit-ups	----------	---
8 km March	Leg strength and upper body strength	.57
Dig Emplacement	Upper body strength	.44
Lift and Carry	Upper body strength	.62
Crawl	Upper body strength	.67
75m Dash	Upper body strength	.67
Aerobic Power	Leg strength + Ex_{hr} + % body fat	.88
Max Lift	Upper body strength	.60

Table 3 presents a summary of the correlations of the components of the test battery with performance on the criterion measures. As can be seen, the isometric upper body strength was the principle component, in the prediction of most of the events, suggesting that this simple measurement may be the best available measure for the prediction of physical performance during basic and the AFEES application. However, if the battery is to be used for MOS assignment, a battery consisting of leg strength, upper torso strength, exercise heart rate, and body composition will provide the best combination of variables for the profiling of recruits for MOS assignment.

The overall discharge rate from basic training for the sample studied was 19%. This comparatively small percentage limits the predictive power of any normally distributed measure. In addition, it should be noted that half of the discharges were accomplished during the first week of training. The remaining discharges occurred during the next six weeks but in either case, no post separation measures were available. A discriminant analysis was used to develop an equation based on the classification of basic trainees into one of two groups: successful completion of basic training or discharge from service for either administrative or medical reasons. A linear combinations of variables or measures gathered prior to the beginning of basic training were entered into the equation, means and SD for these variables are presented in Table 4. The classification results produced by the discriminant analysis (Table 5) indicate that we could correctly classify about 70% of the trainees prior to basic training using only the HOS. However, this discriminant function is subject to a reduced efficacy of prediction common to all regression procedures. That is, the equation maximizes the differences between the independent variables and the categories in this sample population. However, when a new sample or a different training program is instituted or a different discharge policy is implemented, this maximization is not operational and may not produce the same magnitude of predictability. Likewise, the rate of false positives obviates the instruments use for actual entry selection purposes.

TABLE 4

Means and SD for Two Disposition Groups and Variables Introduced into the Predictive Equation

Variable	Completion of BT (N=914)	Discharge from BT (N=97)
Height (cm)	170.3 ± 8.7	170.3 ± 9.0
Body Fat (%)	19.7 ± 7.2	18.9 ± 8.1
HR 2 bpm	124.6 ± 14.6	126.4 ± 13.9
HR 3 bpm	145.7 ± 16.0	147.9 ± 15.0
HR 4 bpm	165.8 ± 15.3	167.6 ± 14.3
Avg Leg Strength (kg)	126.8 ± 42.9	120.8 ± 36.9
Mile Run (sec)	544.0 ± 119.6	568.1 ± 136.6
Push ups	23.9 ± 13.4	21.6 ± 12.2
RTLP (5 items)	13.4 ± 2.8	12.6 ± 3.1
HOS (5 items)	9.5 ± 2.3	10.6 ± 3.1

TABLE 5

Discriminant Function Analysis Using HOS 1 Items for Groups 1 and 2 vs. 3 and 4 (a) Both Males and Females, (b) Males Only and (c) Females Only

		% Correct Classifications
(a)	Males and Females	
	Disposition 1 and 2	67.6
	Disposition 3 and 4	55.2
	Total correct classifications	65.0
	Items which discriminated (in order of appearance)	7,9,1,20,5
(b)	Males	% Correct Classifications
	Disposition 1 and 2	72.4
	Disposition 3 and 4	44.0
	Total correct classifications	68.9
	Items which discriminated (in order of appearance)	4,8,20,9,5
(c)	Females	% Correct Classifications
	Disposition 1 and 2	71.7
	Disposition 3 and 4	62.7
	Total correct classifications	70.6
	Items which discriminated (in order of appearance)	7,9,1,10,4

Discharge or completion of basic training was evaluated separately for males and females. Slightly better predictions could be made for females than males and the correct classifications was better for completion than for discharge. The significant and meaningful factors involved in this prediction were the responses to items of the HOS test ($F = 15.81$ DF 1/1009, $P < .01$). The addition of other variables contributed no valuable information regarding completion of basic training. However, this was not the case for the prediction of specific performance tasks during training.

In summary, the AFEES test battery, consisting of heart rate, body composition (skin fold method), static leg strength and upper torso strength successfully relate to fitness and performance on military tasks during basic training. These components provide a profile that may be suitable for application to the selection and assignment to specific MOS clusters. However, the effectiveness of the battery remains to be validated on populations within each of the MOS clusters. Motivational measures were found to successfully predict completion or discharge from basic training for 70% of the trainees. However, caution must be used in any generalized implementation of these findings, since changes in the accession policies, populations that enter the Army or conditions and requirement of military training may invalidate these findings. We feel that the test battery, if completed at the AFEES, could significantly improve the screening of applicants for both fitness levels, MOS performance and subsequent success for failure in the military setting, but further validation research is imperative if a useful selection instrument is to be developed. Likewise, the efficacy of this test battery to predict performance in specific MOS clusters remains to be accomplished.

Presentations:

1. D. M. Kowal and J. A. Vogel. Fitness assessment for entry into the service -a two edge sword? Military Testing Association Conference, San Antonio, TX, 17 Oct 77.

2. D. M. Kowal, J. A. Vogel and D. Sharp. The prediction of performance and attrition of recruits during basic training. AMEDD Current Trends in Psychology Conference. El Paso, TX, Nov 78.

Publications:

1. D. M. Kowal, J. A. Vogel, J. F. Patton, W. L. Daniels and D. S. Sharp. Evaluation and requirements for fitness upon entry into the US Army. NATO Report DS/DR (78)98, 1978.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	043 Physical Fitness Level Requirements and Evaluation for the US Army
Study Title:	Physiological Demands of MOS Clusters
Sub-Study Title:	Estimates and Classification of Army MOS Fitness Demands
Investigators:	James E. Wright, CPT, MSC, Ph.D. and James A. Vogel, Ph.D.

Background:

There are currently more than 300 Army enlisted occupational specialties, classified into some 30 career management fields. The objective of medical procurement standards in the past has been to screen out individuals deemed incapable of performing in at least two MOS. Selections for MOS assignments have been made by the use of gross physical profiles (Chapter 9, AR 40-501) specified in the MOS manual (AR 611-201). With the recent large influx of women into the military, however, it has become apparent that the findings on medical examination which determine appropriate numerical designators in the physical (medical) profile series, with the exception of auditory and visual functions, do not necessarily translate into accurate indicators of the physical ability (fitness) required to perform the duties in specific MOS.

In addressing this issue, DCSPER tasked TRADOC and the Office of The Surgeon General with revamping the Army physical training program so that standards and training are realigned to meet the specific requirements of MOS, regardless of age or gender. The general tasking was further delineated into two specific requirements: (1) determining the physical fitness requirements for specific MOS, and (2) developing a fitness evaluation system for use in personnel selection for MOS assignment.

Progress:

The basic research approach to the first requirement, reported by Vogel et al. in 1977 (4), consists of the following objectives:

(1) The grouping of individual MOS by inspection into clusters of similar MOS based on their strength and stamina demands.

(2) The selection of representative tasks for each cluster, to include those which appear to possess the most stringent demands for the various fitness components.

(3) The quantitative assessment of the physiological costs of each representative task, and,

(4) The identification of those tasks with the highest strength and stamina demands and subsequent establishment of these demands, converted into performance units (such as push-ups, sit-ups, etc.), as the MOS cluster requirement.

Prior to USARIEM action on the first requirement, all physically demanding tasks within each MOS were identified and described in detail by wartime veterans and instructors from the proponent schools for each MOS (3). These job specifications were analyzed by the principal author and categorized based on the criteria in Table 1. The clustering was accomplished exclusively by means of the task lists submitted by TRADOC without regard to age, grade, or peacetime versus wartime requirements.

TABLE 1

Preliminary Physical Demand Classification Criteria

Physical Demand Category	Muscle Strength Requirements (Lifting-lbs)	Aerobic Requirements KCal/min.	Aerobic Requirements Ft.lbs/min.
1 (high)	85+	11.25+	690+
2 (medium)	66-85	7.5-11.25	475-690
3 (low)	0-65	0-7.5	0-475

Weights for the three categories were selected primarily on the basis of standards established by TRADOC for the Baseline (low demand) MOS and the natural breaks in the weights of objects lifted in the more demanding MOS. This classification is predicated upon the demands of a single lift or lift and carry task. Extended durations of activity (repetitive lifting), unusual postural or other factors increasing or decreasing task demands can alter the classification scheme significantly as can variations in methods or equipment used in task performance, mission requirements, or environmental factors. Stamina classification criteria were derived from estimated energy costs of the most demanding repetitive lifting, pushing, pulling, supporting and/or carrying tasks within the MOS. The few data available in the literature on work classification scales for industrial population (1,2,5) were of limited value in establishing these criteria due to major differences in the demands of military versus civilian jobs and in the physical characteristics and (physical) training backgrounds of the work force itself. Even the low, or Baseline, requirements of the Army would be classified as heavy to very heavy work according to the several accepted classification schemes (1,2,5).

Table 2 indicates the relative strength and stamina demands of the 5 clusters and indicates both the total number of MOS and the percentage of enlisted personnel within each cluster. Table 3 depicts the MOS assigned to each cluster.

TABLE 2

MOS Clusters

	Physiological Requirements		Total	% Enlisted
Cluster	Strength	Stamina	MOS	Personnel
Alpha	High	High	10	19
Bravo	High	Medium	39	13
Charlie	High	Low	63	21
Delta	Medium	Low	53	21
Echo (Baseline)	Low	Low	184	26

TABLE 3
MOS by Cluster

ALPHA	BRAVO		CHARLIE			DELTA		
ENGR	AR	MED	ADA	FA	ORD	ADMIN	INTEL	QM
12B	19D	91H	16D	13E	34G	71L	17K	43M
12C	19E	91J	16E	15D	44B		26E	57E
51B	19F	91L	16F	15E	45B		33S	76D
51C	19G	91N	24C	15J	45K	ADA	98C	76V
51H	19H	91P	24E	17B	63C	24N	98G	76W
	19J	91Q	24G	17C	63F		98J	76X
		91R	24M	21G	63G		05D	
		91S	24P	93E	63H		05G	SIG
FA	FA	91T		93F		CHAP	05H	26D
13F	13B	91U	AR		QM	71M	05K	26L
		91V	45N	MP	57F			26Q
INF	MED	91W	45P	95B	76Y	CHEM	M/M	26R
11B	35G	91Y	45R	95C	92C	54C	27B	26T
11C	35S	92B		95D		54E	27E	31M
11H	35T	94F	ENGR		SIG		27F	31V
	35U		35E	MSL/MUN	36C	ENGR	27G	34B
MED	42C	MSL/MUN	51M	21L	41E	12E	27H	34J
91B	42D	35B	51N	22N	84F	51R	46N	36D
	42E	55X	52D	24H		52E		05B
	71G		53B	24J	TRAN	62G	ORD	05C
	76J	QM	62B	24K	76G	00B	41C	
	91C	43E	62E	24L	67N		45L	TRAN
	91D		62F	35F	67U	FA	63B	64C
	91E		62H	55D	67X	26B	63J	68B
	91F		62J	55G	67Y			68F
	91G				68D			68J

TABLE 3a
MOS by Cluster

Echo (Baseline)

ADMIN	ADA	CHEM	FA	MED	MUSIC	SIG	SIG	TRAN	Proponent Unknown
71C	16B	92D*	13W	01H	02J	26V	33B	57H	00D*
71D	16C		13Y		02K	26Y	33K	61B	00Z*
71E	16H	DEF INFO	13Z	MSL/MUN	02L	31E	33L	61C	09B*
73C	16J	71Q	15B*	22K*	02M	31J	33M	61F	09D*
73D	16P	71R	15F	22L	02N	31N	33P	61Z*	09S*
73Z*	16R		82C	23N	02P	31S	33R	64Z*	09W*
74B	16Z*	ENGR		23Q*	02Q	31T	36E	65B*	
74D	24B*	12Z	INTEL	23S*	02R	31Z	36H	65D*	
74F	24D*	41B	17L*	23T*	02S	32D	36K	65E*	
74Z*	24F*	41K	17M	23U	02T	32F	36L	65F*	
75B	24Q	51G	26C	23V*	02Z	32G	72E	65G*	
75C	24U	51P*	26K*	23W		32H	72G	65H*	
75D	25J*	51T*	26M*	24V	ORD	32Z	72H*	65J*	
75E	25K*	51Z*	26N*	27Z	44E	34E	81E	65K*	
75Z*	25K*	52C	41G*	35H	45Z*	34F	84B	65Z*	
79D	25L*	62N*	96B	55Z	54D	34H	84C	67W*	
00E	26H*	81B	96C		63Z*	34K	84T	67Z*	
00J		81C	96D	MUSIC		34Z	84Z	68G	
00U	AR	81Z	96H*	02B	QM			68H	
05C	19Z*	82B	96Z	02C	43J			68K*	
		82D	97B	02D	76P*			68M	
	AVN	83E	97C	02E	76Z*			71N	
	71P	83F	98Z*	02F	94B				
	93H			02G					
	93J			02H					

*No task list provided to date. Assigned to Baseline pending receipt of task list.

The 6-10 most physicaly demanding tasks within a cluster have been designated as representative tasks for that cluster. Plans call for the measurement of the energy and muscle strength costs of the representative tasks. The data gathered will be used to verify the clustering and, in conjunction with TRADOC, to establish appropriate training exercise levels for each cluster and minimum acceptable exercise levels for individual physical fitness assessment. In addition, these costs will be converted into a physical fitness test battery score which will be established as the cluster entry requirement. The activities selected for physiological cost assessment are provided below.

a. ALPHA Cluster Representative Tasks

(1) MOS 11B — Wearing full combat equipment with 40-lb rucksack, march 32 kilometers in 8 hours on roads during daylight at a normal rate over generally level terrain.

(2) MOS 13F — Wearing 44-lb combat load and 50 lbs of equipment, move with dismounted infantry.

(3) MOS 12C — With 20 57-lb Bailey bridge panels and six-member team, lift and carry each panel 30 feet and assemble panels in 2 hours.

(4) MOS 51B — With 50 94-lb bags of cement, relocate bags by lifting and carrying all bags 20 feet in 1 hour.

(5) MOS 51B — With 28.5-lb gasoline powered chain saw and overhead material, operate chain saw 10 times an hour for 5 minutes at a time.

(6) MOS 91B — With medical equipment, move with dismounted infantry.

(7) MOS 91B — With two-person litter team, patient weighing up to 180 lbs, standard Army litter, and relatively level terrain, position patient on litter IAW FM 8-35 and evacuate patient 250 meters completing four round trips per hour.

b. BRAVO Cluster Representative Tasks

(1) MOS 13B — With projectiles weighing from 35 to 201 lbs and 5-ton cargo truck, lift and carry a maximum of 100 lbs 20 meters 100 times per day.

(2) MOS 13B	With various artillery pieces ranging from 105 mm to 203 mm and associated ammunition, lift and carry a maximum of 100 lbs 5 meters three times per minute for first 3 minutes and once per minute for next 30 minutes.
(3) MOS 19D,E F,G,H,J	With 20-man platoon and pioneer tools, construct a triangular or rectangular shaped crib approximately 5 feet high by 20 feet long in 8 to 12 hours.
(4) MOS 19D,E F,G,H,J	With a M113A1/M557A1 and a crew, load or unload basic issue items, ammunition, and designated and personal equipment and carry 200 meters to store all equipment within 1 hour.
(5) MOS 43E	With a modular platform for airdrop and 90-lb ammunition boxes, lift and carry boxes 22 feet and load onto honeycomb 32 times per hour 8 hours per day.
(6) MOS 55B,X	Wearing full combat equipment without mechanical loader and 70-lb 105-mm ammunition boxes, lift and carry boxes 20 feet and load onto truck continuously for 12 hours per day.

(7) MOS 35G,S,T,U; 42C,D,E: 71G; 76J; 91C,D,E,F,G,H,J,L,N,P,Q,R,S,T,U,V, W,Y; 92B, 94F

With supplies and equipment weighing up to 100 lbs, vehicles or shelving, lift and carry materials 50 meters and push and pull materials 20 meters for periods of 8 hours with short rest periods.

c. CHARLIE Cluster Representative Tasks

(1) MOS 13E; 15J;17C	With 275-lb FADAC generator and two-member team, lift and carry generator 60 meters 10 times per day.
(2) MOS 24H,J K,L	Wearing full combat equipment with electronic equipment weighing up to 390 lbs, no mechanical loader, and four-member team, lift and carry equipment 40 feet four times a day.
(3) MOS 45N,P R	With M48A5, M60, M60A2 and/or M551, toolbox, and appropriate equipment and technical manuals, remove and install various pieces of equipment weighing from 10 to 180 lbs.

Time standards vary and crew assistance is available when needed.

(4) MOS 53B — With 80 250-lb chemical containers and a two-member team in a storage area, lift and carry containers 25 meters and stack them 10 times per hour for 8 hours per day.

(5) MOS 57F — With a litter, 180-lb remains, and two-member team, lift and carry remains 900 feet three times per hour for 8 hours.

(6) MOS 62H — With 50 94-lb bags of cement, lift and carry bags 10 meters and stack them 10 bags every 15 minutes.

(7) MOS 62J — With air compressor, 80-lb jack hammer, and concrete slab at construction site, operate jack hammer 45 minutes per hour for 8 hours.

(8) MOS 84F — With appropriate construction materials and equipment, construct, position, and secure production sets, props, and flats or furniture in TV/MPOIC facilities.

d. DELTA Cluster Representative Tasks

(1) MOS 33S; 98C,G,J; 05D,G,H,K

Wearing full field equipment without pack, lift and carry 55-lb boxes to/from 2 1/2 ton truck bed 30 times in 2 hours; carry 14-lb items 50 meters five times in 30 minutes; drive 2-meter ground rod 1 3/4 meters deep using 5-lb sledgehammer; change flat tire.

(2) MOS 36D — With proper supplies, safety equipment, and three-member team, construct self-supporting antenna tower.

(3) MOS 54C,E — Wearing chemical protective overgarment, mask and hood, lift and carry two 30-lb smoke pots 30 meters and stack them, 10 times in 2 minutes.

(4) MOS 54C,E — Wearing chemical protective overgarment, mask and hood with 50-lb STB cans and a decontamination truck, lift and load 10 cans of STB onto truck in 1 minute.

(5) MOS 62G — With 75-lb pieces of drill steel and truck at drill site, lift and carry four pieces of steel 50 meters in 15 minutes, repeat task for 4 hours per day.

(6) MOS 68J With 255-lb M28A1E1 ammunition, no mechanical lifter, aircraft, and three-member team at flight line, lift and load ammunition magazine into aircraft within 15 minutes six times per day.

(7) MOS 71M Wearing full combat equipment, 1/4-ton M151A truck and M151A trailer, supplies and "equipment" weighing from 10 to 150 pounds, and two-member team, lift and carry "equipment" 15 feet to/from trailer.

(8) MOS 76D With pallets and 60-lb containers of batteries on truck, lift containers from truck and carry 50 feet to pallets 40 times per hour 8 hours per day.

(9) MOS 76V In shipping section of open or covered storage facility with 75-lb containers of tools or weapons, either (1) climb ladder and remove containers from heights of 4 to 12 feet and descent ladder with container, or (2) remove container from storage location with heights from 1 to 4 feet, and carry containers 100 feet five times per hour 8 hours per day.

(10) MOS 76X With class B ration containers weighing 30 to 50 lbs, in troop issue subsistence activity, lift and carry containers 20 feet 60 times per hour 4 hours per day.

In summary, this report describes the initial step of a plan which will ultimately improve the capability of the Army to select and assign personnel to various MOS. The process by which MOS were grouped into clusters and categorized as to their physical demands is described. The representative, or most demanding tasks within each cluster are listed. The actual physiological costs of these tasks will be measured in FY 79 and subsequently used to establish training and entry standards.

Presentations:

Patton, J. F., J. A. Vogel and D. M. Kowal. Requirements for Fitness According to Job Assignment in the U.S. Army. First NATO Symposium on Physical Fitness. Toronto, Canada, April 1978.

Publications:

Same as above

NATO Report DS/DR(78)98, pages 87-92, 1978.

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3. United States Army Infantry School. MOS Physical Task List. Ft. Benning, GA. October, 1978.

4. Vogel, J. A., Patton, J. F., Kowal, D. M., Daniels, W. L. and Sharp, D. S. Determination of the Physical Fitness Requirements of Sedentary MOSs in the Army. USARIEM (Natick, MA) Annual Progress Report, 203-208, 1977.

5. Work classification according to: Air Force Manual 39-1. Airman Classification Manual, 1969.

(83045)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
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3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	045
b. CONTRIBUTING				
c. XXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)*

(U) Treatment of Cold Injury (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 002300 Biochemistry; 002600 Biology; 012900 Physiology; 005400 Environmental Biology; 003500 Clinical Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	2.3	33
	CURRENT 79	3	38

19. RESPONSIBLE DOD ORGANIZATION

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20. PERFORMING ORGANIZATION

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SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: DONOVAN, John C., CPT

NAME: 955-2866 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Cold Injury; (U)Hypothermia; (U)Fasciotomy; (U)Vasodilation; (U)Angiography

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Although cold injury is of little clinical significance in the civilian community, it has had serious impact on every Army that has attempted to fight in the cold. Hospitilization times for Korea and Second World War are 37 and 57 days respectively. Amputation and permanent loss of function and death are routine sequella. Current knowledge suggests that increased blood flow and internal methods of rewarming and surgical approaches to frostbite may decrease the hospitalization time and increase tissue salvage.

24. (U) An intervenous frostbite treatment solution was developed and utilized during the Korean conflict. Animal studies will be done with modifications of this formula to include better vasodilators to determine the effect on long-term tissue survival. Internal methods of rewarming hypothermic animals will be studied for the effects on physiologic parameters that affect survival.

25. (U) 77 10 - 78 09 Use of fasciotomy and vasodilators gave increased short-term tissue survival over non-fasciotomy and vasodilators alone. This paper has been accepted for publication. Significant alterations in venous and lymphatic drainage from frostbite extremities indicates release of cellular enzymes typical of cell damage and destruction. Differential concentrations of CPK and acid phosphotase in lymph versus venous drainage suggests different areas of release of these enzymes and separate pick-up pathways. The effect of high concentrations in different tissue compartments may influence tissue survival. Platelet aggregation within frozen extremities as a result of endothelial damage is also evident in these studies.

*Available to contractors upon originator's approval.

DD FORM 1498, 1 MAR 68 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress Physical Fitness and Medical Factors in Military Performance
Work Unit:	045 Treatment of Cold Injury
Study Title:	Evaluation of Biochemical Changes and Hemodynamics Following Frostbite in the Dog
Investigators:	Murray P. Hamlet, D.V.M. and David R. Franz, CPT, VC, D.V.M.

Background:

Most theories for the pathogenesis of tissue loss following frostbite can be divided into two categories: direct cellular damage from cold (1), and hypoxia and cell death resulting from destruction of the supportive vascular bed at the site of injury (2,3). In an attempt to descirbe aspects of the pathophysiology of frostbite in the dog, arterial venous, and lymphatic flow rates and concentrations of various humoral factors were measured in the canine rear foot before and after freezing injury.

Both moderate and severe injury groups were studied. A moderate injury involved deep foot temperature below freezing for 60 minutes and the severe injury group involved deep foot temperature below freezing for 100 minutes.

Progress:

The study is completed with the exception of evaluation of data and electron microscopy. The following trends can be seen in the raw data: 1) Decreased utilization of O_2 by injured tissue is apparent following injury. 2) Enzyme intracellular origin (CPK, GPT, and Acid Phosphatase) levels are elevated in the venous serum and greatly increased in the lymph of the injured foot following injury. The enzymes selected were used as markers for membrane permeability increases following injury: CPK (creatine phospho kinase, GPT (glutamic pyruvic transaminase), and Acid Phos. (lysosomes). CPK showed 10 to 20 fold increases in serum and as much as 60 fold increases in lymph following injury. GPT showed less increase in both serum and lymph and acid phosphatase normally increased only in lymph. Blister fluid enzyme levels correlated closely with lymph GPT but not lymph CPK or acid phosphatase. 3) Lymph flow rate commonly increased to 3-5 times control rate with the severe edema following rewarming. Lymph flow was not stopped by elevated "compartment pressures." 4) Slight decreases in plasma protein and increases in lymph protein were noted following injury, possibly indicating increased vascular permeability. 5) Total platelet counts were significantly depressed immediately following thaw and sample period. 6) Increased hemolysis of RBC's was noted in both arterial and venous blood following injury.

There are no plans to pursue the study in the immediate future. Physical preparation of the model is somewhat difficult and, as presently designed, useful only as an acute preparation. The investigator, however, believes the model shows promise not only as a means of understanding pathophysiology, but more importantly, a means of acute evaluation of therapy, i.e., rewarming methods, fasciotomy, vasodilators, etc.

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3. Weatherly-White, R. C., Bjorn Sjostrom and B. C. Patton. Experimental studies in cold injury: II, pathogenesis of frostbite. JSR, Vol. 4, No. 1, 1946.

(83046)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OC 6149	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	046
b. CONTRIBUTING				
c. XXXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U) Prevention of Military Environmental Casualties by Epidemiologic Research and Information Dissemination (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 012900 Physiology; 013400 Psychology; 022400 Bioengineering; 013300 Protective Equipment; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
74 07	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	2.6	153
	CURRENT 79	2.5	161

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* DANGERFIELD, Harry G., M.D.

TELEPHONE: 955-2811

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: GOLDMAN, Ralph F., Ph.D.

NAME: VOGEL, James A., Ph.D. DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U) Military Operations; (U) Performance Limits; (U) Military Tactics; (U) Environmental Medicine

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Identify environmental medicine problems in Army units as research requirements. Maintain dialogue with DA staff and line to (a) communicate research results to potential users, (b) provide assistance and resolve difficulties in interpreting and applying research, (c) identify unsolved problems. Provide a continuing source of identified, in-depth expertise on the impact of physiological and psychological status, military clothing and equipment, natural and crew compartment environments, high terrestrial elevations, and physical fitness, on the soldier's health and mission capability.

24. (U)Maintain direct liaison with DA schools, line and staff units by visits, conferences, and correspondence. Maintain reference files on climate, clothing, and equipment, and physical and physiological differences among military populations, as a base for predicting environmental impact and mission capability. Assist in preparation of training films, TB MEDs, FMs, and other doctrine; provide consultation to units planning military operations under stressful conditions; assist with doctrine for physical training and/or acclimatization.

25. (U) 77 10 - 78 09 Predeployment briefings of military units concerning prophylaxis and therapy for the climatic stress of heat and cold have continued and presentation at civilian institutions have furthered transfer of relevant information between USARIEM and civilian organizations involved in common research efforts. Similarly, briefs and consultations with major Army commands, e.g., TRADOC, FORSCOM, have provided expertise and recommendations concerning military problems related to fitness and readiness. In addition, an International Symposium on Medical Evacuation in Cold Weather was planned, organized and conducted.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	046 Prevention of Military Environmental Casualties by Epidemiologic Research and Information Dissemination (22)
Study Title:	Prevention of Military Environmental Casualties by Epidemiologic Research and Information Dissemination (22)
Investigator:	Harry G. Dangerfield, Colonel MC, Research Staff, USARIEM

Background:

The research efforts of USARIEM are directed toward insuring that line components of US Forces can accomplish their missions despite the impact of climatic stress. One aspect of this work is comprised of a highly competent and talented, multi-disciplinary scientific staff providing most current and accurate information emphasizing the prevention of casualties due to environmental extremes.

Another equally important effort is translation of new information, comments and recommendations to those most directly concerned, i.e. US active duty, Reserve and National Guard units. To accomplish this, efforts are directed toward: 1) predeployment briefings of military units; 2) briefings for major Army Commands and Army Staff, e.g. TRADOC, FORSCOM, DCSPER, to provide expertise and recommendations for military problems, related to physical fitness, training and readiness; 3) consultation with Reserve and National Guard units and, 4) consultation with civilian research and academic institutions to transfer relevant and current research data and information.

Progress:

Consultations requested of the USARIEM staff during FY 78 are listed in Appendix D; similarly, briefings and lectures given and detailed respectively in Appendices E and F.

Of special significance was the planning, organization and conduct of an International Symposium, "Problems of Medical Evacuation in Cold Weather", in October 1977 co-sponsored by the Office of Naval Research and USARIEM. The basis of the meeting was to determine requirements for the management of casualties during cold weather military operations. The entire range of those problems was addressed: 1) location on the battlefield; 2) getting assistance to the casualty; 3) treating casualties while minimizing complications of cold, wind and wetness, and 4) evacuation to definitive treatment facilities. This working conference identified specific deficiencies and recommended changes in doctrine, training, and research and development necessary to affect improvement. A summary of the conference was prepared and copies are available for distribution.

(83047)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
				DA OB 6147	78 10 01	DD-DR&E(AR)636
3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	047
b. CONTRIBUTING				
c. [illegible]	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U)Improvement of Physical Fitness Training and Prevention of Injuries Related to Training(22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
012900 Physiology;012500 Personnel Training & Evaluation

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	1.9	53
	CURRENT 79	1.9	76

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
ADDRESS:* NATICK, MASSACHUSETTS 01760
RESPONSIBLE INDIVIDUAL
NAME: DANGERFIELD, HARRY G., M.D., COL, MC
TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
ADDRESS:* NATICK, MASSACHUSETTS 01760
PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* VOGEL, James A., Ph.D.
TELEPHONE: 955-2800
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: DANIELS, William L., CPT, MSC
NAME: 955-2878 DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)US Military Academy; (U)Physical Fitness; (U)Aerobic Power; (U)Psychological Inventories; (U)Submaximal Workload

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Army physical fitness training doctrine is based largely on outdated information and has been slow in adopting new scientific concepts. Physical training in the Army could be made more effective and efficient by appropriate research to meet the Army's needs with this new knowledge and obtain new information in specific areas relevant to the Army (women, older age) where information is lacking.

24. (U)Specific studies will include: (1) Determine the optimum mode, frequency, duration and intensity of training for different applications or needs; (2) Identify differences between men and women, if any, in the qualitative or quantitative response to training; (3) Establish suitable training programs for older age groups in the Army and (4) Document incidence of sports/training injuries and seek their prevention.

25. (U) 77 10 - 78 09 A study has continued to longitudinally evaluate the comparative responses of male and female cadets to an intense physical training program at the US Military Academy. The purpose of the study is to determine the extent to which females can close the fitness gap with men with long term extensive training. The difference in aerobic power at the beginning of the first year was 18%, 60.6 and 49.7 for males and females respectively. At the end of the year, both males and females maintained their aerobic power levels but had not improved. Further studies after their second summer of training have just been completed.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	047 Improvement of Physical Training and Prevention of Injuries Related to Training
Study Title:	Long Term Effects of Similar Training Environment on Men and Women
Investigators:	William L. Daniels, CPT, MSC, Ph.D., Dennis M. Kowal, CPT, MSC, Ph.D., Dan S. Sharp, CPT, MC, M.D. and James E. Wright, CPT, MSC, Ph.D.

Background:

In July, 1976, the first female cadets were accepted into the U.S. Military Academy. With the introduction of co-education at the service academies, a need developed for information on the physiological effects of integrated training programs on men and women. In an effort to meet this need, this Division has worked with the Academy in order to provide physiological guidelines for the establishment of physical fitness test requirements and an assessment of the cardio-respiratory fitness of cadets for comparison to reported norms. Two previous studies have been performed in order to meet these needs. In 1976, the effect of endurance and strength training programs were studied on young women. The two programs were designed after those which had been previously used by male cadets (1). Both the endurance and strength training program caused significant increases in the aerobic power of these women. While this study provided information on the response of females to the type of training programs previously used at the Academy, it did not provide adequate information for comparison of males and females undergoing the same training. In order to provide this information, a second study was undertaken to evaluate the effect of the same training program on males and females. In this study, thirty male and thirty female cadets were studied at the beginning and the end of the summer training that all cadets undergo prior to the start of their first academic year (2). Both males and females were very fit prior to the start of training based upon their initial maximal oxygen consumption ($\dot{V}O_2max$) values. While males showed no significant change in $\dot{V}O_2max$ as a result of training, females showed an 8% increase in $\dot{V}O_2max$. The lack of a significant increase in males was due to their initial level of fitness and to their high activity history prior to arrival at the academy. Females responded to the training in a manner similar to that reported in other studies. The difference in $\dot{V}O_2max$ values between males and females was reduced from 22 to 18%. This study provided information on the effect of a short-term training program on both men and women. However, further study was required in order to determine the effects of extended training on females as compared to males. One of the unique aspects of the Academy is the fact that not only is the training program very similar for both males and females, but their entire life styles are very similar. Due to the regimented life style, activity, dietary, and sleeping habits are very similar for all cadets. Therefore, this provided an excellent opportunity to study the effects of an extended period of similar training on both males and females. The purpose of this protocol is to study the effect of training at the Academy on the aerobic power of men and women. While the training is not identical, it is very similar for all cadets. Every cadet is required to participate in a varsity or intramural sport at all times, as well as attend a physical education class three times per week during the academic year. In addition, during their first two summers at West Point, all cadets participate in the same training programs.

Progress:

In the summer of 1977, thirty male and thirty female cadets were randomly selected from the entering freshman class. Both groups were evaluated before and after the initial basic training that all cadets undergo prior to the start of the first academic year. The pre-test took place during the week of arrival at the Academy and the post-test took place six weeks later, at the end of basic training. All subjects underwent the same pre-and post-training evaluation. Body weight, to the nearest 100 gm. and height to the nearest 1 cm were taken in shorts, T-shirt and stocking feet. Skin fold thickness was taken at four sites, subscapular, tricep, bicep and suprailiac, with a Harpenden caliper in order to estimate body fat content, using the equation of Durnin and Womersley (3).

$\dot{V}O_2max$ was determined using a modification of the interrupted treadmill running test described by Mitchell et al. (4). Each subject performed two submaximal runs, after which blood was drawn by venipuncture to measure lactate levels. Each run was followed by a 5-10 minute rest period. Runs, of increasing severity, continued until $\dot{V}O_2$ no longer increased (less than 2 ml/kg • min increase with 2.0% or more grade increase). A plateau in $\dot{V}O_2$ with increasing work load was considered the $\dot{V}O_2max$.

$\dot{V}O_2$ and minute ventilation were measured from duplicate 20-30 second collections of air during the last minute of the run at each work load. Expired air was collected through a large mouthpiece and low-resistance valve into vinyl Douglas bags. Expired air was analyzed with a Beckman E-2 oxygen analyzer and a Beckman LB-1 CO_2 analyzer. Volumes of expired air were measured with a Tissot spirometer. The heart rate was recorded electrocardiographically.

A series of psychological questionnaires, designed to measure transitory behavioral states and attitudes toward exercise and physical self, was administered to the group. The following tests were given before and after training:

Spielberg State-Trait Anxiety Inventories (STAI),
Profile of Mood States (POMS),
Physical Estimation and Attitude Scale (PEAS),
Response to life problems and
Personal History and Activity Questionnaire.

The results of this study have been partially reported (2). The major portion of the work for this fiscal year involved the continuation of the study into the second summer's training. Eighteen male and fourteen female cadets agreed to participate in the continuation of this study for the remainder of their education at the Academy. In the summer of 1978, subjects were studied before and after the training program that they undergo between their first and second academic year. Subjects underwent the same testing as described above except for the submaximal lactate determinations. Instead all subjects performed a walking protocol up to 24% grade in order to measure submaximal $\dot{V}O_2$ and ventilatory parameters.

Walking was done at 3.5 mph with a 3% increase in grade every 3 minutes. Eight subjects had blood samples drawn at each workload in order to measure blood lactate levels for comparison with ventilatory parameters. Partial results from this study are listed in Table I. Data in Table I represents only means. A detailed statistical analysis is just beginning. Delay in analysis is due to priority that was given to data from the translocation protocol.

TABLE I

Physiological Data

Men	Jul 1977	Aug 1977	Jun 1978	Aug 1978
$\dot{V}O_2$ max (l/min)	4.30	4.38	4.50	4.53
$\dot{V}O_2$ max(ml/kg • min)	60.3	61.2	60.9	60.4
$\dot{V}O_2$ max(ml/LBM • min)	68.9	68.7	69.7	69.6
LBM (kg)	62.4	63.7	64.1	65.1
Weight (kg)	71.5	71.3	73.9	74.6
% Body Fat	12.6	10.5	12.9	12.8
HR_{max}	190.9	182.8	190.1	188.5

Women	Jul 1977	Aug 1977	Jun 1978	Aug 1978
$\dot{V}O_2$ max (l/min)	2.60	2.84	2.90	2.98
$\dot{V}O_2$ max (ml/kg • min)	44.7	48.5	48.8	49.6
$\dot{V}O_2$ max (ml/LBM • min)	53.3	61.5	62.9	62.5
LBM (kg)	44.6	46.2	46.1	47.5
Weight (kg)	59.3	59.1	60.0	59.1
% Body Fat	24.2	21.1	22.4	22.5
HR_{max}	191.1	184.5	190.8	185.7

Data obtained during submaximal workloads is also in the process of being analyzed. Preliminary review of the data indicates that through the academic year both males and females maintained the high levels of fitness that they had achieved by the end of the summer training in 1977. They were able to do this despite the fact that both showed increases in body weight and per cent body fat.

They also showed increases in the absolute $\dot{V}O_2$max values (l/min). Whether any of these represent statistically significant changes is now being determined.

Presentations:

Daniels, W.L., J.A. Vogel and D.M. Kowal. Fitness Levels and Response to Training of women in U.S. Army. NATO Symposium on Physical Fitness with Special Reference to Military Forces. April 1978.

Publications:

Daniels, W.L., J.A. Vogel and D.M. Kowal. Fitness Levels and Response to Training of Women in U.S. Army. Proceedings of NATO Symposium on Physical Fitness with Special Reference to Military Forces. Pp. 183-188, April, 1978.

LITERATURE CITED

1. Kowal, D. M., J. A. Vogel and J. Peterson. Comparison of Strength and Endurance Training on Aerobic Power in Young Women. Med. Sci. Sports 9:1970.

2. Daniels, W. L., D. M. Kowal and J. A. Vogel. Fitness Levels and Response to Training of Women in the U.S. Army. Proceedings of the NATO Symposium on Physical Fitness with Special Reference to Military Forces. Pp. 183-188, April, 1978.

3. Durnin, J. V. G. A. and J. Womersley. Body fat assessed from total body density and its estimation from skinfold thickness: Measurements on 481 men and women aged 16 to 72 years. Brit. J. Nutr. 32:77-97, 1974.

4. Mitchell, J. H., B. J. Spoule, and C. B. Chapman. The physiological meaning of maximal oxygen intake test. J. Clin. Invest. 37:538-547, 1957.

(83048)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
	DA OA 6123	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	048
b. CONTRIBUTING				
XXXXXXXXc	CARDS 114f			

11. TITLE (Precede with Security Classification Code) (U) Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS
013300 Protective Equipment; 022400 Bioengineering

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
64 01	CONT	DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER: NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	8	392
	CURRENT 79	8	383

19. RESPONSIBLE DOD ORGANIZATION
NAME: USA RSCH INST OF ENV MED
ADDRESS: Natick, MA 01760
RESPONSIBLE INDIVIDUAL
NAME: DANGERFIELD, HARRY G., M.D., COL, MC
TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
NAME: USA RSCH INST OF ENV MED
ADDRESS: Natick, MA 01760
PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME: BRECKENRIDGE, John R.
TELEPHONE: 955-2833
SOCIAL SECURITY ACCOUNT NUMBER: [redacted]
ASSOCIATE INVESTIGATORS
NAME: STRONG, Louis, Ph.D.
NAME: GOLDMAN, Ralph F., Ph.D. DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Tolerance Prediction; (U)Protection; (U)Biophysics; (U)Thermal Exchange; (U)Insulation (clo); (U)Evaporative Cooling Index; (U)Moisture Permeability Index

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Study energy exchanges in a Man-Clothing-Environment system, to provide basis for improving thermal protection and recommending crew environments in military vehicles.

24. (U)Analyses of materials, uniforms and/or equipment using heated "sweating" flat plates, manikins, etc. indicate their effects on heat and moisture exchange and aid in predicting the user's physiological responses. Results provide guidance for military designers and identify stressful items or environments. Findings may be verified on soldiers in chamber or field studies.

25. (U)77 10 - 78 09 A mathematical model for predicting supplementary cooling derived from a wetted cover on an impermeable ensemble, in terms of its insulating characteristics and environmental factors such as temperature, humidity, wind speed and sunlight has been completed. A pilot study to determine safe exposure times with immersion to the waist or chest during swamp crossings has shown that 10°C water is tolerable for 2 hours during moderate activity, but that 5°C water reduces body temperatures below a safe 25°C level and causes leg problems within 25 minutes. Insulation studies on several dry suit-undergarment combinations were conducted for the Navy using an immersed copper manikin under water pressures up to 16 ATA, and various gases (N_2, CO_2, and H_e) in the suits. Coated fabric dry suits over pile or foam undergarments were least affected by depth; helium reduced effectiveness in most cases by over 50%. Insulation studies of candidate sleeping bags for survival use and contingency planning, and of commercial ski boots were conducted for DARCOM developers. Experimental Navy divers handwear employing fine fiber liners were evaluated in air and immersed in water. Comfort characteristics of standard and proposed Air Force security police shirts were determined. Consultation services on various aspects of thermal protection were provided various US military and civilian agencies, and NATO research personnel.

*Available to contractors upon originator's approval

DD FORM 1498, 1 MAR 68 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Comfort and Heat Stress Characteristics of Air Force Police Shirts (ME-USAF-1-78)
Investigators:	George F. Fonseca and Thomas L. Endrusick

Background:

Civilian security police at Brooks Air Force Base, Texas, in late 1977 were required to wear a shirt made of 6.6 oz/yd^2 fabric (65% polyester, 35% rayon) during the hot summer months. The Chief, Security Police, supported by opinions of Dept. of the Air Force, Kelly AFB, TX, favored use of a lighter weight 4 oz/yd^2 polyester/cotton shirting similar to that in use by San Antonio police, and officer shirts of the USAF, for the summer temperatures of 45^{o}C and higher that have been recorded at Brooks AFB. USARIEM was requested to conduct copper manikin comparisons of the convective and evaporative characteristics of ensembles which included the two shirts, to determine whether one imposed less heat stress than the other. Work was performed under a Letter of Agreement between USARIEM and Brooks AFB which has been in effect for the past two years.

Progress:

The convective and evaporative characteristics of the two weights of shirting were first measured on a sectional copper manikin, on which the torso section could be isolated to provide a direct indication of fabric characteristics without considering the influence of clothing over other body sections. Later, the two shirts were cut into squares and a sample from each was measured on a guard ring flat plate. The copper manikin results showed that, although the insulation of the 6.6 oz shirt was higher as expected, its wicking characteristics were far superior to those of the 3.5 oz/yd^2 shirting. As a result, the evaporative potential with the 6.6 oz shirt was higher than with the thinner shirt, i.e., more cooling could be obtained by sweat evaporation in the heavier shirt. Our report to the Air Force indicated that the poor wicking characteristics of the lighter shirting was not normal for a polyester, cotton blend; some additive, which could not be removed by washing, was presumably responsible. Results on the torso section were as follows:

	clo	i_m	i_m/clo
3.5 oz shirting	1.45	0.39	0.27
6.6 oz shirting	1.58	0.47	0.30

The evaporative coefficient is given by the ratio i_m/clo, where clo is the insulating value and i_m the vapor permeability index. (An i_m value of 0.47 is normal for most loose-weave textiles.) The torso results indicate that the net heat loss through the shirt in a 45°C, 30% humidity environment would be limited to 39 watts/square meter in the 3.5 oz shirt, but could increase 32% to 51 watts/square meter in the 6.6 oz shirt. These values are exclusive of solar radiation effects; however, these effects would be less in the thicker 6.6 oz shirt. Results of the flat plate measurements agreed qualitatively with those obtained on the manikin torso, although they were of a different magnitude owing to such factors as shape (flat vs curved surfaces), orientation (horizontal vs vertical) and different wind speeds.

A full report of findings with interpretation has been forwarded to Dr. Sarah Nunneley, USAFSAM, Brooks Air Force Base, Texas for necessary actions. Dr. Nunneley was advised that, if a clear preference for the 3.5 oz shirt was found (probably because of some aspect of comfort not related to heat dissipation), it could be worn without compromising tolerance to heat except in high humidities with sustained high activity level. Investigation of the wetting characteristics of this shirt was recommended, since immersion in water and wringing it out wetted it completely and raised its vapor permeability index to 0.6.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Comparison of Ambient WBGT as Measured by Original Laboratory Technique and Current US Army WBGT Kit
Investigators:	SP5 Basavapathruni Onkaram and Leander A. Stroschein and Ralph F. Goldman, Ph.D.

Background:

In 1957, Yaglou and Minard (1) reported success in reducing environmental heat casualties at military training centers by employing a new empirical heat stress index, the Wet-Bulb Globe Temperature (WBGT) to dictate the extent of training activities allowable for unconditioned recruits. This index, which is derived by adding 10% of the shaded dry-bulb (air) temperature, 20% of the temperature attained by an exposed black globe 6 inches in diameter, and 70% of the unshaded, unaspirated wet-bulb temperature, has become increasingly accepted as the standard for indicating the severity of heat stress of a hot environment; although perhaps less physiologically based than Belding's Heat Stress Index, McArdle's Predicted 4-Hour Sweat Rate (P4SR), and Effective Temperature, the WBGT is more simply measured and appears to correlate well with observed human strain in the heat. Specifications for the standard configuration of measuring elements, which is basically that originally used by Minard, are given in TB MED 175, The Etiology, Prevention, Diagnosis and Treatment of Adverse Effects of Heat, 25 April 1969. Other arrangement of devices for measuring WBGT have been developed in the past few years as substitutes for the standard measuring system. Notable among these arrangements is a highly portable system contained in a small plastic or metal box in which the 6-inch black globe has been replaced with a small 1/4" diameter black sleeve (covering the thermometer) inside a perforated clear plastic container approximately 1/2" in diameter and 1 1/4" long. This miniaturized version of the WBGT kit comes equipped with a slide rule and is available in the Federal Supply System (NSN 6665-00-159-2218).

As an alternative to the WBGT system, Botsford (2) has proposed the use of a so-called Botsball for measuring environmental stress. This device consists simply of a 2 3/8 " black copper sphere covered with a black cloth into which a simple metallic tube temperature sensor with dial thermometer is inserted. This device is immersed in water to wet the cloth and provides an index called the wet-globe temperature (WGT). Studies by others have suggested that WGT is linearly related to the WBGT as measured by the standard TB MED 175 configuration. A study was therefore undertaken at this Institute to compare the WGT obtained by Botsball with WBGT indications obtained using the TB MED 175 configuration, the miniaturized NSN kit, and two other systems employing 6-inch black globes; one of these is commercially available and features direct WBGT readout.

Progress:

A comparison of the four WBGT kit indications of environmental stress and WGT index (Botsball) was conducted during the summer months on the roof of the USARIEM building under a variety of air temperature, humidity, windspeed, and sunlight combinations. Data for calculating the indices were obtained by visual observation and by an automatic data collection system using thermocouple temperature sensors attached to the various temperature sensors in the instruments. The results show that, although trends of dry bulb temperature, wet bulb temperature, and globe temperature with solar radiation and wind speed were different, the WBGT readings from each instrument compared well with those for the TB MED 175 system (within about 1.3°C) over a solar radiation range from 0 to 1000 W/m^2, and also for wind speeds up to about 7 m/s. WBGT by the miniaturized kit showed wider disagreements, up to 2.0°C, at high radiation levels (500-900 W/m^2) and also at low wind speeds (below 2 m/s). Regression equations between instrument WBGT and WGT values and the standard TB MED kit values are given in the following table.

Instrument	Equation	Correlation Coefficient
Miniaturized (NSN)	$Y=0.311+0.982x$	0.981
Yellow Springs direct reading	$Y=0.728+0.977x$	0.994
Botsball(WGT)	$Y=0.187+1.044x$	0.980

(Y=Standard WBGT and x=WBGT or WGT (Botsball) from the substitute instrument)

These results show in particular that a device employing a 6-inch globe (Yellow Springs Kit) provides readings which correlate best with those of the standard TB MED Kit. Of more importance, however, they demonstrate that the miniaturized kit can be considered an acceptable substitute for most WBGT measurements, although more variation from the true WBGT may be expected. The results also reveal that the Botsball, which is probably the most desirable field instrument from an ease of use standpoint, correlates with standard WBGT readings as well as those using the miniaturized kit, and the regression equation indicates that readings from this instrument, i.e., WGT, can be directly converted to read WBGT using a linear relationship. A Technical Report has been submitted for clearance in preparation for publication.

The basic comparisons of WBGT and WGT measuring instruments have been completed. However, reports of WBGT discrepancies between the original miniaturized NSN Kit, employing a plastic case, and the newer version employing a metal case, modified design and different type thermometers are under investigation. WBGT differences of as much as $3^{\circ}C$ in hot environments have been reported, and comparisons of the two systems will be continued in an effort to learn the cause for any differences so that appropriate corrective steps may be recommended.

Publications:

Onkaram, B., L. A. Stroschein and R. F. Goldman. Heat stress by WBGT (STND & Miniaturized) and Botsball. Technical Rpt. (In Press).

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2. Botsford, J. H. A wet globe thermometer for environmental heat measurement. Am. Indust. Hyg. Assoc. J. 32:1, 1971.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Cooling Effects of Wettable Covers on Impermeable Clothing Ensembles
Investigators:	John R. Breckenridge, Clement A. Levell and Leander A. Stroschein.

Background:

For adequate protection against toxic agents, it is frequently necessary to encapsulate the soldier in a completely impermeable ensemble. Two such systems which have been employed by the U.S. Army are the Toxicological Agent Protective (TAP) suit and the Engineer Ordnance Demolition (EOD) ensemble. Such impermeable systems almost entirely eliminate sweat evaporation, the most important and often the only means for dissipating metabolic heat generated by a soldier in hot environments, and results in a rapid storage of heat in the body and collapse in less than one hour of moderate activity in a 35°C environment. "Safe" exposure times as given by Custance (1) for moderate work in an impermeable system are shown in Table 1.

TABLE 1

"Safe" Wear Times for Moderate Work (300 Watt Energy Production) as Presented by Custance

Environmental Temperature (°C)	Wearing Time
0° or less	8 hours
0° to 10°	5 hours
10° to 20°	2-3 hours
20° to 30°	1-2 hours
32°	30 minutes
above 32°	15 minutes

Goldman (2) has pointed out that there are essentially only three possible solutions to the problem: a) use of a ventilating filtered air supply near the skin to cause evaporative cooling, as is done in the EOD suit, b) altering tactical operations to permit adequate recovery time between short work periods, and c) use of a wetted cover over the impermeable ensemble; a fraction of the cooling by evaporation from the cover is reflected in increased heat dissipation from the skin, the fraction depending essentially on the insulation of the clothing and the air movement over the cover. The present investigation was undertaken to develop a mathematical model based on physical principles of heat transfer for predicting the amount of skin cooling which could be achieved by employing the wetted cover concept, in terms of such clothing parameters as insulating value, percent of area under the wet cover, and nature of layers beneath the impermeable shell, and such environmental parameters as ambient temperature, humidity, wind speed, and incident solar radiation.

Progress:

Development of the mathematical model, which predicts increased skin heat dissipation with a wet cover, the net dissipation from the skin, and the water requirements for maintaining the cover wet, has been completed. The model has been tentatively validated for one impermeable ensemble with wet cover using data obtained indoors on a copper manikin operated both with a dry "skin" and when maintained completely wet. Measured net skin heat dissipations for environments ranging from 26° to 35°C, and relative humidities from 20 to 90% agreed with model predictions within 5 watts except in 2 of 15 experiments, where differences of 7 and 10 watts were noted. Cooling at the cover from evaporation was also correctly predicted, in most cases within 10% or less of that calculated from cover water losses as determined with an automatic weighing scale on which the manikin stood.

The model predicts, for the ensemble studied, that a wet cover increases skin heat losses in a tropical environment (air temperature 30° to 35°C, relative humidity 50 to 75%) by from 40 to 80 watts, or 20 to 25% of an active soldier's average heat production. In a desert environment (air temperature 45° to 50°C, relative humidity 10 to 20%), the predicted increase in skin heat dissipation caused by evaporation from the cover ranges from 125 to 180 watts, or about half of that generated. Corresponding cover water requirements under these conditions are predicted as 0.26 to 0.97 kg/hr, and 0.62 to 1.91 kg/hr, respectively. Also of importance is the fact that the model predicts a reduction in solar heating of the man with a wet cover, from 75 to 30 watts in open sunlight in the tropics, and the same reduction in a desert environment.

This model will be validated initially by comparing predicted values of heat dissipation and water requirements with results from a copper manikin exposed to different combinations of air temperature and wind speed. Extensive validation on human subjects represents a lengthy procedure and will not be attempted; however, data from chamber and field trials will, where applicable, be applied to provide an indication of the model's validity.

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1. Custance, A. C. Stress-Strain Relationships of Man in the Heat. Med. Serv. J. Canada 23:721, 1967.

2. Goldman, R. F. and J. R. Breckenridge. Current Approaches to Resolving the Physiological Heat Stress Problems Imposed by Chemical Protective Clothing Systems. Proc. 1976 Army Science Conference, West Point, NY.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Aircraft Survival Kit Sleeping Bag (ME-E2-78)
Investigator:	Onofrio F. Compagnone

Background:

NARADCOM has a requirement to develop a Cold Weather Aircraft Survival Kit Sleeping Bag which will permit a minimum of four hours uninterrupted sleep at $-40^{\circ}C$ with the man dressed only in long underwear and wool socks. The bag may be used on tree boughs, when available, or on bare or snow covered ground. USARIEM was tasked with the job of comparing the insulation value of a regular size North Face Expedition Bag with that of the standard LINCLOE Extreme Cold Bag, which meets the stated requirement.

Progress:

A copper manikin comparison of the candidate bag with the standard LINCLOE Bag, both measured on bare ground, has demonstrated that the candidate bag, with 1.8 kg of down fill, provides 0.2 clo more protection than the standard LINCLOE Bag. Similar superiority of the candidate bag was noted when the two bags were compared while lying on the standard insulated inflatable mattress.

This study has been completed and report of findings submitted to NARADCOM. The insulating values and bag weight data on the LINCLOE control bag and candidate survival bag were as follows:

	Insulation Value On Bare Floor (clo)	Insulation Value On Std.Insulated Mattress (clo)	Bag Weight (kg)	Weight of Filling (kg)
Control				
Standard LINCLOE Extreme Cold Bag	8.0	8.8	4.3	2.1
Candidate Survival Bag (North Face Expedition)	8.2	9.2	2.5	1.8

The results show that the candidate bag provides as much or more protection than the LINCLOE bag, and also weighs less, primarily because of its lighter weight (but less durable) cover fabric.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness, and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Commercial Medical Hot and Cold Packs (ME-E6-78)
Investigators:	John R. Breckenridge and Clement A. Levell

Background:

A request by the Defense Logistics Agency (DLA) was received to evaluate two items (a chemical heating pad and a chemically-activated cold pack) for possible application as items of medical issue which had been submitted to the Defense Logistics Agency by Product Design, a commercial distributor located in Tucson, Arizona. After negotiations with DLA, an informal evaluation and assessment of the therapeutic value of the items by USARIEM was arranged, with the understanding that findings would be transmitted to Product Design but not bind the Government in any manner to procure the items.

Progress:

Evaluation of the heating pad, performed by measuring its heat production capabilities, has been completed. This pad, a 3µx6" pouch containing two chemicals, produces heat when the two chemicals are mixed; an air vent, which can be sealed when heating is not required, permits entrance of oxygen to support the reaction. The heat output of the pad was measured by placing it in a cutout in a 3/8" thick felt sheet located on an electrically heated guarded hot plate and measuring the power required to maintain a constant plate temperature of 32°C (1) before the chemicals were mixed, (2) after mixing the chemicals, and (3) after resealing the air vent in the pad. Measurements were made in a constant temperature chamber at $5^{\circ}C$; the felt and pad were covered first with a 1/8 inch layer of felt to insure high heating efficiency, and later with a thick polyester quilt to guarantee that all the heat produced by the hot pad would be reflected by the power reduction to the flat plate heating elements. Initially, two hours after mixing the chemicals, the pad produced 3.1 watts of heat; however, resealing the vent did not completely stop the chemical reaction (heat production remained at about 0.8 watt). On the second day, the heat output of the pad was reduced to 2.7 watts maximum. Two weeks later, despite only about 4 hours total use of the pad, the measured heat output was only 0.8 watts, a relatively unimportant warming contribution. Since Goldman (1) has shown that an auxiliary heat supply of 3 watts applied to a hand in an Arctic mitten is not sufficient to maintain manual dexterity for a relatively inactive man except possibly at temperatures above $-25^{\circ}C$ ($-13^{0}F$), results of this evaluation indicated very little protective merit for this heating pad, especially after a few hours of use. The pad would have no other application than as a handwarmer, since a foot in a well-insulated boot requires 5 to 7 watts of power for thermal protection; use of the pad as a body warmer would have no important benefits, despite the claims of the manufacturer.

The ice pack, a much larger device containing chemicals will be assessed in a similar fashion, and also for its ability to form a flexible ice bag for treatment of sprains, etc. A report of findings will be made available to Product Design and Defense Logistics Agency.

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1. Goldman, R. F. The Arctic Soldier: Possible Research Solutions for His Protection. Proc. Fifteenth Alaskan Science Conference, College, Alaska, 401-419, 1964.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of "Dry" Type Navy Divers Suits
Investigators:	John R. Breckenridge, James Bogart, Clement A. Levell, Louis Strong, Ph.D., Thomas Endrusick

Background:

In 1976, the Navy, through the Naval Coastal Systems Center, Panama City Florida, initiated a program to develop or procure through commercial sources a diver's suit with improved thermal insulating properties; existing suits, mostly wet suits, were inadequate and permitted only short-duration deep dives to 500 ft. Most of the candidate suits selected for study were of the "dry" type, and were supplemented with various commercial insulating undergarments to improve thermal protection. Because of the USARIEM capability to measure thermal insulation of systems immersed in water, using a waterproof copper manikin, Institute support in selecting the best candidate suit-undergarment combinations was requested. In 1977, under reimbursement contract with Naval Coastal Systems Center (NCSC), measurements of a series of "dry" suit-undergarment combinations were performed with the manikin either in air or immersed to the neck. Based on the findings of this initial phase of work, three promising "dry" suits and six undergarments were selected for further study under water pressures up to 16 atmospheres (500 ft depth) in a small hyperbaric chamber at NCSC, with nitrogen, carbon dioxide, and helium purge gases in the suits and undergarments.

Progress:

During a two month study at Panama City, the projected measurements were conducted using the waterproof manikin immersed to the neck in the hyperbaric chamber. Required pressures were obtained by pressurizing the space above the water with the purge gas. Preliminary results will be presented by NCSC before the American Society of Mechanical Engineers (ASME) at their winter meeting in San Diego, California. In general, with nitrogen in the suits, neoprene foam dry suit plus undergarment combinations provided the highest insulating values at the surface (1 atmosphere (ATA)) but were compressed and had only about 60-70% of the surface value at 16 ATA depth. A third "dry" suit consisting of a rubber coated knit fabric provided 30% less insulation at the surface, with some variation depending on the undergarment used, but insulation was relatively constant as depth increased (less than 10% loss at 16 ATA). With helium gas in the suits, all insulating values were lower by from 30 to 60%, due to the high thermal conductivity of this gas. Copper manikin results fell very close to predicted curves of insulation versus depth (ATA), providing validation of the NCSC prediction model based on materials characteristics, reduction of foam thickness under pressure, etc. With the rubber coated fabric "dry" suit, compression of the undergarment layers was contraindicated by the relative independence of insulating value and depth; reduction of thickness of the undergarment apparently was slight, as the model predicted, because the pressure across the undergarment was constant. Measured values for this coated "dry" suit fabric and a deep-pile polyamide undergarment are given below.

Pressure (ATA)	Nitrogen Gas (clo)	Helium Gas (clo)
1	0.71	0.29
2	0.66	---
4	0.66	---
8	0.67	0.26
16	---	0.24

These insulating values, although constant, are inadequate for prolonged protection in cold water.

Although insulation measurements under this project have been completed, USARIEM and NCSC personnel will continue to collaborate in developing a system with improved insulating characteristics.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS, AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of POL Handwear and Insulating Pump Handles
Investigators:	Fred R. Winsmann, Kent B. Pandolf, Ph.D., Leander A. Stroschein, and Clement A. Levell

Background:

Currently, fueling operations in the Arctic are accomplished using gravity-feed type fuel nozzles. This requires the fuel handler to grasp and hold the cold soaked metal trigger mechanism for periods up to 12 minutes at temperatures down to -45°C. Those in the fuel handling equipment design area have been experimenting with closed circuit refueling of helicopters, etc., which would eliminate the need for holding the nozzle. However, until this system is operative, insulation of the pump handles plus use of effective liners in POL handwear is desirable to prevent rapid contact cooling of the hand. Toward this end, an Anti-Contact Insulation Kit for gravity type fuel nozzles has been developed. Improved liners for POL gloves have also been fabricated; the latest version had an insulating value of 2.0 clo as measured uncompressed on the sectional copper hand. The work to be reported was requested by NARADCOM handwear designers to study the effectiveness of the POL glove worn over three different types of liner systems, when used in conjunction with insulated and uninsulated pump handles.

Progress:

Two fuel pump handles (one insulated and one not) were mounted on a table and cold soaked at -45°C. Subjects dressed in the full cold-dry arctic ensemble, individually entered the chamber and grasped a pump handle with the right hand, pulled the trigger to the fully open position for two 6-minute periods separated by a 3-minute rest and "warm-up" period. The left hand always remained "at rest" for temperature comparison purposes. Each hand was instrumented with thermocouples to measure temperatures on the palmar surfaces of the index, middle, and ring fingers, the tip of the middle finger, and the outer edge of the small finger. A heat flow disc was also mounted on the trigger of each nozzle to record heat flow from the gloved hand.

Six volunteer subjects were exposed during six days, for one 16-minute period each day, using one of the three handwear combinations and grasping either an insulated or uninsulated pump handle. The handwear consisted of the POL glove (8-finger, 2.0 clo POL insulated mitten) worn with either (a) a foam liner, (b) a foam liner plus wool insert, or (c) a fine fiber liner and wool insert. A balanced order of presentation was used in determining the handwear-pump handle combination for each subject on a given day.

For the right hand (pumping) the greatest fall in temperature from minute 1 to minute 15 occurred with the foam liner alone; and the least fall in temperature with the fine fiber plus insert combination. The data for the left hand also showed that the foam liner was least insulative, and that the other two combinations permitted lesser but similar temperature drops. In all cases the finger temperatures of the right (pumping) hand fell more rapidly than those on the left hand. No consistent differences due to the insulation on the one pump handle could, however, be shown.

The results of this study must be considered inconclusive since the POL glove became hard and brittle after 5 minutes of wear in the -45°C environment. The compression of the handwear and the manner in which the pump handle was contacted by the subject were seriously affected by the glove rigidity, and drops in finger temperature were therefore not representative of those which would be obtained with a flexible glove. The only meaningful results of the study were the rank ordering of the insulation values of the three handwear systems, based on left hand finger cooling rates. It is evident that a need for complete re-evaluation of the 2 clo POL glove design exists.

No further work is planned until a suitable POL glove with demonstrated flexibility at -50°C is provided.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Two Commercial, Intermediate Cold Range, Sleeping Bags (ME-E3-78)
Investigator:	Onofrio F. Compagnone

Background:

In the event of emergency, consideration is being given to the purchase and use of commercial items until sufficient military sleeping bags are available to meet military needs. Currently, one particular Intermediate Cold commercial bag has been selected as a candidate for this application; USARIEM was requested to compare its protection with that provided by the standard Intermediate LINCLOE Bag, under reimbursement contract. Two samples of commercial bag were supplied, and these plus the standard were to be evaluated on the standard insulated air mattress.

Progress:

The two samples and the standard bag have been measured using a copper manikin at an air temperature of $-6^{\circ}C$. The results, plus fill and total bag weights, are given in the table below:

Sleeping Bag	Weight of Filling (kg)	Total Weight (kg)	Insulation values (Clo) On Bare Floor	On Insulated Mattress
Intermediate LINCLOE (control)	1.7	3.4	6.2	6.7
Commercial Sample #1	2.5	2.8	6.9	7.5
Commercial Sample #2	2.0	2.3	6.5	7.2

The commercial samples provided 0.8 and 0.5 clo more insulation than the Intermediate LINCLOE Bag when measured on the air mattress; similar differences were noted with measurements on bags placed on the bare floor. The two commercial bags showed small differences (0.3 clo) in insulation, presumably because one had more filling and weighed approximately 0.5 kg more than the other. Both commercial bags were lighter in weight, by 0.6 and 1.1 kg, than the standard LINCLOE Bag, mainly because of the heavier (and presumably more durable) cover on the military bag.

This study has been completed and the results have been reported to NARADCOM designers. The conclusions were that, since the two commercial bags tested had 5 to 10% more insulation than the Intermediate LINCLOE Bag, they would be highly satisfactory interim items for emergency use until sufficient military type bags could be procured for troop use.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Insulating Values of Navy Handwear (ME-USN-1-78)
Investigators:	Clement A. Levell and John R. Breckenridge

Background:

As is the case with Army cold weather handwear, the Navy has an extreme problem in providing adequate insulation for the hands of a diver, especially at depth. Foam rubber mittens alone are unsatisfactory since, although they can be made thick enough for protection at the surface, compression of the foam at depth quickly degrades the handwear insulation value. Much more satisfactory results have recently been obtained by including relatively incompressible fiber liners inside a foam mitten. These liners must of necessity be kept dry to avoid the additional heat losses associated with evaporative transfer across the fibers. Because of availability of a multi-section electrically heated copper hand, USARIEM was tasked under a Navy Military Interdepartmental Purchase Request (MIPR) to evaluate a series of shell liner combinations in air and immersed in water (surface depth).

Progress:

Sectional and overall insulation values have been measured in air for seven combinations of fine fiber mitten liners under a standard Navy 3-finger, rubberized mitten. These liners were all cut from the same pattern but, because of differences in fiber design and density, had somewhat different insulating efficiencies. Overall insulating values for the various combinations ranged from 1.16 to 1.47 clo; the latter value was obtained with one liner which provided as much as 75% more insulation over the base of each finger but very little more insulation over the finger tips than three combinations with intermediate overall insulation of 1.3 clo. Two other experimental liners were also included in the series but failed to reveal any outstanding insulating characteristics (1.20 and 1.33 overall clo for the systems). A 5-finger, wet suit glove (standard) measured only 1.02 clo, overall. During water immersion, the best fine fiber mitten combination measured only 1.05 clo (vs 1.47 in air), but remained superior to overall values for other combinations tested. At the surface, this drop is caused simply by the loss of insulating value of the air layer overlying the combination (which contributes about 0.5 clo in air); with a dry liner, the protective characteristics of the mitten combination per se are not altered by water immersion to surface depth.

Work on this project is continuing. Other designs will be studied after the present data have been analyzed and deficiencies corrected. Studies with helium gas in the mittens (less protection than with air) and at shallow depths will be performed.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	The Effect of Size and Fit on the Thermal Insulation Afforded by Handwear
Investigator:	Louis Strong, Ph.D.

Background:

Previous studies from this laboratory have shown that the sizing and fit of protective handwear affects its thermal insulation properties. However, there has been no systematic approach to study these factors, in part because the extremities do not have simple surfaces with sufficient symmetry to be represented by convenient mathematical models. On the face of it, one might expect that a loose fitting glove or mitten would insulate better than a tight fitting one because increasing the glove size also increases the average air gap between the hand surface and the inside surface of the glove and thereby decreases the conductive heat loss. At the same time, however, the effective area for heat loss is increased as well as the likelihood of convective currents of air flowing within the gap. Radiant heat transfer is further facilitated by the high emissivity of the human skin and the radiation resistance across an air gap is much less than across a fabric of the same thickness. Minimization of the extra heat loss due to increased surface area, convective currents and radiation sets an upper limit to the thickness of contiguous air layers adjacent to the skin surface. Because of the apparent tradeoffs required to minimize the sum of conductive, convective and radiative components, we may expect that there is an optimal garment size for a given hand size consistent with requirements for manual dexterity.

Progress:

We have measured the thermal resistance of a collection of standard issue Army handgear as a function of hand size and glove size. Four different copper hand calorimeters having surface areas ranging from 0.049 m^2 to 0.065 m^2 were reconstructed, each having three separate heating circuits, all of which were thermally isolated from each other. The circuitry allowed a comparison of the thermal resistance of the whole hand against that of a representative single digit.

Table 1 shows some of the results for the standard arctic mitten, liner, shell, and the POL protective glove. The clo values represent the total hand insulation including that provided by the still air insulation surrounding the bare hand. As the still air insulation is equivalent for each calorimeter, we are able to directly compare the thermal resistances measured on different hands. In general, the table shows that for any particular hand size, the larger glove size results in greater thermal protection. Conversely, for any particular glove size, the smaller hand receives the better protection. We have not observed an optimal size differential between hand size and glove size where the insulation value peaks and then falls off with increasing void space. Such an optimum could presumably be found, but is apparently beyond the range of useful glove sizes.

We have determined the thermal resistance of the air gap directly, by measuring the thermal gradient between the hand surface and the inside surface of the garment, and compared this value to the thermal resistance of the fabric alone. A convenient way to express the insulation afforded by the trapped air layer is in terms of an effective fabric thickness. Fig. 1 shows the variation in clo value of the arctic liner with fabric thickness obtained on the 0.049 m^2 calorimeter. The measured insulation is roughly logarithmic with the fabric thickness. The theoretical curve approximating the experimental assumes a cylinder of internal radius 6.35 centimeters which is wrapped by a fabric having 1.57 clo per centimeter. This radius roughly corresponds to the linear dimension across the flat surface of the hand. Extrapolation of these curves to 0 clo indicates that the equivalent thickness of the air gap is 2.5 millimeters for a size S liner, 5 millimeters for a size M liner and 6.4 millimeters for a size L liner. These values are the same order of magnitude as the average gap dimensions calculated from the difference between surface areas of the calorimeter and the handwear assuming their shapes to be right circular cylinders.

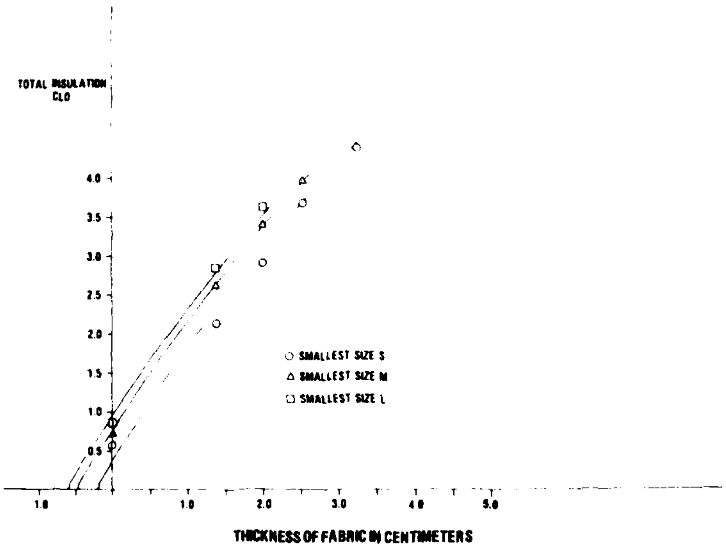

Figure 1. The variation of hand insulation with fabric thickness for the artic mitten liner calorimeter area 0.049 m^2.

The model which best agrees with our calorimetry data for the thumb assumes a right circular cylinder of radius 2.5 centimeters. The horizontal intercept at 0 clo indicates that the air gap has an equivalent fabric thickness of 2.5 millimeters, 5 millimeters and 7.6 millimeters for sizes S, M and L respectively.

Efforts are under way to account for a disparate array of variables influencing the rate of heat transfer including the thermal insulation of protective fabrics, humidity, wind chill and radiation sources in order to anticipate the time development of extremity cooling under various environmental conditions.

TABLE 1

The Effect of Sizing and Fit on the Insulation Properties Afforded by Various Standard Issue Handgear

Area(m^2) Hand Calorimeter	Hand Clo ± 0.08				Thumb Clo ± 0.08			
	Small	Medium	Large	XLarge	Small	Medium	Large	XLarge
				Arctic Mitten Wool Insert				
0.049		1.42	1.52			0.96	0.95	
0.054		1.44	1.53			0.92	0.93	
0.060		1.34	1.41			0.87	0.97	
0.065		1.23	1.29			0.94	0.92	
				Arctic Mitten Liner (nylon & polyester)				
0.049	2.07	2.54	2.86		1.53	1.59	1.68	
0.054	2.12	2.54	2.74		1.47	1.52	1.80	
0.060	1.80	2.31	2.41		1.32	1.52	1.67	
0.065	1.65	2.20	2.50		1.36	1.42	1.58	
				Arctic Mitten Shell (leather & fur)				
0.049	1.90	2.04	1.99		1.37	1.52	1.64	
0.054	1.77	1.95	1.95		1.19	1.29	1.23	
0.060	1.83	2.06	2.06		0.98	1.19	1.16	
0.065	1.68	1.91	1.89		1.02	1.24	1.20	
				POL Protective				
0.049	1.97	1.98	2.06	2.11	1.19	1.15	1.31	1.35
0.054	1.94	1.96	2.05	2.15	1.18	1.14	1.30	1.32
0.060	1.66	1.56	1.75	1.82	0.99	1.00	1.25	1.30
0.065		1.44	1.57	1.58		0.97	1.22	1.26

(83049)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6140	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	H.Terminated	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	049
b. CONTRIBUTING				
c. XXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)*

(U) Factors Predisposing to Cold Injury (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 002300 Biochemistry; 002600 Biology; 003500 Clinical Medicine; 005900 Environmental Biology; 012900 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
10 01	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING		
	CURRENT 78	1.3	42

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* HAMLET, Murray P., D.V.M.

TELEPHONE: 955-2865

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: ROBERTS, Donald E., Ph.D.

NAME: 955-2863 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Cold Injury; (U)Dehydration; (U) $\dot{V}O_2$ max; (U) Hypovolemics

23. TECHNICAL OBJECTIVE.* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Total allied casualties due to cold injury in World Wars I, II and Korea exceeded one million cases. Four integrated studies are planned to elucidate factors predisposing to cold injury and ultimately reduce its incidence: dehydration, physical fitness, fatigue and shock. It has not been demonstrated whether dehydration, a common cold weather occurrence, adversely affects extremity cooling curves. The state of physical fitness more than likely will have a beneficial effect on peripheral cooling rates. Conversely, fatigue may well have an adverse affect. The fourth study will determine the affect of shock on predisposing the wounded to hypothermia and frostbite.

24. (U)Hand cooling of human subjects before and after an extensive physical training program will identify changes in cooling and rewarming rate after physical training. In a second study subjects will be dehydrated to 5% of body weight. Cooling and rewarming responses before and after dehydration will be monitored. The third study in which subjects are fatigued by heavy exercise and/or sleep deprivation will proceed next quarter.

25. (U) 77 10 - 78 09 Ten subjects were dehydrated over a 2-1/2 day period to a fluid loss of 4.6% body weight. The fingers of ten experimental subjects were 18% colder following dehydration than were hydrated subjects at the same times. This is a significant change in cooling rate for minimal dehydration. Physical fitness study data is being analyzed and will be reported under subsequent work unit. This work unit is now cancelled.

*Available to contractors upon originator's approval

DD FORM 1498, 1 MAR 68 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	049 Factors Predisposing to Cold Injury
Study Title:	Effects of Dehydration on Peripheral Cold Response
Investigators:	Joel J. Berberich, CPT, MSC, Ph.D. and Donald E. Roberts, Ph.D.

Background:

The state of hydration has a definite effect on both central and peripheral heat transfer rates in a warm environment, even in a resting subject (1). Dehydration causes an increase in heating rate, in part due to a reduction in peripheral blood flow. Although dehydration should logically also have a pronounced effect on peripheral cooling rate, due in part to blood redistribution, altered osmolality and increased hematocrit, this effect has never been investigated. Since soldiers routinely may dehydrate in cold environment in the field, it is important to ascertain whether this dehydration adversely affects hand cooling and cold injury susceptibility. It might be predicted that mild exercise would potentiate the effects of dehydration in the cold. This prediction is based on the premise that increased cardiac and muscle blood flow shunted by exercise would further reduce blood flow to non-exercised extremities (2).

Progress:

To evaluate the effects of dehydration on response to peripheral cooling, a two phase study was conducted: resting men (Phase I) and exercising men (Phase II).

During Phase I, the effects of dehydration were evaluated by studying individual's responses to a prolonged cooling test in cold air before dehydration, after dehydration, and following rehydration. Two groups of twelve subjects were studied in Phase I. One group was dehydrated to 5% body weight loss by mild exercise and restricted fluid intake, the other group (controls) underwent the same

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experimental procedures but maintained their fluid balance by drinking water *ad libitum*.

During Phase II the same design was followed except that while undergoing the prolonged air cooling test subjects also exercised at a low level. The rationale of Phase II was to evaluate the effect of moderate physiological demand in addition to dehydration on the subjects, as this is a more usual military situation.

The subjects were dehydrated by restricted fluid intake and mild exercise over a period of 3 days. Dehydration was monitored by body weight changes and my daily blood and urine chemistry profiles.

The cold test consisted of sitting in a chamber at $0^{o}C$ for 135 minutes dressed comfortably in military cold weather clothing. For the last two hours of this test, one bare hand was exposed to the cold air to assess hand cooling. During this test, 16 skin temperatures, rectal temperature and heart rate were continuously measured. Blood pressures and oxygen consumption were measured at intervals. During Phase II of the study, the test subjects exercised on a bicycle ergometer for interrupted periods at low exercise levels.

The data for Phase I has been analyzed and a publication is in the final stages of approval prior to being sent to a journal. Data from ten subjects in each group was used and the average drop in body weight was 4.6%. All blood and urine measures indicated dehydration and within 20 hours of restoration of fluid, their weight was within 0.3%.

Figure 1 shows the results of the dehydration on the two groups. In all three exposed fingers, the change was highly significant and the response following rehydration was almost back to normal.

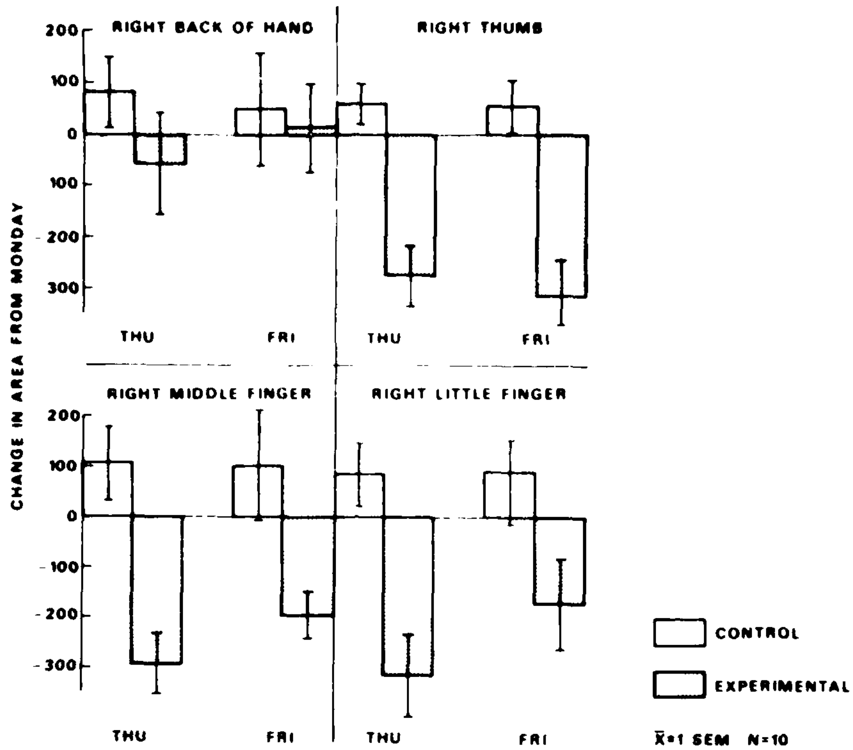

Figure 1. The change in the area of the temperature-time curve (units: °C-minutes) from the Monday baseline values is illustrated for the 4 right hand sites for control and experimental subjects.

We concluded that dehydration does have a determinal effect on the response of a person to cold. Every effort should be expended to provide adequate fluid to soldiers under field conditions to counteract this.

The data from Phase II is presently being analyzed.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	049 Factors Predisposing to Cold Injury
Study Title:	The Effects of Physical Fitness on Extremity Temperature
Investigators:	Donald E. Roberts, Ph.D., James J. Jaeger, CPT, MSC, Ph.D. and Joel J. Berberich, CPT, MSC, Ph.D.

Background:

In most studies of acclimatization to cold, the response to cold has become intermingled with the response to both work and cold. Several investigators have attempted to ascertain the effect of changes in physical fitness and separate them from the response of a cold exposure. Almost all of the studies have used some type of training program and a standard cold stress which involves a nude subject residing in a cold environment for some time period (1,3,11).

Adams and Heberling (1,11) have shown in two separate studies that physically fit subjects tended to have a higher control skin temperature and a lower core temperature. The changes in physical fitness levels were estimated by a fitness index and are of minimal value for comparison with maximum levels of oxygen consumption (max $\dot{V}O_2$).

In a study by Keatinge (13), there was no documentation of physical fitness changes and training was performed during cold exposure. These studies (1,13) were somewhat different in the temperatures used and in the duration of cold exposure, but both had similar results. They both reported elevated skin temperatures and reduced core temperatures during cold exposure; however, the heat output (metabolic rate) was different for the two groups.

Hammmel et al. (10) have shown in a study involving a five week training program with a cold group and a warm group, that conditioning had no apparent effect on central or peripheral body temperatures. The conditioning raised the metabolic rate in the warm environment as well as in the cold environment and caused an increase in tissue conductance (H_{loss} Skin/Tr-Tmw) during cold exposure.

Hellstrom (12), using a small group of subjects, was unable to show any relationship between max $\dot{V}O_2$ and skin temperatures during test in a cold environment. However, Fusco and Gatin (8) have shown that training will increase tolerance to a cold stress.

Based on these studies, it appears that there may or may not be an elevated skin temperature and decreased core temperature following training, but changes in metabolism and blood flow to the periphery do occur.

The effect of exercise during cold exposure on rewarming has also been investigated. Andersen et al. (2) have shown, in a study involving outdoor and indoor workers, that outdoor workers tend to rewarm the periphery faster than indoor workers. In both groups, the metabolic rate during exercise in the cold is elevated. Stromme et al. (16), in a study using students, fishermen, and lumberjacks, showed the outdoor workers rewarming the skin faster during exercise in the cold than did the indoor workers. No physical fitness measures were taken, but the lumberjacks were considered extremely fit. Hellstrom et al. (12) have shown that untrained subjects require the use of 40-65% of aerobic capacity to rewarm fingers when exposed to zero degrees C. The time course of rewarming was slower for toe temperatures than for finger temperatures and tended to show an increase when work was stopped.

The mechanism by which changes in physical fitness affects the skin temperature is not clearly defined. It has been reported that the sensitivity of the sweating mechanism during exercise is increased with improved physical fitness which would tend to cool the skin (12). The improved cardiac effects coupled with increased muscle vascularization with training may account for the increased peripheral blood flow and the resultant higher skin temperature.

Progress:

The purpose of this study was to investigate the magnitude of skin temperature elevation following training and to determine its role in the maintenance of a warmer extremity during cold exposure. Two groups of test subjects were tested for physical fitness (max $\dot{V}O_2$) and responses to cold. The cold test involved a cold room ($0^{\circ}C$) exposure of 135 min. with no hand bare. Each subject was instrumented with 16 thermocouples on hands and other body areas, a rectal probe, and an ECG harness. Following the initial testing, one group was trained (aerobic work) and the other group was allowed their normal activity (control group). Comparisons of the area under the cooling curve for the thumb, little finger and middle finger on the exposed hand were made for each group.

One group of subjects (6 trained, 3 non-trained) was run from April 1976 to July 1976. Based on the results of this group, another group was run from July 1977 to September 1977.

The preliminary results from the first group (1976) show the following from the trained group.

TRAINING GROUP DATA - GROUP I

Area under hand cooling curve -- deg-min

	Pre-training	Post training	Significance level
thumb	1115 ± 93 deg-min	2014 ± 187 deg-min	$p < 0.01$
middle finger	993 ± 135 deg-min	1580 ± 199 deg-min	$p < 0.05$
little finger	902 ± 120 deg-min	1483 ± 181 deg-min	$p < 0.05$

These data show a significant increase in the warmth of the hand following training (a 99% increase in max $\dot{V}O_2$).

The control group and the trained group were not similar in that all trained subjects completed the 135 min cold test while none of the three control subjects did. Therefore, it was decided to test a second group in the summer of 1977. The subjects to be tested were being trained for an altitude study.

The data from the second (1977) group has been analyzed. There were problems in this second study due to trying to use subjects for two studies. The subject requirement were not the same and subsequent adjustments in the control and trained group population and problems with max $\dot{V}O_2$ determinations make the data from the second study not comparable to the original study.

The data from the first study will be presented as is and is in the process for publication at this time.

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(83051)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OA 6148	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	N/A	N/L	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	051
b. CONTRIBUTING				
XXXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U) Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
012600 Pharmacology; 005900 Environmental Biology; 013400 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
70 07	CONT	DA	In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	9.0	261
	CURRENT 79	7	260

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
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20. PERFORMING ORGANIZATION
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ADDRESS:* Natick, MA 01760
PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
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TELEPHONE: 955-2851
SOCIAL SECURITY ACCOUNT NUMBER
ASSOCIATE INVESTIGATORS
NAME: CYMERMAN, Allen, Ph.D.
NAME: 955-2885 DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Acute Mountain Sickness; (U)Exercise at Altitude; (U)Visual Search Performance; (U)Blood Coagulation

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Exposure of soldiers to high terrestrial elevations results frequently in reduced military performance as well as medical disabilities which are incompatible with the successful completion of military operations. The purpose of this work unit is to investigate methods of prevention and treatment of these performance decrements and disabilities.

24. (U) Studies will be conducted in animals and man to (1) determine the mechanisms of the physiologic alterations and medical disabilities at altitude; (2) assess and predict the performance of individuals and small units operating at altitude; (3) evaluate the efficacy of pharmacological agents and other means in preventing or reducing performance decrements and illness; (4) enhance the rate of adaptation to high terrestrial elevations.

25. (U) 77 10 - 78 09 (1) An increase in factor VIII coagulant activity was observed during the first week of exposure of soldiers to high altitude; (2) Manual tracking of a random sinusoidal pattern was significantly impaired within 6 hours of high altitude exposure and completely recovered after 24 hours; (3) Target detection capability of soldiers was impaired by increased observer distance, peripheral displacement and size reduction of the target. Further impairment by hypoxia was indicated but was obscured by a positive practice effect; (4) Soldiers with higher maximal oxygen consumptions and anaerobic thresholds sustained larger decrements after 24 hours of altitude exposure but suffered from acute mountain sickness to the same extent as less fit soldiers; (5) Studies have been conducted to assess the importance of load carriage on physical performance at altitude.

*Available to contractors upon originator's approval

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Program Element: 6.27.77.A. ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations

Study Title: Effects of Altitude Exposure on Energy Expenditure During Physical Work

Investigators: Allen Cymerman, Ph.D., Kent B. Pandolf, Ph.D., John L. Kobrick, Ph.D., John T. Maher, Ph.D., Andrew J. Young, CPT, MSC, Ph.D., and Thomas J. Kinane, LTC, MC

Background:

An important concern of this Institute for the past several years has been the development of a theoretical model for predicting the energy cost to the soldier of walking with a load at various speeds and up various grades (1,2). This prediciton model has been developed, and further research has extended its application to include terrain variations ranging from hardtop to deep snow. The model provides a reasonable estimation of the work output a soldier can sustain under various terrain conditions. However, the model has not been verified under conditions which may impose a physiological limitation to the work output. This is especially true at high terrestrial elevations where the reduced oxygen pressure results in lower maximal oxygen uptake (3) and lower endurance capacity (4). The situation is further confounded when acute mountain sickness (AMS) and/or pulmonary edema are present. Recognizable symptoms of AMS can occur at elevations as low as 2,500 m, increasing in direct proportion with the altitude. These adverse reactions add a more complex subjective component to any physical exercise effort involving voluntary termination such as maximal oxygen consumption, endurance capacity, or even carrying an ammunition box several hundred yards.

Submaximal oxygen consumption at the same absolute workload is unchanged at different altitudes (9). Thus, with increasing workloads at sea level or at altitude, oxygen consumption increases linearly until a maximum is attained.

Furthermore, increasing the weight a soldier must carry will result in a linear increase in his oxygen consumption or energy expenditure depending on the constancy of such factors as mechanical efficency, load placement, etc. That this is the case at sea level is shown by the formula devised by Pandolf et al. (5):

$$M = 1.5\ W + 2.0\ (W + L)\ (L/W)^2 + (W + L)\ (1.5\ V^2 + 0.35\ VG)$$

The third component in this equation is the forcing function with respect to energy expenditure (M) while walking. The energy expended varies directly as the sum of the body weight (W) and load (L) times a factor involving the square of the velocity (V) plus the product of velocity and grade (G). While the additional weight carriage will force a soldier to work at an O_2 consumption level that is closer to his maximal, the predictive equation should on a theoretical basis still hold true at altitude. However, such factors as altered protein metabolism at altitude, changes in efficiency of load carriage, increased respiratory and cardiac work, and the use of different working muscle groups may combine additively to alter the formula.

The work protocol followed will also allow determination of the changes in walking endurance times that may occur with continued exposure to altitude. Increases in endurance capacity with continued sojourn at altitude have been observed in the past on the bicycle ergometer (4). Thus, a comparison can be made between two different types of work, i.e., walking and bicycling. A practical estimate of the load and duration a soldier could be expected to work at altitude and the degree of improvement to be expected with stay at altitude will be obtained.

As mentioned previously, it is known that steady-state submaximal oxygen consumption at altitude is not different from sea level. However, it appears that the total volume of O_2 utilized during exercise and recovery at a specific absolute workload and duration is definitely larger at altitude (4-8 weeks at 3,750 m) (8). This last statement is somewhat controversial since it depends to a great extent on the method of measurement and the manner in which the data are reported. Raynaud et al. (6) reported that under any of the conditions of work or duration studied (60 to 150 W, 10 or 25 min), oxygen debt is smaller at altitude (3 weeks at 3,800 m). Their results are given as percent of maximal oxygen consumption, and thus the absolute workloads were less for some subjects. Since O_2 deficit and debt are directly proportional to work intensity and duration, their results are not surprising. A greater O_2 deficit and debt were also obtained by Knuttgen and Saltin (7) for acute exposures to altitude (4 hrs at 4,000 m) when results were examined in absolute terms. However, in relative terms virtually all differences were eliminated. The purpose of this aspect of the protocol was to examine the kinetics of energy production as indicated by oxygen uptake after 2, 6, and 10 days at 4,300 m. This was accomplished using an on-line O_2 consumption system which provided a more definitive representation of O_2 uptake kinetics. It also allowed us to examine whether a subject's level of "fitness" had changed with regard to oxygen deficit and its repayment.

Progress:

Eight Army male volunteers were recruited and given standard USARIEM altitude physical examinations. One week prior to altitude exposure at Pikes Peak (4,300 m), the subjects were familiarized v ith all testing procedures and maximal oxygen consumptions were determined on each subject both at sea level and 4,300 m simulated altitude. Oxygen deficit and debt determinations were also made at sea level.

While in residence at Pikes Peak, subjects carried pack loads ranging from 0 to 30 kg on grades ranging from 0 to 16% on days 1, 3, 5, 7 and 9 for a maximum of 10 min or until voluntary termination. On days 2, 4, 6, 8 and 10, oxygen deficit and debt were determined using a standardized test protocol. All oxygen consumption measurements were made every 15 secs using an on-line computer system which sampled expired O_2, CO_2 and expiratory air volumes. Maximal oxygen consumptions were again determined after return to sea level to rule out the possibility of any training effect.

All data collection has been completed and mathematical and statistical analyses are presently being performed.

LITERATURE CITED

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Program Element:	6.27.77.A. ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	Effects of Hypoxia on Selected Aspects of Visual Target Detection
Investigators:	John L. Kobrick, Ph.D., James A. Devine, Allen Cymerman, Ph.D., Kent B. Pandolf, Ph.D., John T. Maher, Ph.D., Andrew J. Young, CPT, MSC, Ph.D., and Thomas J. Kinane, LTC, MC

Background:

In a previous study, Kobrick (1) showed that capability for the detection of military targets is directly related to the viewing distance, and to the degree of peripheral displacement of the targets from the central line of sight. These results are in agreement with a variety of published findings of reduced performance efficiency in the periphery compared to foveal capability (2,3,4,5,6,7,8,9,10,11). Kobrick also showed that target detection was significantly impaired during hypoxia conditions, as compared to the same performance at sea level (12,13,14,15,16). This finding is consistent with other reports of hypoxic impairments of both central and peripheral visual performance (17,18,19). In that study (1), the subjects viewed projected slides of a soldier in rifle firing position at various locations in the visual field and at different viewing distances. Performance efficiency was assessed on the basis of response time to locate each target. This task was judged to be of practical value in studying effects of hypoxia on several important dimensions of target detection, and was accepted by the subjects as a realistic equivalent of an imaginable combat situation. However, the veiwing situation contained corrupting factors which were not initially apparent. Various segments of the natural background of trees and brush contained widely different degrees of color, brightness, and contrast with the target, so that target detection was inherently easier at some positions than at others. Also, use of the same target in all cases made it more predictable and, therefore, easier to find than would be the case in most search situations where the targets would be unknown. Finally, the field upon which the slides were photographed sloped moderately upward away from the background, conferring some advantage for target detection at the farther viewing distances due to the increased elevation factor. A new target detection task was developed to correct for these deficiencies, and to allow the use of several targets and a more uniform background.

Progress:

The following study was conducted to assess the effectiveness of the revised target detection task both at sea level and at a field location at an elevation of 14,110 feet.

Thirteen male soldier volunteers, ages 18-35, were employed. They were screened for normal visual acuity, depth perception, and for any medical abnormalities which might be aggravated by hypoxia.

The experimental task involved viewing a series of color slides projected on a large screen. The slides were representations of authentic 1/35-scale models of five U.S. military objects (Sheridan tank, 2 1/2-ton truck, armored personnel carrier, jeep, soldier with rifle). The objects were chosen to encompass a range of typical target object sizes. Each target object was photographed in all combinations of 5 positions in the visual field of the observer (center, 10° right, 20° right, 10° left, 20° left), and 3 viewing distances equivalent to 60, 90, and 120 yards. The targets each appeared against a backdrop of standard Army camouflage cloth, which also covered the horizontal surface on which the objects were placed. This cloth contained a variegated but repeated pattern of black, dark green, olive green, brown, and tan areas in the same overall brightness range as the models.

The 75 slides were presented in randomized order of occurrence, and were randomly interspersed with 15 slides containing only the background (5 for each viewing distance). These were used to allow the opportunity for false-positive responses. The subject viewed the slides at a distance such that the image subtended at the eye was the same as would be the case for the real object at the actual distance involved. Each subject was trained to search each scene when it appeared, and to call out the identity and location of each target as soon as it was recognized. A millisecond timer was activated at the onset of each slide, and was stopped by a voice-operated relay driven by a throat microphone worn by the subject.

After instruction and training, each subject completed a preliminary practice session and two complete performance trials on two successive days at sea level. Thereupon, they were transported to a high-altitude field laboratory at the summit of Pikes Peak, CO (14,110 feet elevation), and completed one performance session daily for the following five successive days.

The basic datum used for analysis of the results was the response time (RT) for recognition and location of the target in each slide. A one-way analysis of variance based on the individual RT's was first performed across daily sessions to determine if hypoxia exposure had any effect on target detection. The results of this analysis showed that neither the hypoxia main effect nor any of the simple interactions with the other design dimensions were significant. Subsequent examination of the data indicates that a continuing increase in RT capability due to practice beyond the training period probably acted to cancel any measurable developing impairment due to hypoxia exposure, the net result of the two processes being no change in performance which could be observed. In future use of this task, subjects will have to be trained for a longer period than had been anticipated in this study.

Since the hypoxia exposure as experienced in this study had no measurable effect on target detection performance, the data were pooled across test days into one matrix, and an overall treatments x subjects multivariate analysis of variance was performed to determine the effects of dimensions of the task itself on target detection performance (target size (T), target position (P), and viewing distance (D)). The results of this analysis are presented in Table 1. Based on the subject mean-square interactions, the T, P, and D main effects and their simple and second-order interactions were all highly significant ($P < .001$).

TABLE 1
Summary of Analysis of Variance of Effects of Target Size, Location and Viewing Distance on Response Time

Source	DF	MS	F	P
Size of target (T)	5	1155369184.00	130.93	<.001
Viewing distance (D)	2	568498384.00	185.82	<.001
Target position (P)	4	51471312.00	20.71	<.001
T x D	10	53237856.00	17.40	<.001
T x P	20	24417476.75	9.82	<.001
D x P	8	11409840.00	5.30	<.001
T x D x P	40	8938084.75	4.15	<.001

In order to describe the trends represented by the significant main effects, the group mean RT's associated with the various targets, position, and viewing distances were calculated, and are shown graphically in Figures 1 and 2. In Figure 1, the overall group mean RT's averaged across all targets are presented for each target position as a function of each viewing distance. It is clear that the more peripheral targets were consistently more difficult to detect at all viewing distances, even though 20^{o} into the periphery of the visual field is only a moderate excursion. It is also quite evident that large systematic increases in RT occurred with longer viewing distances. The irregularity at the center of the 60-yard curve was due to an imperfection in the target slide for that particular combination.

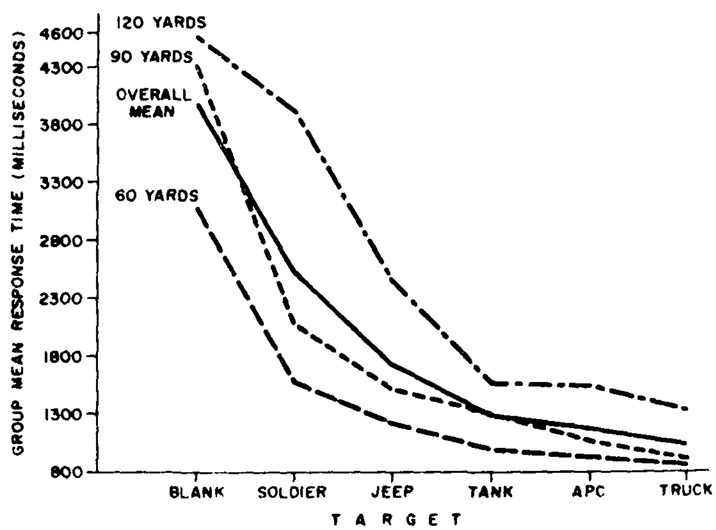

Figure 1. Group mean response times for the various target sizes as a function of each viewing distance.

In Figure 2, the overall group mean RT's are shown for each type of target averaged across target positions for each viewing distance. Targets are arrayed along the abscissa in order of increasing size, preceded by the value for "no-target" slides. It is clear that RT's virtually decreased with increased target-object size across all other viewing conditions. The data are quite consistent, as evidenced by the slight differences between the RT's for armored personnel carrier, tank and truck targets, which correctly reflect small differences in size and configuration among those vehicles. The RT's for the blank slides were the longest in all cases, suggesting that the subjects took longer to decide about the absence than about the presence of targets. The three curves once again display the marked influence of viewing distance on target detection for all target sizes, which in fact show larger differences due to distance for the smaller targets, as one might expect.

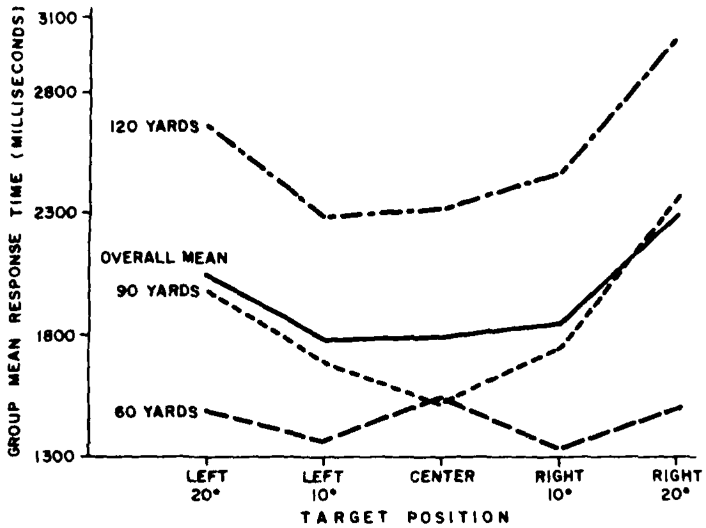

Figure 2. Group mean response times for the various target positions as a function of each viewing distance.

This task shows promise as a model for studying target detection processes, and should be studied further under hypoxia exposure, taking account of the need for greater preliminary training before final testing is undertaken under stress.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	Hemostatic Changes Before and After Maximal Exercise at Sea Level and High Altitude
Investigators:	Gerald L. Davis, Ph.D., John T. Maher, Ph.D., Allen Cymerman, Ph.D., James J. Jaeger, CPT, MSC, Ph.D., and Ronald G. Williams, LTC, MC

Background:

Acute mountain sickness (AMS) is observed in unacclimatized individuals following the sudden exposure to altitudes above 3,000 meters. The severity of physical symptoms displayed by individuals afflicted with AMS ranges from anorexia, vomiting and headache to the development of high altitude pulmonary edema (HAPE). AMS, even in its mildest form, impairs the functional abilities of an individual.

While the symptoms of AMS are easily recognizable and well defined, the mechanism of the pathogenicity is not understood. Various theories have been proposed to explain the etiology of AMS and HAPE (1,2). One of these theories involves the possibility of capillary occlusion by red cells, platelet aggregates or microthrombi. Thrombotic occlusion of several capillaries subjects the patent capillaries to increased perfusion pressures and possible edema formation. If this occurs to a sufficient degree in the lung vasculature, HAPE may develop. If sufficient cerebral capillaries are involved, cerebral edema may result. The latter hypothesis was proposed by Hansen and Evans (3).

Any number of stimuli (exercise, pain, etc.) can produce changes in the hemostatic system. One of the most significant changes in the coagulation component of hemostasis is a large increase in factor VIII (Antihemophilic factor). The highest values have been observed 5-10 min following maximum exercise (4).

The mechanism responsible for the large increase in coagulant activity is not known.

Of all of the coagulation factors, factor VIII is the least understood. Neither the molecular structure nor the site of synthesis of this protein is known and yet it is the most common of the inherited coagulation deficiencies and increases have been observed in conditions associated with thrombi formation. A major problem with understanding factor VIII is that it is not known whether it is a single protein with multiple functions or two proteins, a high molecular weight (HMW) portion and a low molecular weight (LMW) sub-unit linked either covalently or by hydrogen bonding (5).

The coagulant activity of factor VIII has been associated with the LMW portion of the factor VIII molecule and the antigen portion has been associated with the HMW portion of the molecule. Another property associated with the HMW portion of the factor VIII molecule is the effect which factor VIII has on the functional ability of blood platelets to stick together and to foreign surfaces. This function is referred to as the von Willebrand's factor. If the von Willebrand's factor is not present, the platelets will not stick together and the individual will have a bleeding problem. If the von Willebrand's factor is present in large amounts, the platelets may have an increased tendency to stick together resulting in an increase in platelet aggregates and thrombi formation.

Previous investigations which have studied the effects of high altitude on factor VIII have reported a decrease after one hour of exposure (6), no change (7) or an increase in subjects who developed HAPE (7). The changes which were reported were concerned with only the coagulant or functional activity of the molecule. Studies on the effects of high altitude on the antigenic concentration of factor VIII and/or the von Willebrand's factor have not been reported. Singh and Chohan (7) reported an increase in platelet adhesiveness (platelet stickiness) which they associated with an increase in platelet factor VIII. The increase in platelet adhesiveness may have been due to an increase in von Willebrand's factor which they did not measure.

In the present study changes in factor VIII coagulant activity, (VIII:C), factor VIII related antigen (protein)(VIII R:AG) and the von Willebrand's Ristocetin Cofactor (VIII:Rcof) were measured before and after acute maximal exercise at sea level and at 4,300 m (HA). The purpose of measuring the three different properties of factor VIII (VIII:C, VIII R:AG, VIII:Rcof) under these conditions was to investigate the possible role of this protein in AMS and to gain insight into the functional activities associated with the molecule.

Progress:

Analyses of VIII:C, VIII R:AG, VIII:Rcof before and after maximal exercise at sea level and at HA have been completed. Preliminary data computations and interpretations of the results are presented in this report. More complex statistical computations are being processed by computer analysis.

Factor VIII coagulant activity (VIII:C) was measured on two different occasions at sea level (Table 1). Blood samples for coagulation studies were drawn, using a two-syringe technique without stasis, before exercise, immediately after maximal exercise and 8 minutes post-maximal exercise. The mean pre-exercise VIII:C was 147% $\pm$ 14 SE on the first day of sea-level testing and 129% $\pm$ 11 SE on the second testing day. Even though the two pre-exercise values are not significantly ($P > 0.05$) different from each other, the lower mean value obtained on the second day of testing may reflect a reduced level of anxiety on the part of the subjects.

Immediately after maximal exercise the VIII:C was markedly increased from pre-exercise levels with the highest activity being recorded 8 minutes post-exercise. This finding is in agreement with previously reported results (4). The immediate post-exercise and the 8 minutes post-exercise results on day 1 were not different from those obtained on day 2 of testing.

The mechanism for the post-exercise increase in VIII:C is not known. In order to investigate the possible influence of blood pH on the VIII:C activity, venous pH values were determined. A negative correlation between percent increase in VIII:C and change in venous blood pH was observed. The negative correlation between % change in VIII:C and venous pH immediately after maximal exercise is not readily explainable. It is possible that the increase in hydrogen ion concentration is affecting the factor VIII protein (pH activation of a molecule) and increasing its activity. It is also possible that the factor VIII protein is being released into the blood stream along with metabolic end products, such as lactic acid which is a major contributor to the increase in hydrogen ion, and the observed correlation is only coincidental to the change in venous pH. Synthesis of factor VIII related antigen by cultured endothelial cells has been reported by Jafee et al. (8). In light of the reports of Jaffee et al. (8), the suggestion of a release of this material from the endothelial cells along with metabolic end products is feasible. However, it does not explain why the VIII:C at 8 minutes post-exercise was greater than the immediate post-exercise value, whereas the venous pH value had returned toward base-line levels. Further studies are needed for the development of a better understanding of the mechanism of the post-exercise increase in VIII:C.

The mean pre-exercise factor VIII related antigen (VIII R:AG) was approximately the same on both sea-level testing days (Table 1). The post-exercise changes in VIII R:AG immediately after exercise and 8 minutes post-exercise followed those recorded for the VIII:C. Largest increases in the VIII R:AG were observed 8 minutes post-exercise.

The mean values obtained for von Willebrand's Ristocetin Cofactor (VIII:Rcof) on both days of sea-level testing were not different (Table 1). The immediate post-exercise VIII:Rcof recorded on day 1 was less than that recorded on day 2. Even though the mean value for the 8 minutes post-exercise VIII:Rcof was less than the mean 8 minutes post-exercise VIII:Rcof value, the two values were not statistically different. The 8 minutes post-exercise VIII:Rcof was less than the immediate post-exercise VIII:Rcof on both day 1 and day 2. This observed decrease at 8 minutes post-exercise was unexpected considering that both VIII:C and VIII R:AG were greater than the immediate post-exercise value. If the factor VIII protein is one molecule then all three variables (VIII:C, VIII R:AG and VIII:Rcof) should change in the same direction. While technical problems must always be considered, it is also possible that this information indicates that the VIII:Rcof function, which has been associated with the HMW portion of the factor VIII protein, may be due to either a smaller fragment which either attaches to the HMW portion or is dissociated from the parent protein during activation.

The pre-exercise VIII:C after 1 day and 7 days of high altitude (HA) were significantly greater (Table 1) than pre-exercise sea-level measurements ($P < 0.05$). The immediate post-exercise VIII:C was markedly increased over pre-exercise values after 1 and 7 days at HA, with the highest levels being recorded 8 minutes post-exercise. The VIII:C activities recorded following maximal exercise (immediate post- and 8 minutes post-exercise) at HA were not different from values recorded at sea level.

Maher et al. (6) reported a decrease in the VIII:C after one hour of exposure to HA. By 24 hours the mean VIII:C had returned toward pre-exposure values and by 48 hours the mean VIII:C was slightly higher than the pre-exposure value. The 24 hour and 48 hour HA VIII:C values in the present study were not significantly different from pre-exposure levels. Singh and Chohan (7) compared the VIII:C of sea-level controls to those of HA controls and found no difference. The HA controls represented 32 of 38 soldiers who had lived at HA for two years without developing HAPE. The six soldiers who did develop HAPE had elevated VIII:C levels. The increase in the pre-exercise VIII:C observed after one day of exposure to HA in this study might be accounted for by the stressful situation introduced by travel to a new location, changes in circadian rhythm, and excitement. However, after 7 days of exposure to HA, these external factors should be minimal and yet, the same mean VIII:C value was recorded. Tissue hypoxia may be an important factor in the observed increase in VIII:C at HA. Using venous occlusion (which results in tissue hypoxia), marked increases in VIII:C have been demonstrated (9).

The pre-exercise VIII R:AG after 1 and 7 days at HA were not different from sea-level measurements (Table 1). The response of VIII R:AG to exercise at HA was not different from that observed at sea level.

The pre- and post-exercise values recorded after 1 and 7 days of exposure to HA were not different from the pre- and post-exercise values recorded at sea level (Table 1).

In summary, an increase in VIII:C, VIII R:AG and VIII:Rcof was observed immediately post-exercise. At 8 minutes post-exercise VIII:C and VIII R:AG were greater than immediate post-exercise levels whereas the VIII:Rcof activity had returned towards pre-exercise values. After 1 and 7 days at HA the VIII:C activity was greater than sea-level values whereas VIII R:AG and VIII:Rcof levels were not. The response of VIII:C, VIII R:AG and VIII:Rcof to maximum exercise at HA was not different from observations made at sea level.

The observations that 1) VIII:C and VIII R:AG increased following maximum exercise while VIII:Rcof, at 8 minutes post-exercise, was less than immediately post-exercise and 2) there is a relationship between the venous pH and VIII:C and VIII R:AG immediately after exercise, but not at 8 minutes, are important findings and warrant further investigation.

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TABLE I

Factor VIII Coagulant Activity, Antigen, von Willebrand's Factor, and pH Results Before and After Maximal Exercise at Sea Level and at High Altitude

	F VIII Coag Act		F VIII Antigen		von Willebrand's Factor		pH	
CONDITIONING	n	%Act ± SE*	n	units ± SE*	n	units ± SE*	n	pH ± SE*
DAY ONE (sea level)								
1. Pre-exercise	7	147 ± 14	7	0.9 ± .16	4	0.7 ± .23	10	7.365 ± .01
2. Immediately post-exercise	7	244 ± 34	7	1.6 ± .34	4	1.1 ± .34	12	7.249 ± .02
3. 8 minutes post-exercise	6	260 ± 36	6	1.8 ± .40	3	0.7 ± .14	10	7.268 ± .01
DAY TWO (sea level)								
1. Pre-exercise	13	129 ± 11	12	1.0 ± .14	9	0.9 ± .12	13	7.368 ± .01
2. Immediately post-exercise	13	276 ± 18	12	2.0 ± .23	9	1.6 ± .17	13	7.166 ± .02
3. 8 minutes post-exercise	12	292 ± 26	11	2.1 ± .27	9	1.3 ± .18	12	7.195 ± .01
DAY ONE (high altitude)								
1. Pre-exercise	12	160 ± 14	11	0.9 ± .09	8	0.9 ± .11	12	7.422 ± .01
2. Immediately post-exercise	10	294 ± 30	12	1.6 ± .17	8	1.4 ± .32	13	7.285 ± .03
3. 8 minutes post-exercise	9	326 ± 36	11	1.7 ± .23	8	1.4 ± .30	13	7.306 ± .02
DAY SEVEN (high altitude)								
1. Pre-exercise	11	169 ± 24	12	0.9 ± .15	7	0.9 ± .08	13	7.391 ± .01
2. Immediately post-exercise	10	267 ± 27	11	1.5 ± .24	7	1.2 ± .25	12	7.293 ± .02
3. 8 minutes post-exercise	10	278 ± 27	11	1.6 ± .23	6	1.1 ± .22	13	7.313 ± .02

*Standard error of the mean

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	Performance on a Tracking Task at Sea Level and High Altitude
Investigators:	SP5 Carl J. Basamania, John L. Kobrick, Ph.D., James A. Devine, Allen Cymerman, Ph.D., Andrew J. Young, CPT, MSC, Ph.D., and John T. Maher, Ph.D.

Background:

In recent years, there has been a considerable amount of development in the area of tracked weapon systems. Some of these systems include the TOW and Dragon anti-tank missiles, the Copperhead and HELLFIRE missiles and a variant of the Stinger anti-aircraft missile. The major difference between these and other basic weapons is that once fired, the tracked weapon can be guided on to the target, by means of laser beams or fine wire connected to a control unit. This represents a divergence from other systems in that the target, in addition to being detected, must be tracked for a period of time. There is a counterpart to this type of task in psychomotor research which is referred to as tracking or pursuit tasks. While there has been considerable research into the effects of various stressor factors on tracking performance, such as vibration (1), drug intoxication (2), sleep loss (3), temperature extremes (4), and the effects of changes within the parameters of the tracking task itself (5,6), there has been little research into the effects of high altitude or hypoxia on tracking performance. There were a few studies conducted during the World War II and post-war period (7,8,9,10); however, the lack of sophistication in terms of instrumentation and analysis makes interpretation of this data difficult. There have been recent studies (11,12) which made use of more complex computer analysis; however, these studies focused only on very short-term exposure (1 to 120 minutes) to hypoxic conditions. While these conditions are important to pilots. they are of little interest to the Army which can realistically be expected to operate at terrestrial elevations of 10,000 to 15,000 feet (3,050 to 4,573 meters) for periods extending from a matter of hours to weeks. Since it has already been shown that extended hypoxia has a detrimental effect in such areas as cognitive reasoning and decision making (13), target detection (14), auditory acuity (15), and others (16), no research has been conducted on how tracking performance is affected.

In view of the development in the area of tracked weapon systems, which can be expected to continue, and the Army's need to deal with high altitude conditions, such as encountered by forward observers or helicopter pilots whose problem is exaggerated by carbon monoxide from engine exhaust, the present task was designed to assess the performance in a two-axis, compensatory tracking task under sea level and high altitude conditions. The compensatory task was chosen because it most closely resembles the task of keeping the crosshairs of a weapon on a moving target.

Progress:

The following study was conducted to assess the ability to track a target at sea level and at a field location at an elevation of 14,110 feet.

Seven male, right-handed soldier volunteers were used as subjects. They were screened for normal visual acuity and any medical abnormalities which might be aggravated by hypoxia.

The experimental task basically consisted of viewing a stimulus which was moving in two planes, horizontal and vertical, and making the necessary adjustments so as to keep the stimulus (hereafter referred to as the target) in the center of the screen on which the target was projected. The target was projected on a Tektronix 502A dual beam oscilloscope with a CRT 12 cm in diameter. The upper beam vertical amplifier was used instead as a horizontal amplifier for the lower beam. The movement of the target on the CRT was controlled by a composite sine wave consisting of three sine waves generated by two Hewlett-Packard 3300A and one Hewlett-Packard 3312A function generators and recorded on a Hewlett-Packard 3968A recorder. The frequency of the sine waves was 30, 21, and 15 cpm with all having the same amplitude. The same, albeit out of phase, composite sine waves controlled the horizontal and vertical movement of the target thus giving it what appeared to be, within the viewing time of the subject, random movement. The maximum range of movement of the target was ± 4 cm along each axis. The maximum range of movement on the CRT for the subject's response was ± 5 cm thus allowing the subject to overshoot or overcompensate for changes in target movement. The control unit for the subject was a Measurement Systems 521-G251 two-axis joystick mounted perpendicular to and centered 10 cm below the CRT. Power to the CRT from the joystick was provided by a Datel MS-7 ± 5vdc power supply. A Honeywell 5600C eight-channel recorder was used to record the stimulus (target movement) along each axis, the subject's response along the two axes, a signal to identify each subject and other information which was recorded on a voice channel. The subjects were told that the object on the CRT represented a target that they must, through movements of their joystick, keep in the center of the CRT screen which was represented by the convergence of a horizontal and vertical crosshair. They were also told that, although perfect performance was very difficult, they should try to minimize movement of the target out of the center area. The subjects' movement of the joystick compensated for movement of the target; i.e., if the target moved up on the screen, a corresponding movement of the joystick downward brought the target back into the center of the screen. During the training period, which lasted four days, subjects were presented five three-minute tracking periods with a two-minute break between each period. During the test sessions, the individual tracking task for each subject was 120 seconds with each subject being given two trials. The subjects were tested the same time each day before any other testing took place and all subjects saw the same segment of composite sine wave on the same day of testing and different segments on different days of testing. The test sessions took place at sea level and at the high-altitude laboratory at the summit of Pikes Peak, CO. Another sea-level measurement was taken upon return to USARIEM.

The basic datum used for this experiment was the voltage output from the stimulus and from the subject's control unit to the oscilloscope. This voltage signal was converted to computer units by means of an A/D converter controlled by a DEC 11/40 computer. The conversion of these computer units was to root meansquared (RMS) error values. The RMS values were analyzed by means of a two-way analysis of variance and trend analysis. This design allowed the assessment of the effects of high altitude vs sea level on the performance of a tracking task in two dimensions and the assessment of performance over time at altitude to see if there was a corresponding decrement or improvement in performance as time at altitude increased.

Initial analysis of the data showed that there was no significant difference in responding along each axis between the first and second sea level measurements which were made before and after high-altitude exposure, respectively. There was, however, a significant decrement in performance while subjects were at high altitude (Table 1). The analysis of variance also revealed that there was a significant trial effect but not a significant axis effect, although one should note that the trial effect may have overshadowed the main effect of the axis of movement since the interaction of altitude, trial and axis was significant. Also, a paired Student's t-test of the means (Table 2) showed that by the third test at altitude, there had been a significant recovery in performance and this improvement continued for the duration of the sojourn although never reaching a level comparable to sea-level performance.

TABLE 1

Repeated Measures Analysis of Variance Table

Source	Sum of Squares	df	Mean Square	F	P
Test Day	18193.46411	7	2599.06628	124.383	< 0.000
Trial	256.89335	1	256.89335	222.933	< 0.000
Axis	171.26653	1	171.26653	3.821	< 0.086
Day x Trial	470.64462	7	67.23495	62.165	< 0.000
Day x Axis	108.09824	7	15.44261	.739	< 0.640
Trial x Axis	.19719	1	.19719	.171	< 0.690
D x A x T	52.57040	7	7.51006	6.944	< 0.000

TABLE 2

Mean Relative RMS Error Scores

*Test:		1	2	3	4	5	6	7	8
Axis:									
Hor.Trial	1	18	46	46	45	40	35	37	16
	2	18	43	40	39	34	34	36	17
Ver.Trial	1	18	52	50	49	41	36	36	18
	2	18	49	41	40	36	38	38	18

*Tests 1 and 8 conducted at sea level; 2-7 conducted at 14,110 feet

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	The Effects of Physical Fitness on Performance at High Altitude
Investigators:	Allen Cymerman, Ph.D., James J. Jaeger, CPT, MSC, John T. Maher, Ph.D., John L. Kobrick, Ph.D., Gerald L. Davis, Ph.D., and Ronald G. Williams, LTC, MC

Background:

The successful accomplishment of specific physical tasks during high altitude (HA) exposure may be compromised by the development of acute mountain sickness (AMS) and high altitude pulmonary edema (HAPE). These maladies should be considered in the deployment of troops at or above 3,000 meters altitude in order to maintain optimal physical and mental performance. The variability to both AMS and HAPE has been noted by many investigators. Such factors as rate and degree of ascent, diet, exercise, previous exposure, and degree of physical fitness may all play a role in the severity of symptoms. One purpose of the present investigation was to determine whether a relationship exists between physical fitness and the occurrence and severity of AMS symptoms. Several investigators have suggested that physical fitness may confer some benefit and that physical conditioning should be considered as a possible measure to ameliorate AMS (1,2). This assumption has not been confirmed (3,4). Hansen et al. (3,5) reported that cardiovascular fitness did not protect against AMS since symptom severity did not correlate with maximal oxygen consumption. However, in the latter study well-defined groups of "fit" and "unfit" subjects were lacking.

A second purpose of the present investigation was to determine the relationship between aerobic power (maximal oxygen consumption, $\dot{V}O_2$ max) at sea level and its reduction at altitude. Results of several investigators, summarized by

Buskirk (4), indicate that the $\dot{V}O_2$ max of well-conditioned young men decreased less per thousand feet elevation than in all subjects combined. This conclusion is difficult to accept when one considers the possible variables in different studies by different investigators. In fact, Saltin (6) and Grover (7) both noticed larger decrements in $\dot{V}O_2$ max in subjects with greater working capacities.

The design of this study also allowed the indirect determination of anaerobic threshold (AT). Several investigators (8,9) have shown that the ventilatory response to an incremental exercise test is related to the anaerobic threshold, i.e., the point at which exercise is sufficiently severe to produce a metabolic acidosis due to increased blood lactate levels. It was our purpose to use this indirect method, which eliminates the necessity for repeated blood sampling, to investigate the effects of altitude on anaerobic threshold.

Progress:

Fourteen Army volunteers were recruited, given USARIEM standard altitude physical examinations, and divided into a "high" and "low" group based on levels of $\dot{V}O_2$ max as determined using a continuous cycling test regimen. The "high" group maintained or improved its level of fitness by participating in sprint and endurance exercises 5 days/week for one month prior to altitude exposure. The "low" group did not participate in any strenuous exercise during the same time period. The groups were then randomly divided in half, and each half was transported by air and auto to the summit of Pikes Peak, CO (4,300 m), followed one week later by the second half of each group.

Each subject was administered the general high altitude questionnaire (GHAQ) daily during altitude exposure and tested on a bicycle ergometer at sea level and after 1, 3, 5 and 7 days of altitude exposure. The GHAQ has been found to adequately assess symptoms of AMS. The test consists of a 30-item questionnaire with each item rated on a 5-point scale. Subjects were briefed on the test as well as on the symptoms of AMS before any baseline or altitude measurements were made.

An on-line computer system was developed and used for determination of O_2 consumption, CO_2 production, and pulmonary ventilation every 15 sec. During testing the subject inspired humidified air or a humidified 35% O_2 gas mixture and expired through a breathing valve into a 5-liter mixing chamber. Gas samples were continuously sampled from the chamber for O_2 and CO_2 levels using an oxygen fuel cell and LB-2 gas analyzer, respectively. Expired air volume was determined using a pneumotachometer. Analog signals from each instrument were digitized and together with manually entered temperature measurements were used to calculate the fractional concentrations of expired oxygen and carbon dioxide, the minute respiratory volume ($\dot{V}_E$), and the oxygen consumption ($\dot{V}O_2$) and carbon dioxide production ($\dot{V}CO_2$). In addition, $\dot{V}O_2$, $\dot{V}CO_2$, $\dot{V}_E$, and the ventilatory equivalent for oxygen ($\dot{V}O_2/\dot{V}_E$) were plotted simultaneously.

This system was used in an exercise protocol to determine anaerobic threshold and $\dot{V}O_2$ max. Exercise testing consisted of cycling at 50 rpm on a Monark ergometer for four minutes with no workload (0 kpm/min), followed by incremental increases in work rates of 100 kpm/min until the subject stopped of his own volition despite verbal encouragement by investigators.

One subject, upon immediate arrival at 4,300 m, withdrew from further participation and was returned to sea level. The remaining subjects participated in the entire study and developed AMS symptoms to various degrees. No subject exhibited symptoms, either at rest or during exercise, suggestive of high altitude pulmonary edema. Data are presented on subjects only when completeness was obtained throughout the entire study.

Table 1 shows the temporal relationship in AMS symptoms during the course of the study. Symptoms were most severe and only significantly different from any other measurement after the first day at 4,300 m. Improvement occurred with continued exposure. This phenomenon is well-known and indicates: (1) that our subjects responded as expected with a range of no symptoms to symptoms necessitating withdrawal from the study and (2) that only correlations made between day 1 and various physiological parameters are appropriate.

TABLE 1

Total General High Altitude Questionnaire (GHAQ) Score of Subjects Exposed to 4,300 Meters

	Days at High altitude				
	0	1	3	5	7
Mean	59	78*	63	65	58
S.D.	15	23	23	23	18
S.E.	4	7	7	7	5

N = 11 subjects

* = $P < .01$, using the Wilcoxon matched pairs signed-ranks test and comparison with 0 days (sea level)

Possible range of GHAQ = 30-150

Non-parametric statistical analyses were performed using the GHAQ responses on the first day of altitude exposure and various physiological measurements. No correlation could be found between the severity of symptoms and either maximal aerobic power (sea level), anaerobic threshold (sea level), or percent decrement in aerobic power induced by altitude exposure. In addition, no correlation was found between various ventilatory measurements obtained during exercise and symptom severity. Significant correlations have been found by both Sutton et al. (10) and King and Robinson (11) between a lower resting alveolar ventilation or hypoxic sensitivity and increased symptom severity. These results, however, should be verified using a larger number of subjects and under actual high altitude conditions.

A second question asked in this study was whether the initial level of physical fitness is related to the decrement in $\dot{V}O_2$ max that is observed at altitude. Figure 1 indicates the existence of a linear relationship, i.e., the greater the sea level $\dot{V}O_2$ max, the greater is the decrement observed at altitude. Figure 2 illustrates a similar phenomenon for AT. The net result is a normalization of all subjects with respect to maximal aerobic power and anaerobic threshold. This does not mean to imply that more fit individuals are more severely handicapped by altitude exposure. On the contrary, it is more likely that the biochemical and physiological capabilities associated with a high level of physical fitness enable one to work longer at a specific workload.

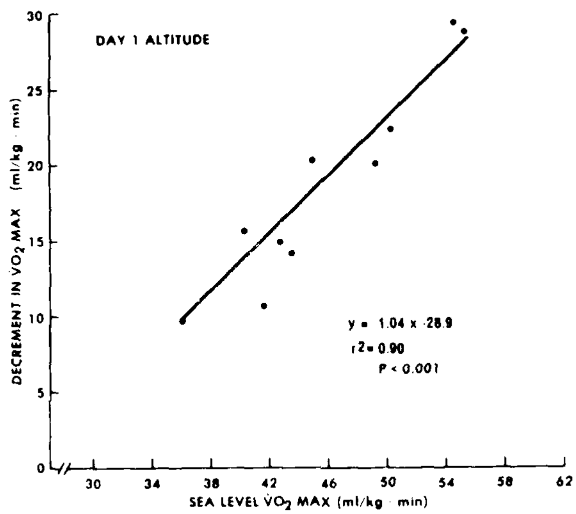

Figure 1: Linear relationship between sea level maximal oxygen consumption and the decrement observed after one day exposure to 4,300 meters.

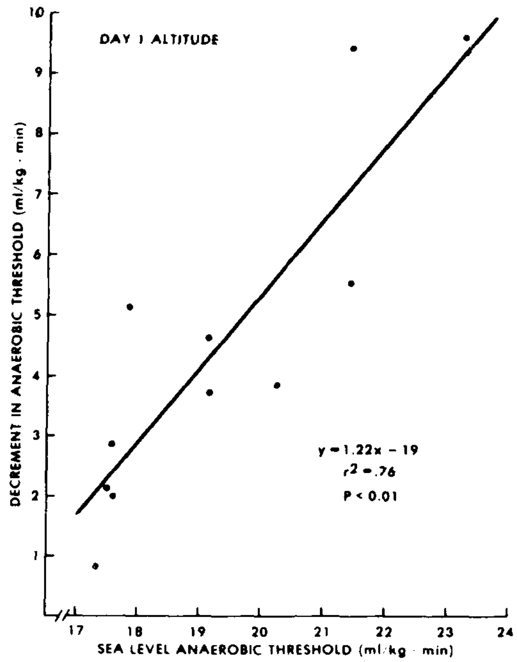

Figure 2: Linear relationship between sea level anaerobic threshold and the decrement observed after one day of exposure to 4,300 meters.

Recent evidence indicates that anaerobic threshold is related to $\dot{V}O_2$ max. This is corroborated by Figure 3 which illustrates a direct relationship between sea level AT and $\dot{V}O_2$ max. In this respect AT should be altered during altitude exposure in a manner similar to $\dot{V}O_2$ max. Figures 4 and 5 illustrate that this is indeed the case. Both AT and $\dot{V}O_2$ max were immediately reduced on the first day of altitude exposure and remained so for the remaining 6 days. These figures also illustrate that both phenomena are readily reversible with the administration of 35% O_2, which is the altitude equivalent of normal sea level PO_2. These results indicate that both reductions are probably due to the persistent hypoxemia incurred at altitude.

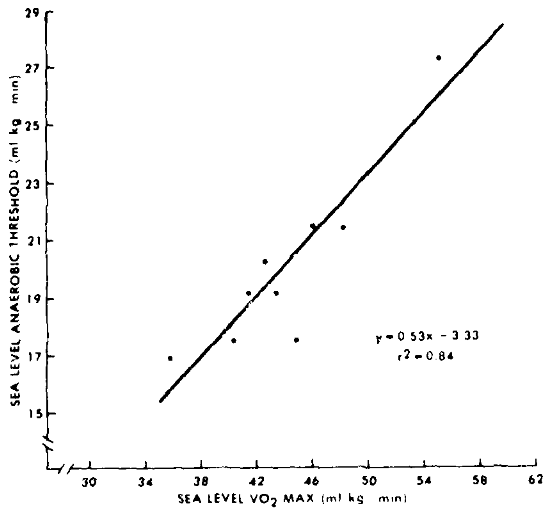

Figure 3: Relationship between sea level maximal oxygen consumption and anaerobic threshold.

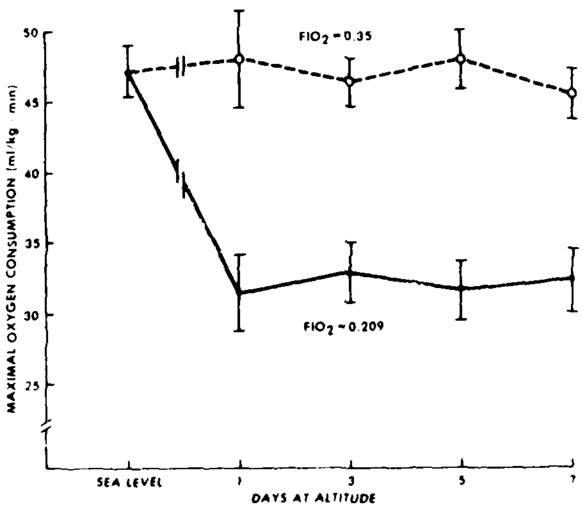

Figure 4: Reduction of maximal oxygen consumption with exposure to 4,300 meters and reversal with inspiration of normal PO_2 (FIO_2 = 0.35).

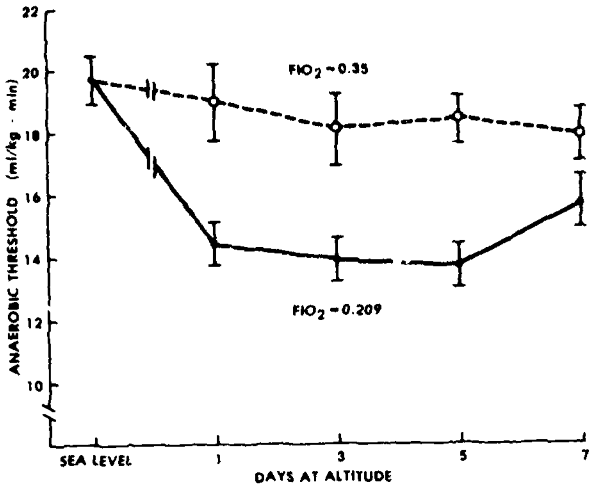

Figure 5: Reduction of anaerobic threshold during altitude exposure and reversal with inspiration of normal PO_2 ($FIO_2 = 0.35$).

We conclude that:

(1) the level of physical fitness does not appear to be associated with either the development or the severity of acute mountain sickness,

(2) percent reductions at altitude in $\dot{V}O_2$ max and AT are larger in subjects with higher levels of physical fitness,

(3) the hypoxemia incurred at altitude results in a reduced supply of O_2 to the working muscles which is evidenced by the decrement in $\dot{V}O_2$ max and AT, and

(4) estimation of anaerobic threshold using ventilatory parameters provides a means of studying circulatory and metabolic responses to the combined stresses of altitude and exercise.

Presentations:

Cymerman, A., J. J. Jaeger, J. T. Maher, G. L. Davis and R. G. Williams. Relationship between altitude-induced changes in maximum O_2 uptake and anaerobic threshold. Presented, Annual Meeting, FASEB, Atlantic city, NJ, 9-14 April 1978 (Fed. Proc. 37:831, 1978).

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 321 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations

Study Title: Ventilatory Muscle Training and Ventilatory Control during Loaded Breathing

Investigators: David E. Leith, M.D., Ronald A. Gabel, M.D., Beverly Philip, M.D., Vladimir Fencl, M.D. and Henry Feldman, Ph.D.

Background:

The effectiveness of a military operation may be limited by inability of the troops to function in a hostile environment. Such limiting environments would be found at high terrestrial altitudes and in the presence of incapacitating chemical or biological agents. In these settings, the requirement often exists for the soldier to wear protective devices which add resistive loads at the airway.

Human exercise capacity is decreased when the resistance to breathing is increased, for example by oxygen or gas masks or by dense gases (1,2). The early cessation of exercise under these circumstances is associated with relatively low ventilation and high CO_2 levels. It has not been understood whether or how much this should be attributed to fatigue of the breathing muscles due to increased work of breathing, or to behavior of the respiratory control system under conditions of heavy exercise and loaded breathing.

Endurance of the ventilatory muscles can be increased by suitable training (3,4). If exercise performance is limited by fatigue of the breathing muscles, ventilatory muscle training might have the potential to improve whole-body exercise performance during loaded breathing. Little is known, however, about changes which might be induced in the ventilatory control system by substantial alterations in the ventilatory effector system. If behavior of the respiratory control center is not fundamentally changed by ventilatory muscle training, neural efferent activity for a given level of afferent activity might be the same before and after ventilatory muscle training, resulting in a greater ventilatory response to a given physiologic stimulus after training. Alternatively, because of substantial feedback of proprioceptive information regarding adequacy of ventilation, neural efferent traffic from the respiratory centers may be decreased after ventilatory muscle training, such that the ventilatory response to a given physiologic stimulus after training is equal to or less than that before training. But regardless of what those relationships prove to be in the unfatigued state, we think it likely that in situations which cause fatigue of the ventilatory muscles, increase in their endurance would delay the onset of fatigue and prolong the ability to continue.

In this study, two experiments have been designed to answer the questions above. The first experiment examined the ventilatory response to carbon dioxide before and after ventilatory muscle training, with and without added inspiratory resistance. The second experiment will examine exercise tolerance and the ventilatory response to exercise, with those same interventions.

The experimental work for the first experiment was completed last year. The protocol, and some initial results of data analysis, are described in detail in the last annual report. The training program required daily voluntary normocarbic hyperpnea to exhaustion with inspiratory resistance such that ventilations of 80-120 L/min required mouth pressures of -70 to -90 cm H_2O with each breath. This severe program, after six weeks, resulted in an increase of 28% in the ventilation which subjects could maintain for long periods, a greater change than was found after "unloaded" training by Leith and Bradley (4).

Progress:

During the past year, steady and satisfactory progress has been made in the time-consuming task of data analysis. All the tape-recorded data from the four-month experiment have been played back for verification. Data have been punched on 2600 cards, which have been verified and duplicated. Analytical models have been developed, tested, and refined using specialised computer programs prepared by Dr. Henry Feldman.

Here we outline the results. In each case, the effects of two levels of added resistance, of habituation to the experimental situation, and of ventilatory muscle training were examined at end-expiratory PCO_2 of 45, 50, and 55 mm Hg. The results are presented under three headings:

1) multiple regression models relating PCO_2 to
   a) minute ventilation, ($\dot{V}_E$)
   b) mean inspiratory flow, ($\bar{\dot{V}}$) and
   c) pressure in the airway 0.1 second after onset of occluded inspiration, ($P_{0.1}$)
2) mean inspiratory flow and fraction of the time in inspiration, (V_T/T_i and T_i/T_{tot})
3) tidal volume as a function of inspiratory duration (V_T and T_i).

Other approaches have been tried and found less useful; they are not presented here. Thus, we have worked systematically through several approaches to both classical and current concepts of central and peripheral control of ventilation, using CO_2 and inspiratory resistance as one set of variables, and adding the effects of ventilatory muscle training as a new dimension.

1) Multiple regression models. In each of the three cases presented below, the model is in the usual form of a straight line regression,

$$y = a + bx$$

where x is the end-expired PCO_2 and y is the variable of interest.

The value of "b", (the slope of the regression line) was arrived at as follows:

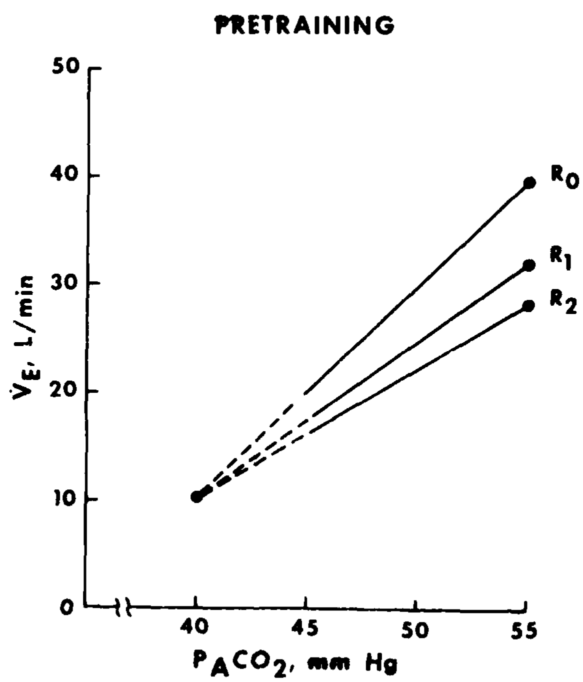
b	=	b_0'	"baseline" slope, pretraining, no added resistance, probably an individual characteristic.
	+	b_1'	effect of added resistance (pre-training).
	+	b_2'	effect of habituation or adaptation, post-training. Assumed to be an effect common to controls and trainers.
	+	b_3'	effect of the training process, trainers only, post-training.
	+	possible other terms for interactions.	

Unexpectedly, we found that, in some instances, using an intercept value "a" taken at a PCO_2 of 40 mm Hg we allowed separation of changes in slope from changes in position; i.e., when slope changes occurred, the lines rotated around their intercept at a PCO_2 of 40. We do not presently attach biological significance to that fact.

The questions asked of the model were, first, what are the values for the coefficients, and second, is b_3 significantly different from zero?

a) Ventilatory response to CO_2:

Pre-training pattern: A "fan" of lines, one line for each value of equipment resistance, originates from a common point at a PCO_2 of 40 mm Hg. The position, orientation, and "spread" of the fan are different for each subject.



Adaptation effect: The fan is rotated downward about its pivot. Each line has a slope decrease of 0.41 L/min/mm Hg, regardless of resistance. This occurs in both controls and trainers.

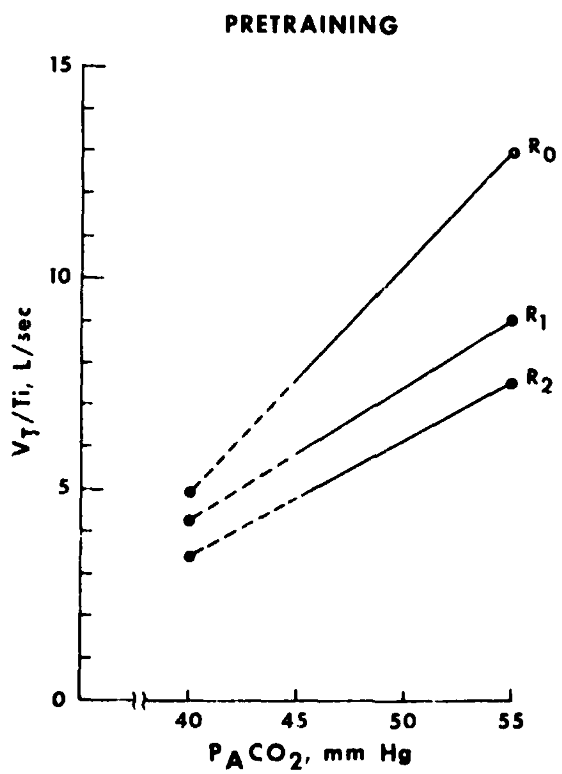
Training effect: The fan is translated upward, in trainers only. The amount of translation is +2.5 L/min, regardless of resistance.

Average parameters for $\dot{V}_E$ lines:

	Intercept at PCO_2 = 40 (L/min)	Slope (L/min/mm Hg)
No R	11.3 ± 5.8	1.83 ± 0.45
Lo R	11.3 ± 5.8	1.35 ± 0.31
Hi R	11.3 ± 5.8	1.15 ± 0.30
	+2.5 after training	-0.41 after adaptation

b) Mean inspiratory flow response to CO_2:

Pre-training pattern: "Fan" of lines, one line for each resistance, fails to converge at a PCO_2 of 40 mm Hg. The position, orientation, and "spread" of the fan are different for each subject.



Adaptation effect: The fan is rotated downward, each line about its own intercept at 40 mm Hg. Each of the three lines loses the same amount of slope, i.e., changes by −0.007 L/sec/mm Hg.

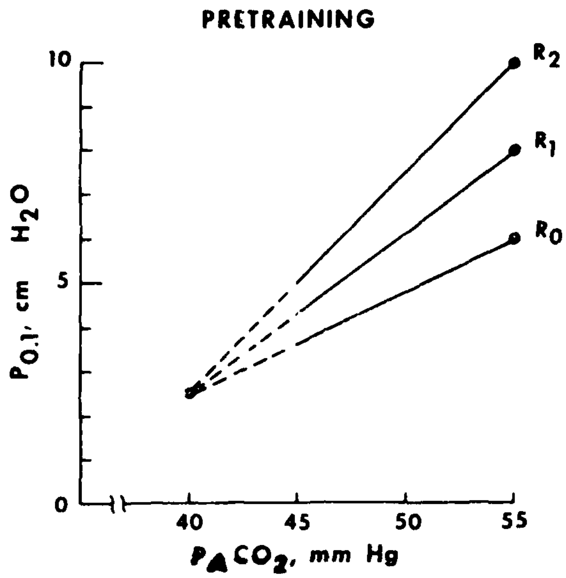
Training effect: The fan is translated upward, for trainers only. The amount of translation is +0.03 L/sec, regardless of resistance.

Average parameters for mean inspiratory flow lines:

	Intercept at PCO_2=40 mm Hg (L/sec)	Slope (L/sec/mm Hg)
No R	0.51 $\pm$ 0.25	0.053 $\pm$ 0.017
Lo R	0.43 $\pm$ 0.14	0.033 $\pm$ 0.008
Hi R	0.36 $\pm$ 0.15	0.028 $\pm$ 0.007
	+0.03 after training	-0.007 after adaptation

c) $P_{0.1}$ response to CO_2:

Pre-training pattern: A "fan" of lines, one line for each resistance, originates from a common point at a PCO_2 of 40 mm Hg. The spread of the fan is the same for each subject, in the following sense: the slope of the R_1 line is steeper than that of the R_0 line, by 0.13 cm H_2O/mm Hg. The slope of the R_2 line is steeper still, by another 0.13 cm H_2O/mm Hg. The position and orientation of the fan are different for each subject.



<u>Adaptation effect</u>: The fan is pivoted downward, each line decreasing its slope by 0.13 cm H_2O/mm Hg. The fan is also translated upward by 1.7 cm H_2O.

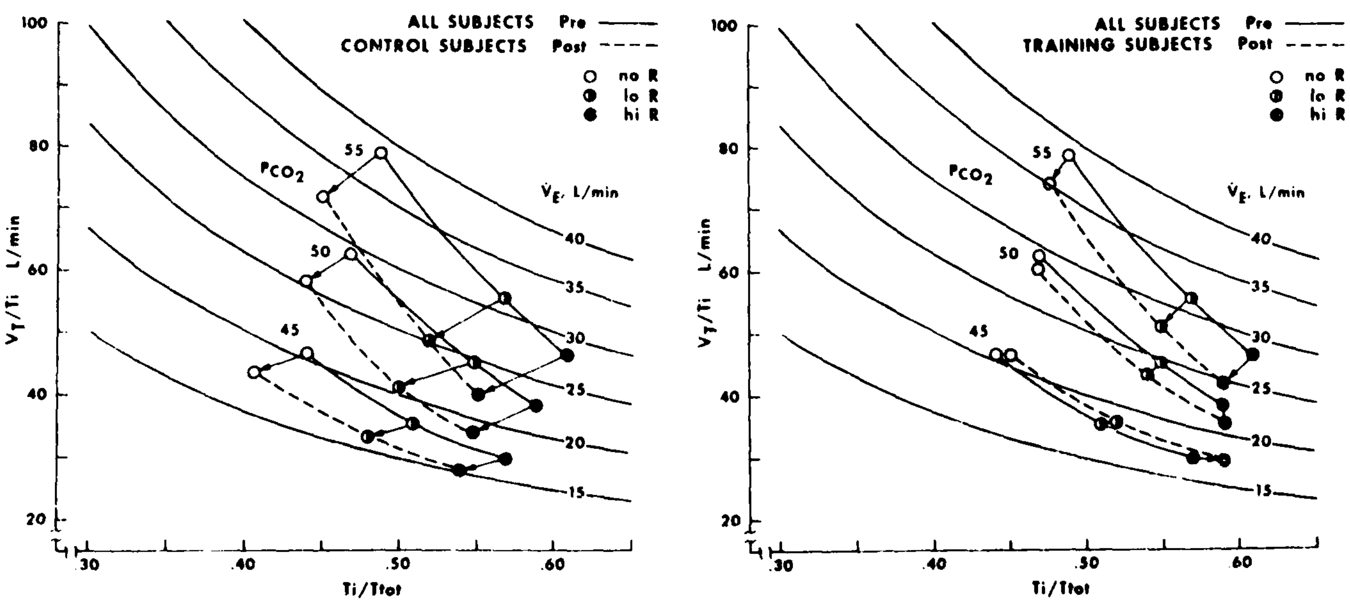
<u>Training effect</u>: None detected.

<u>Average parameters for $P_{0.1}$ lines:</u>

Intercept at PCO_2 =40 mm Hg (cm H_20)	Slope (cm H_20/mm Hg)
2.5 ± 1.9	0.24 ± 0.12
+1.7 after adaptation +	0.13 with R_1 0.26 with R_2
	-0.13 after adaptation

2) V_T/T_i and T_i/T_{tot}.

These two extraordinarily complex graphs summarize much of the data. The axes are chosen for two reasons. First, the respiratory "controller" can adjust two characteristics of its output to the ventilatory muscles: the intensity of their stimulation, and the duration of their stimulation. The former determines inspiratory flow, which we calculate as $V_i = V_T/T_i$, and the latter determines the fraction of a single cycle, or of a minute, spent in inspiration, which we calculate as T_i/T_{tot}. Second, total ventilation, in any given time (e.g., minute ventilation) is the product of V and T_i/T_{tot}; thus ventilation isopleths can be drawn as a family of rectangular hyperbolas. Departures from such isopleths with changes in CO_2 or resistance are easily shown, and shifts in the "choices" made by the ventilatory controller with respect to duration and intensity of output can be seen at the same time (keeping in mind that added resistive loads can be associated simultaneously with increases in muscle activation and decreases in the ventilation achieved).



The dashed lines are the same in these two plots, and represent pooled data before the training period. The changes in control (and in trained subjects) are indicated as departures from control values, the final data being represented by the solid lines.

Our interpretations of these plots are as yet rudimentary, but note that at PCO_2 values near normal, the changes in control and trained subjects are in opposite directions.

3) V_T and T_i.

This approach is based on recent views about the reflex control of tidal volume as being determined by a time-varying central "cutoff" threshold for V_T which is compared with volume signals coming from the lung via vagal afferents. The graphical representations of our data are so complex, and our interpretations so incomplete, that we do not think it useful to present these results here.

Last year we observed that some trained subjects showed a decreased ventilatory response to CO_2. Further data analysis now allows us to say that those decreases appear to be shared by control subjects, and are therefore attributable to habituation. When the habituation effect is taken into account, the slight increases in ventilation and mean inspiratory flows mentioned above still remain, in the training group only, and are therefore attributable to the muscle training itself. This (provisional) conclusion is important, for it answers the troubling question we raised in our report last year, namely, does this kind of training process decrease the subjects' sensitivity to CO_2? If so, such training may be unsafe in persons with obstructive lung disease, in whom CO_2 retention accompanies respiratory failure. Since the answer appears to be "no", we are now satisfied that we can proceed with another research project held in abeyance until now, i.e., cautious trials of ventilatory muscle training in patients with chronic obstructive lung disease.

We are preparing a manuscript of this study and planning for the second experiment in which exercise tolerance and the ventilatory response to exercise will be studied with and without inspiratory resistive loads, before and after ventilatory muscle endurance training.

Presentations:

1. Leith, D. E., R. A. Gabel, B. Philip, V. Fencl and H. Feldman. Ventilatory muscle training and ventilatory control. The International Symposium on the Diaphragm, University of Virginia, May 31-June 2, 1978. (To be published in abstract, Amer. Review Respir. Dis.)

Same general topic and same authors also presented at:

2. USARIEM, Natick, MA, March 9, 1978.

3. Pulmonary Division, Columbia-Presbyterian Hospital, New York City, March 15, 1978.

4. American Thoracic Society Refresher Course, May 12, 1978.

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(83053)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
				DA OB 6148	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	053
b. CONTRIBUTING				
c. XXXXXXXG	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U)Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing, and Equipment (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
016200 Stress Physiology; 013400 Psychology; 011700 Operations Research

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
75 07	CONT	DA	C. In-House

17. CONTRACT GRANT
a. DATES/EFFECTIVE — EXPIRATION
b. NUMBER* NOT APPLICABLE
c. TYPE — d. AMOUNT
e. KIND OF AWARD — f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	9	321
	CURRENT 79	9	350

19. RESPONSIBLE DOD ORGANIZATION
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ASSOCIATE INVESTIGATORS
NAME: PANDOLF, Kent B., Ph.D.
NAME: STROSCHEIN, Lee DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Environmental Tolerance; (U)Performance Limits; (U)Energy Expenditure; (U)Terrain Coefficients; (U)Dehydration

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Develop and validate by physiological studies, mathematical models which synthesize information on military task requirements and the interaction between man, his clothing and equipment, and the environment, to predict mission performance capability and identify areas where additional information is needed.

24. (U)Predictive models of heat production and loss, subjective sensation, and limiting criteria in terms of maximum work capacity as well as unsafe levels of extremity temperature and/or body heat content are evaluated. Systems for predicting individual comfort and unit mission performance decrements and tolerance time are developed from these models. Results are validated in chamber and field trials, involving human volunteers as subjects, and guide clothing and equipment design, suggest tactical doctrine, and indicate potential environmental casualties.

25. (U)77 10 - 78 09 A study to compare the wet-bulb globe temperature (WBGT) indications of various three-element measuring systems indicates that a miniaturized kit (NSN 6665-00-159-2219) for field use is an acceptable substitute for the standard kit prescribed in TB Med 175 for measuring severity of hot environments. Data from an earlier study on the effects of heat rash on tolerance in hot environments has been analyzed for incorporation in the heat stress prediction model. Studies to measure the solar heat load on active and resting subjects, with a view toward the correct method of incorporating the solar load into the prediction model, have been initiated. Energy costs of standing and slow speed walking up or down a grade with loads have been measured. Work to determine energy costs of oversnow walking with skis and snowshoes, and self-paced walking speeds in snow at heavy activity levels is in progress.

*Available to contractors upon originator's approval

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Establishing Terrain Coefficients for Predicting the Energy Cost of Oversnow Movement Aided by Military Skis and Snowshoes
Investigator:	Richard L. Burse, Sc.D. and Frederick R. Winsmann

Background:

Previous studies in the Military Ergonomics Division have defined coefficients for predicting the energy cost of walking in combat boots at a fixed pace on specific terrains, relative to the energy cost of walking on treadmills (1,2). Coefficients for 6 terrains devoid of snow were first established (4,5). Recently, coefficients for walking in snow have been defined as a function of the depth of footprint (2) to extend the energy cost of prediction equation for military foot movement reported in 1971 (1). To include oversnow movement in Arctic footwear, with skis and snowshoes, coefficients are needed for the energy cost of:

a. Fixed-pace snow walking in the current Army standard cold-dry vapor barrier boot.

b. Fixed-paced snowshoeing and cross-country skiing, utilizing current Army standard equipment.

It is expected that the energy cost would be greater due to the added weight of the footwear and oversnow equipment (4), but the added cost cannot be predicted accurately because of differences in traction, penetration in the snow and snowloading of skis and snowshoes. Although the energy cost of oversnow movement on skis and snowshoes of civilians has been reported in the literature, these reports cannot serve as a data base for prediction because the subjects are generally very skillful, highly fit subjects of varying ages, most often using recreational or competitive equipment which is much lighter in weight than that provided the less experienced U. S. soldier.

Progress:

During the winter of 1977-78, energy cost data were collected from 10 subjects carrying 5.8 kg packloads, 6 subjects carrying 15.8 kg loads and 2 subjects carrying 25.8 kg loads as they snowshoed for 30 min on a packed trail. Speeds were 0.67, 0.89 and 1.34 $m \cdot s^{-1}$ (1.5, 2 and 3 mph); speeds below 1.5 mph were found too slow for the maintenance of proper balance. Depending on the individual, the weight of clothing, boots and snowshoes added from 6.7-10.1 kg to the total load.

Energy cost data is shown in Table 1 for the 6 subjects who carried 5.8 and 15.8 kg loads at the 3 speeds. Analysis of variance showed that speed affected the energy cost of snowshoeing significantly ($p < 0.01$), while increasing the pack weight 10 kg did not. Quite possibly, the 10 kg increment in pack weight added only a relatively small amount to the metabolic cost of transporting the total load of body, pack, clothing and foot gear. This possibility can be explored statistically when data from a larger sample of individuals is collected.

TABLE 1

Comparison of Measured (meas) and Predicted (pred) Energy Costs of Snowshoeing and Calculated Terrain Coefficients (η) as Related to Speed and Pack Weight, Means of 6 Subjects ± Standard Error

Speed ($m\ s^{-1}$)	Pack Weight (kg)	Energy Cost (W) meas	Energy Cost (W) pred	η
0.67	5.8	317 ± 23	175 ± 12	3.4 ± 0.2
	15.8	335 ± 19	196 ± 10	3.1 ± 0.2
0.89	5.8	418 ± 94	221 ± 15	2.9 ± 0.3
	15.8	418 ± 19	247 ± 13	2.5 ± 0.1
1.34	5.8	615 ± 39	351 ± 23	2.1 ± 0.1
	15.8	674 ± 36	392 ± 22	2.1 ± 0.1

The predicted energy cost of carrying the same total weight as a single load on a blacktop road (3) is also shown in the "pred" column in Table 1. Comparison of the measured and predicted values shows the energy cost of snowshoeing to range from 1.7 to 1.9 times that of road walking, irrespective of speed or pack weight. The overall average factor is 1.76, with a very small standard deviation of 0.08. If this preliminary estimate is confirmed by data from a larger sample carrying the same loads and for heavier loads, then snowshoeing on a level, packed trail is about 75% more difficult than carrying the same total load on a hard road.

In all the other terrains investigated, including snow walking (1,2,5), only the speed term needed correction by a terrain factor (symbolized by η) to adequately predict the energy cost. This is the first time that one overall multiplier for the entire energy cost equation was required in order to express the effect of terrain on energy cost. However, such a result is not unreasonable, as the current energy cost prediction equation (3) consists predominantly of terms for load bearing while standing and for walking on the level which each may be affected by a different aspect of snowshoeing on a level trail.

Just lifting the legs while on snowshoes with no forward motion while bearing the weight of the snowshoes, boots and extra cold weather clothing may well involve added muscular effort in order to maintain balance, particularly on slippery snow surfaces. This is shown by the difficulty in maintaining balance while walking on snowshoes at very slow speeds. It was obvious that subjects walked with the legs spread apart in order to prevent stepping on the inside edges of the shoes. This induced a side-to-side rocking motion which disturbed normal balance and quite reasonably could induce a large increment in the energy cost of just moving the feet in place. Forward motion also demands more energy when hobbled by cold weather clothing and with weight on the extremities (4). Back- or side-slip of the snowshoes also add another increment to the energy cost of forward motion on snowshoes.

In order to determine the multiplicative coefficient for either the total energy cost equation or the speed component (η), the sample of subjects walking at the 3 speeds and wearing the 3 pack loads must be enlarged to 8-10. In addition a separate study of the energy cost of breaking trail is required to assess the metabolic effects of different depths of unbroken snow, not addressed in the current study, but necessary for applying the energy cost prediction equation in the battlefield environment.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environmental Clothing and Equipment
Study Title:	Safe Exposure Times for Partial Immersion in Cold Water
Investigators:	Richard L. Burse, Sc.D. and Leander A. Stroschein

Background:

Previous studies at this Institute have investigated changes in heat production and body core and skin temperatures of resting men exposed to cold air (nude) or immersed in cold water (nude and immersion suited), some with body temperatures previously elevated by exercise (1-4). However, to date there have been no studies of exercising men partially immersed in cold water, or with fully wetted clothing, which could provide data concerning safe exposure times for foot soldiers moving in swamps or across streams. Such information is required for the safe conduct of field training exercises under cool, but non-freezing conditions and for the prediction of tolerance limits under combat conditions. The actual or extrapolated times at which rectal temperature (T_{re}) drops below 35°C or violent shivering incapacitates an individual serve as the criteria of impending hypothermia and represent a lower limit from which individuals can be safely rewarmed (5).

Progress:

A pilot study has been completed in which 3 male volunteers were immersed in water to the waist and chest levels. Water temperatures (T_{H_2O}) were 10, 7.5 and 5°C controlled to ± 1.0°C by refrigerated coils along the wall of a cylindrical tank in which the subjects stood. Clothing was the standard fatigue uniform, steel helmet assembly and a 25-pound weighted vest to simulate the combat load. Air temperature was maintained equal to water temperature.

To simulate a movement and pause activity, subjects stood quietly for 10 min immediately after immersion and then performed repeated cycles of physical work for 20 min followed by 10 min quiet standing. These work-rest cycles were repeated until the tolerance time was reached or two hours had elapsed. Work rate was held constant by requiring the subjects to step on and off a 43 cm high platform at a fixed rate. The measured energy expenditure while working ranged from 415 to 700 W, depending on the weight and buoyancy, and represents levels of moderate to moderately hard work.

Table 1 shows the physical characteristics of the volunteer group who were selected to cover a range of body sizes and fat percentages. Subject 1 was of average build and quite lean, subject 3 was of average build and slightly above average body fat content and subject 2 was a large man, again with slightly above average body fat content.

TABLE 1

Ages and Physical Characteristics of the Volunteer Subjects

Subject Number	Age (Yr)	Height (cm)	Weight (kg)	Body Fat (%)
1	21	179.4	71.4	12.4
2	27	185.4	100.7	21.5
3	21	177.6	84.8	19.4

Table 2 shows the initial and final rectal, skin and mean body temperatures and tolerance times after immersion in each of the three water temperatures, and Table 3 shows the initial and final resting and working metabolic and heart rates. The 10°C immersions to either the waist or chest level did not cause core temperature to fall below 36°C, even after 2 hours. Although uncomfortable, the subjects withstood the exposures well. Heart rates were quite low for the severity of the work level presumably because of an augmented venous return induced by the profound vasoconstriction. Only one subject withdrew before 120 min exposure time, and that at 73 min for a severe headache. His T_{re} was 36.9 and showed an essentially flat trend similar to those who withstood the full exposure. There was no suggestion in any of these exposures that T_{re} would have fallen to 35°C even had the exposures been lengthened to four hours.

The exposures at 5°C to waist level were another matter entirely. Neither of the two subjects was able to withstand even one hour exposure. The leanest subject suffered a rapid decline of core temperature to 35°C in about 20 min. The largest and fattest subject maintained his body temperature well, but was unable to lift his body weight with his legs after a little more than one-half hour. The presumed cause was cold-induced anaesthesia of the motor nerves serving the leg musculature, which could well have resulted in his drowning in a field situation. From the rapid onset of these two potentially fatal disabilities, it is readily apparent that 5°C water represents a thermal environment unsuitable for even brief military training operations. The onset of neuromuscular block or hypothermic core temperature conditions give no warning; indeed, the numbing effect of the cold water after immersion may give a false sense of security.

Immersion to the chest in 7.5°C water resulted in subject 2 suffering from a cramp in his left gastrocnemius muscle after 101 min. Since he was the same subject who suffered weakness of the leg musculature in 5°C water, the cause may have been the same. Body core temperatures were well maintained by both subjects for 1-1/2 to 2 hours; the leanest subject was not available for test. Since body fatness affects body cooling, especially when exercising (6), the impact on lean individuals cannot be predicted. However, since one disability did occur at 7.5°C with potentially serious consequences in the field, this water temperature also appears unsuitable for military training operations.

The one individual able to withstand two hours at this temperature repeated his exposure with 50 min work and 10 min rest each hour in addition to the 20–10 work-rest cycle. The only difference was a 0.4°C warmer final T_{re} at the exposure for 2°C colder $\bar{T}_{sk}$.

The results of this pilot study have served as the basis for planning a more extensive investigation into the effects of waist and chest immersion in 7.5 and 10°C water and exposure in wet clothing. The effects of air temperature and motion will be incorporated in a design utilizing 8-10 subjects of different body fitness to verify that 10°C water is safe for training operations up to four hours while 7.5°C is not.

Presentations:

Burse, R. L. Safe exposure times for partial immersion in cold water: a pilot study. Presented, Brouha Symposium on Work Physiology, Rochester, New York, September 20-22, 1978.

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TABLE 2

Initial and Final Rectal (T_{re}), Mean Skin ($\bar{T}_{sk}$) and Mean Body Temperatures and Tolerance Times for Immersions to Waist and Chest Depth at Water Temperatures (T_{H_2O}) of 10, 7.5 and 5°C

T_{H_2O} (°C)	Immer. depth	No.	T_{re} (°C) Initial	T_{re} (°C) Final	$\bar{T}_{sk}$ (°C) Initial	$\bar{T}_{sk}$ (°C) Final	$\bar{T}_b$ (°C) Initial	$\bar{T}_b$ (°C) Final	Tolerance Time (min)
10.0	waist	1	37.6	36.2	27.8	24.6	32.7	30.4	120
		2	37.5	37.2	27.1	24.9	32.3	31.1	120
	chest	2	37.6	36.9	23.8	19.4	30.8	28.2	73***
		3	37.5	36.0	29.2	18.7	33.4	27.4	120
7.5	chest	2	37.7	36.5	24.9	18.2	31.3	27.3	101**
		3	37.4	35.7	24.5	17.5	31.0	26.6	120
		3#	37.6	36.1	26.6	15.6	32.1	25.9	120
5.0	waist	1	37.3	34.4	23.8	21.6	30.5	28.0	21*
		2	37.7	37.5	27.3	22.9	32.5	30.2	36**

NOTES:

* = subject removed for T_{re} 35°C

** = subject removed for neuromuscular difficulty

*** = subject removed for severe headache

= rest-work cycle: 10 min rest -50 min work

TABLE 3

Initial (I) and Final (F) Metabolic Rates and Heart Rates (HR) During Work and Rest While Immersed to Waist and Chest Depth in 10, 7.5 and 5°C Water. Tolerance Times Given in Table 2.

T_{H_2O}	Imm.	Subj.	Metabolic Rate (W)				HR (beat min^{-1})			
			Work		Rest		Work		Rest	
(°C)	Depth	No.	I	F	I	F	I	F	I	F
10.0	Waist	1	698	784	299	200	98	118	69	64
		2	650	595	165	146	100	96	60	62
	chest	2	453	490	169	239	88	92	69	66
		3	532	690	178	411	108	116	96	92
7.5	chest	2	415	596	140	279	88	82	80	66
		3	490	696	228	497	108	114	88	97
		3#	446	692	194	504	120	124	98	106
5.0	waist	1	701	--	211	--	100	--	72	--
		2	604	--	142	249	105	--	70	76

NOTE: # = rest-work cycle: 10 min rest -50 min work

Program Element:	6.27.77.AA ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Additive Effects of Solar and Metabolic Heat Load in Predicting Heat Intolerance
Investigators:	Kent B. Pandolf, Ph.D., Yair Shapiro, M.D., Fred R. Winsmann and John R. Breckenridge

Background:

The solar radiant environment as a function of the particular geographic region, hazy or clear sky, cloud cover, terrain cover and albedo, time of day and solar elevation is an important consideration for military operations in hot environments. This Division has developed methods of prediction for the actual solar heat load arriving at the skin in lightly clothed men (1) and more heavily clothed men (2). However, these studies have been of a theoretical physical nature, validated by direct measurement on heated, sweating copper manikins.

Although we have been able to develop the ability to predict rectal temperature and heart rate responses to work, environment and clothing (3,4), further refinement of our predictive capabilities are seen to be necessary. It was the purpose of this study to evaluate the decrement in tolerance time or performance to work or rest in the heat as effected by a simulated ambient solar heat load. The results of these experiments should provide adequate data for integrating the metabolic responses of solar and metabolic heat and enable us to predict more accurately the soldier's responses to operational combat clothing and equipment during actual field situations in hot environments.

Progress:

Recently, we have completed the first in a series of experiments involving the effects of the solar radiant environment on soldiers' performance to work or rest in the heat. Initially, 24 subjects were acclimatized to heat walking in shorts at 1.34 m/s for two, 50-min periods separated by 10 min rest at 49°C, 20% R. H.. After six days of acclimatization, the 24 subjects were divided into three groups of eight for experimental evaluations during either rest, walking at 1.34 m/s, or walking 1.34 m/s at a 5% grade. A bank of 72 infrared 350 watt lamps were secured at near ceiling height in the USNARADCOM tropical environmental chamber. This bank of lights simulated approximately 90% of a typical, severe solar heat load. All subjects were evaluated during rest or walking t(1.34 m/s, 0 or 5% grade), at 40°C, 32% R. H. and 35°C, 75% R. H. with and without the solar radiant load while wearing either shorts, socks and sneakers or the combat tropical uniform. The proposed experimental duration was a total of two hours (10 min rest, 50 min work, 10 min rest, 50 min work). During these experiments water was administered ad libitum while air motion was constant at approximately 1 mph.

Although the extensive statistical and quantitative analysis of these experimental findings has not been completed, preliminary inspection of these data indicate that, as anticipated, the decrement in tolerance time due to elevated rectal temperature and/or heart rate is significantly greater with the solar radiant heat load for both temperatures, both clothing systems and all three activity levels (rest, walking 1.34 m/s, walking 1.34 m/s at a 5% grade).

A complete analysis of these recent experimental findings involving simulated solar heat load will be continued and the data added to the predictive capabilities of our model. As part of this same study, other individual blocks of experimentation will be in the future. In these studies, physiological responses to simulated solar heat load will be evaluated in the full arctic ensembles in cold environments; CBR protective clothing and body armor ensembles will also be evaluated in hot environments. Additionally, various work/rest periods will also be evaluated as effected by a simulated solar heat load.

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Hard Work for Walking on Snow of Various Depths

Investigators: Kent B. Pandolf, Ph.D., Fred R. Winsmann and Ralph F. Goldman, Ph.D.

Background:

In a previous study, the metabolic energy expenditure and terrain coefficients for walking on snow were determined using 6 male volunteer subjects. These subjects each walked for 15 minutes at each of two fix-paced speeds, 0.67 and 1.12 m/s (1.5 and 2.5 mph), on a treadmill (level) and on a variety of snow depths. Energy expenditure increased linearly with increasing depth of footprint depression, reaching a ratio of about 5:1 when a 45 cm footprint depression was compared to 0 cm depression. Although these subjects were considered above average in terms of physical fitness mean $\dot{V}O_2$ max = 5.4 ml/kg • min, all stopped walking because of exhaustion at an average footprint depth of 35.0 cm at a walking speed of 1.12 m/s. Practical limits for snow walking without snowshoes not exceeding about 50% $\dot{V}O_2$ max were developed, with 20 cm being the maximal depth at 0.67 m/s and 10 cm at 1.12 m/s (3).

Certainly, walking on snow is a very tiresome form of human locomotion (1,2,3). However, little is known about the self-paced work rates soldiers would adopt as "hard work" for prolonged durations of snow walking.

Progress:

This study was developed to provide information about (a) the measured steady-state energy expenditure for self-paced snow walking at various snow footprint depths and (b) the effect of load carrying (backpack) on self-pacing at various snow depths.

Six healthy male volunteers, each less than 30 years of age, from the Institute staff will first have a determination of their maximal oxygen uptake performed on a treadmill in the laboratory. They will walk at 1.56 meters per second (3.5 mph) on a level treadmill; the grade will be increased by 2.5% every two minutes, heart rate will be determined from continuously recorded electrocardiogram. At and above a heart rate of 160 beats/min expired air samples will be obtained during the last minute of each grade elevation. A plateau in calculated oxygen uptake (sample differences of less than 150 ml/min or 2.1 ml/kg•min) increase will determine the maximum $\dot{V}O_2$ (analysis and calculation will be completed before each successive grade increment is instituted).

In the second part of the study, the subjects will each walk a mile outdoors in 3–5 different depths of snow (up to approximately 20 inches deep). Subjects will walk at a self-determined voluntarily "hard"pace which they are able to sustain for 2–4 hours under each of three load conditions: in field clothing, and combat boots, but without backpack, with a 10 kg backpack and with a 20 kg backpack. At each quarter mile, expired gas samples will be collected in a Max Planck gasometer for four minutes; these will be analyzed for oxygen and the results used to determine energy expenditure. Heart rate will be determined by radial pulse count, for 30 seconds after each quarter-mile walk. After each walk, the temperature, wind velocity, snow-water content, and the depth of footprint depression in the snow will be measured. Techniques and calculations will be as reported by Pandolf et al. (3).

Presentations:

1. Goldman, R. F., M. F. Haisman and K. B. Pandolf. Metabolic energy cost and terrain coefficients of walking on snow. Paper delivered at the Third International Symposium on Circumpolar Health, Yellowknife, Northwest Territory, (Cda) July 8-11, 1974.

2. Pandolf, K. B., F. R. Winsmann, M. F. Haisman and R. F. Goldman. Metabolic energy expenditure and terrain coefficients for walking on snow. The Physiologist 17(3):301, 1974.

Publications:

Pandolf, K. B., M. F. Haisman and R. F. Goldman. Metabolic energy expenditure and terrain coefficients for walking on snow. Ergonomics. 19(6):683-690, 1976.

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1. Heinonen, A. O., M. J. Karvonen and R. Ruosteenoja. The energy expenditure of walking on snow at various depths. Ergonomics. 2:389-393, 1959.

2. Ramaswamy, S. S., G. L. Dua, V. K. Raizada, G. P. Dimri, K. R. Viswanathan, J. Madhaviah and T. N. Srivastava. Effect of looseness of snow on energy expenditure in marching on snow-covered ground. Journal of Applied Physiology. 21:1747-1749, 1966.

3. Pandolf, K. B., M. F. Haisman and R. F. Goldman. Metabolic energy expenditure and terrain coefficients for walking on snow. Ergonomics. 19:683-690, 1976.

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Predictive Modeling of Man Undergoing Whole Body Immersion Cooling With and Without Protective Clothing.

Investigators: Hylar L. Friedman, M.D., CPT and Louis H. Strong, Ph.D.

Background:

This Institute has long been involved in the evaluation of clothing for its insulative properties in air and while immersed in water. In the past, various types of wet suits have been evaluated by copper manikin studies; insulation values for 1/4" vinyl, 3/8" polyurethene, and 1/4" neoprene suits have been found to be 0.43 clo, 0.61 clo, and 0.76 clo, respectively. Several studies have been carried out on nude men totally immersed in water at temperatures ranging from 20°C to 35°C, and other studies were performed in 20°C to 28°C water, both on nude men and men wearing the aforementioned wet suits. Data collected in these studies included changes in rectal and mean weighted skin temperature with time, and in some studies, metabolic rates and heat flow measurements.

A second model for predicting whole body rewarming in air after prolonged immersion is also being developed.

Progress:

Two models have been developed for the prediction of mean weighted skin temperature during cold water immersion. Factors considered include body mass, body fat, and height, peripheral insulation and central conductance, and initial skin and rectal temperatures.

The mathematical form of Model I is:

$$T_{s\,(t)} = Ae^{-bt} + Ce^{-dt} + Tw$$

where $T_{s\,(t)}$ = skin temperature as a function of time

T_w = water temperature in degrees Kelvin

A, C, b, and d are constants individualized for each subject and condition.

By utilizing the T_s (60 minutes), the end point of each experiment, it was possible to construct a formula to predict the difference between $T_{s\,(t)}$ and T_w at 60 minutes. Through many arduous calculations, values for b and d were optimized in terms of the parameters outlined above. A and C then were fixed by solving the boundary conditions of the experiment, with initial skin temperature $T_{s\,(o)}$, and T_w, and the equation for 60 minutes

(1) $T_{s\,(o)} = A + C + T_w$

(2) $T_s\,(60) = Ae^{-60b} + Ce^{-60d} + Tw.$

Model II is similar to the concentric shell model of Stolwijk (1) and considers the heat transfer through N contiguous compartments (N arbitrarily large) including the body core, a fat layer, a skin layer and thermal protective layers. The net energy density stored in the ith compartment is given by the heat transport equation to be

$$P_i\, C_{vi}\, \frac{dti}{dt} = \underset{j \neq i}{xxx}\; a_{ij}\; (T_i - T_j) + Qi\,(t)$$

where we have ignored the energy flux through the thermal gradient within each compartment. P_i and C_{vi} are respectively the mass density and specific heats of the ith compartment. The a_{ij} are heat transfer coefficients which describe the heat flux from compartment i to compartment j. Their reciprocals are the thermal resistances. The Q_i represent active sources or sinks of thermal energy operative in this compartment and may include metabolic heat production, an externally applied heating source, or heat directly applied to the skin through the cutaneous blood supply.

The general solution to the system of N coupled differential equations has been obtained in closed form for N temperature profiles T_i subject to an arbitrary set of boundary conditions. The system has also been solved in reverse for Q_i (t) in terms of an arbitrary temperature profile T_i.

A computer program was used to simulate the time development of mean weighted skin and rectal temperatures of six nude, male subjects having body fats ranging from 10 to 25%, and immersed in water at 20 and 28^{o}C. The heat transfer coefficients from core to fat, and from fat to skin were determined by successful simulations of the time variation of experimental temperatures using the measured metabolic rates. These heat transfer coefficients, which differed from subject to subject by as much as a factor of 2.5, were found to be inversely proportional to the compartment surface area. These coefficients were successfully used to predict skin and rectal temperatures for the same set of subjects in protective clothing.

Work on Model I this project is continuing. Attempts are being made to manipulate the model equations to improve its validity at temperatures below 20^{o}C. Studies leading to expressions for predicting rectal temperature will also be continued.

With reference to Model II, the data base for the derived heat transfer coefficients should be improved by studying the temperature profiles of additional subjects having a wider distribution of body fat. While the solutions we have obtained show the skin and rectal temperatures to be greatly dependent upon metabolic heat production, the heat shunted directly to the skin via the peripheral circulation can account for between 0-50% of the total heat loss. The model can account for circulatory heat loss, although no direct measurements are available. Presently this effect is incorporated within the derived heat transfer coefficients. It may be possible to separate peripheral circulation losses from passive conduction losses by an additional set of experiments in which subjects are presented to colder ambient temperatures where nearly complete cutaneous vasoconstriction is expected.

LITERATURE CITED

1. J. A. J. Stolwijk. Mathematical model for thermoregulation (Ch 48; in Physiological and Behavioral Temperature Regulation, J. D. Hardy, A. P. Gagge and J. A. J. Stolwijk, eds.; Charter C. Thomas, Springfield, Illinois, 1970.)

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 - Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Role of Dehydration in Limiting Human Performance While Working in the Heat
Investigators:	Kent B. Pandolf, Ph.D., Baruch Givoni, Ph.D. and R. F. Goldman, Ph.D.

Background:

Approximately two years ago an investigation was conducted to study the acute phase of dehydration which is more characteristic of a military operation in hot environments. Predictive modeling of the effects of dehydration for important physiological performance parameters, such as rectal temperature (T_{re}) and heart rate (HR), was, to our knowledge, non-existent. Thus, the purpose of this investigation was to derive predictive formulas for rectal temperature and heart rate considering human performance of exercise in the heat.

Progress:

The technique for induction of dehydration was to define a characteristic morning weight for each of the 16 subjects by weighing over a period of four or five days before the start of the study. This established a "baseline" weight for each individual subject. Subjects were then brought into the laboratory and acclimated by walking in the heat at 1.34 m/s for two, 50-min periods separated by a 10 min rest at 49°C, 20% R. H. State of hydration was altered by having the subjects report to the Climatic Chamber at 2200 hrs each evening and "rest" at 49°C, 20% R. H. while withholding, allowing or encouraging water intake until the desired target dehydration was approached. At approximately 0300 hrs each morning, subjects were weighed and transferred to a comfortable room to sleep. At 0700 hrs all men were weighed, state of dehydration estimated, and given a light standard breakfast with fluid adjustment appropriate to the target dehydration individually attempted.

Target hydration levels of 0, -3 and -5% of baseline were evaluated during rest or walking at 1.34 m/s, 0 and 5% grade, at 54°C, 10% R. H.; 49°C, 20% R. H.; 35°C at 24, 48 and 72% R. H. and 25°C, 84% R. H. Exposure time totaled 110 min while exercise involved two, 50-min walking periods with a 10 min intervening rest. Rectal temperature and mean weighted skin temperature were recorded continuously and HR checked periodically. The individual level of dehydration was maintained throughout the exposure by administration of water in amounts determined from the acclimatization days as adequate to maintain body hydration at the initial level. Subjects were studied only two days per week, allowing 48 hrs between exposures for full recovery of hydration and restful sleep. Thus, we evaluated three levels of metabolic rate, a wider variety of air temperatures and levels of humidity at three levels of hydration.

From the analysis of the experimental data described above, it was possible to express the effect of dehydration as proportional to the final elevation in the rectal temperature of hydrated individuals exposed to similar environments and work levels. The effects of the level of dehydration on rectal temperature are a faster rate of elevation and, therefore, a higher final level where the duration of exposure was limited; however, the final equilibrium temperature, if established, appears to be no higher than without dehydration at these levels (< 6%). Formulas previously published for predicting rectal temperature (1) were modified using an exponent containing both a dimensionless constant and the level of dehydration in percent. Previously published predictive formulas for HR (2) were also modified to include a dimensionless constant which considered percent dehydration.

During rest, dehydration was found not to alter T_{re}. Predictive formulas (modified from J. Appl. Physiol. 32:812, 1972) at any time (t) and final T_{re} (T_{ref}) and the time pattern of change during work (T_{rew}) and recovery (T_{rer}) are:

$$T_{ref} = 36.75+0.004(M-W_{ex})+ \left[(0.0128\ clo^{-1})(T_a-36)+0.8e^{0.0047}(E_{req}-E_{max})\right] e0.01D$$

$$\text{Work:} \quad T_{ref} = T_{reo} + (T_{ref} - T_{reo}) \left[1 - e^{-k} (t - t_d) (1 + 0.1D)\right]$$

$$\text{Rec:} \quad T_{ret} = T_{rew} - (T_{rew} - T_{rer}) \left[1 - e^{-00} (t - t_{drec}) e^{-0.07D}\right]$$

where: D = % dehydration; op cit for other terms. A preliminary formula, which predicts heart rate considering dehydration is:

$$I_{HR}\ (\text{Dehyd}) = 25 + (\text{IHR} - 25)(1 + 0.06D)$$

Using this I_{HR} for dehydration, final HR, and HR at time t, are computed as previously published (J. Appl. Physiol. 34:201, 1973).

This predictive capacity to consider state of hydration has been tentatively added to our model which predicts military performance capacity and the occurrence of heat stress and/or heat casualties during military operations.

The tentative coefficients developed from these experiments resulted in only a minor adjustment to the original predictive formulas. However, these coefficients were derived from only one group of test subjects and somewhat limited work and environmental conditions. An entirely different group of test subjects need to be evaluated to validate the coefficients derived from previous dehydration experiments. The validation study will involve 8-16 acclimatized subjects, three levels of dehydration (0,3,5%), two levels of physical work (300 and 500 watt) and two environmental conditions (35°, 45°C).

Presentations:

1. Pandolf, K. B., R. L. Burse, B. Givoni, R. G. Soule and R. F. Goldman. Effects of dehydration on predicted rectal temperature and heart rate during work in the heat. Medicine and Science in Sports. 9(1):51-52, 1977.

2. Pandolf, K. B., R. L. Burse, B. Givoni, R. G. Soule and R. F. Goldman. Predicting rectal temperature and heart rate responses to dehydration while working in the heat. XXVIIth International Congress of Physiological Sciences (Programme), pp. 12-21, 1977.

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2. Givoni, B. and R. F. Goldman. Predicting heart rate response to work, environment and clothing. J. Appl. Physiol. 34(2):201-204, 1973.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Studies on the Energy Cost of Load Carriage Considering Slow Walking Speeds and Standing
Investigators:	Nancy A. Pimental, Kent B. Pandolf, Ph.D., Fred R. Winsmann and Ralph F. Goldman, Ph.D.

Background:

Previous work at this Institute has led to the development of a mathematical model which enables prediction of the metabolic cost of walking and standing with loads (1). The energy expenditure prediction formula is:

$$M = 1.5W + 2.0(W + L)(L/W)^2 + \quad (W + L)(1.5V^2 + 0.35VG)$$

where
M = metabolic rate, watt
W = subject weight, kg
L = external load, kg
= terrain factor, defined as 1.0 for treadmill walking
V = velocity, ms^{-1}
G = grade (slope), %

The energy expenditures of walking at very slow speeds (0.2 to 1.0 ms^{-1}) were all taken on horizontal surfaces (grade = 0%). It seemed desirable to study the effects of walking at very slow speeds on a grade, and also standing on a grade. Grades used were both positive and negative (uphill and downhill).

Progress:

Eight fit male subjects (24 yr, 176 cm, 79 kg) stood, or walked at speeds of 0.5 or 0.9 ms^{-1} for 20-min periods on grades of -10 to +25% with loads of 20 or

40 kg. Energy expenditure (watt), heart rate (HR) and ratings of perceived exertion (RPE) were measured. Energy expenditure was not found to be significantly different in any of the standing conditions. (See Table 1 for measured and predicted energy expenditure (mean ± SE) for all conditions.) Grade and load increased energy expenditure while standing but not significantly. In some cases heart rates were actually lower for standing on a +25% grade than for standing on a +10% grade, and standing on a +25% grade was rated (RPE) lower than standing on a +10% grade on the perceived exertion scale. This may be because standing on a +25% grade simulates standing on the level since leaning forward with a load placed on the back moves the center of gravity so as to counteract the effect of the load. It is important to note than although all the standing energy expenditure means were relatively low, this does not indicate that these conditions can be maintained for long periods of time; high perceived exertion ratings suggest limits to tolerance time in some of these conditions.

TABLE 1
Measured and Predicted Energy Expenditure Means ± SE
for Standing and Walking Slowly on Grades with Loads

Measured Energy Expenditure (watt)	Predicted Energy Expenditure (watt)	Velocity (ms^{-1})	Load (kg)	Grade (%)
112.8 ± 4.8*	131.5 ± 7.1	0.0	20	+10
131.7 ± 5.0*	182.8 ± 3.1	0.0	40	+10
123.1 ± 4.1*	131.5 ± 7.1	0.0	20	+25
136.4 ± 5.3*	182.8 ± 3.1	0.0	40	+25
253.3 ± 7.1	†	0.9	20	-10
325.1 ± 5.7	†	0.9	40	-10
385.1 ± 8.2*	345.9 ± 19.0	0.5	20	+10
462.8 ± 8.7*	440.9 ± 14.4	0.5	40	+10
550.3 ± 15.8	558.5 ± 30.6	0.9	20	+10
691.4 ± 12.6	696.5 ± 26.1	0.9	40	+10

*Measured values significantly different form predicted values.

†Formula unable to predict for negative grades.

All the walking energy expenditure means were significantly higher than the standing means. Contrary to the standing conditions, changes in grade and/or load significantly affected energy expenditure while walking. These changes were not linear, however; as the condition became more strenuous by increasing load, speed, and/or grade, energy expenditure became more sensitive to changes in these variables. This study and previous studies (1) suggest that, within the range of 0.0 to 1.0 ms^{-1}, the effect of increasing speed on energy expenditure is also not linear, and is more pronounced in more strenuous conditions. Following a sharp increase in energy expenditure as velocity increase above zero, there seems to be a steady increase between 0.2 than 0.6 ms^{-1}, and at approximately 0.8 ms^{-1} another sharp rise can be observed.

A point may be mentioned concerning the results of this study on downhill walking. It was found that the energy cost of walking downhill on a -10% grade (0.9 ms^{-1}, 40 kg load) was higher than walking at approximately the same speed and load (1.0 ms^{-1}, 40 kg) on the level. This could be due to the involvement of the back and leg muscles in resisting the downward pull of gravity while walking on a negative slope.

The current energy expenditure prediction formula (1) was found to predict slightly high for the standing conditions, low for walking 0.5 ms^{-1} on a +10% grade, and accurately for walking 0.9 ms^{-1} on a +10% grade. When all the differences between individual predicted and measured energy expenditure values were averaged, an r value of 0.99 was found (See Figure 1). In the standing conditions the deviation between predicted and measured was higher at the 40 kg load than at the 20 kg load. Along with the other data, this suggests that the prediction formula may place too much emphasis on the effects of speed and load while standing and walking slowly.

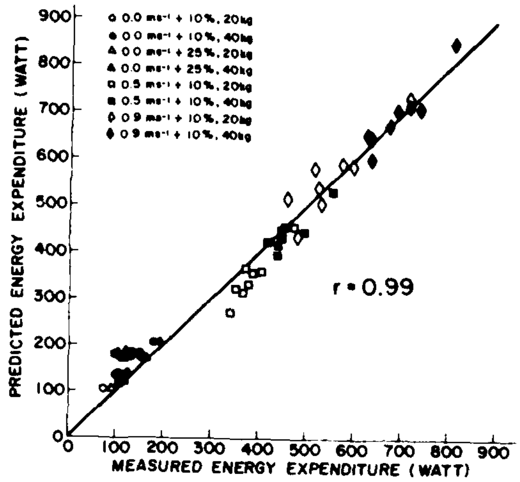

FIGURE 1. The relationship between individually predicted (1) and measured energy expenditure values for standing or walking slowly on positive grades with loads.

At present the prediction model is not equipped to consider negative (downhill) grade. This must be remedied, since man goes both uphill and downhill. Future research will be initiated to assess the energy cost of running with loads at reasonably slow running speeds.

Publications:

1. Pandolf, K. B., B. Givoni and R. F. Goldman. Predicting energy expenditure with loads while standing or walking very slowly. Journal of Applied Physiology, 43(4):577-581, 1977.

2. Pimental, N. A. and K. B. Pandolf. Energy expenditure while standing or walking slowly uphill or downhill with loads. Ergonomics. (In press).

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1. Pandolf, K. B., B. Givoni and R. F. Goldman. Predicting energy expenditure with loads while standing or walking very slowly. Journal of Applied Physiology, 43(4):577-581, 1977.

(83054)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OB 6139	78 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	H.Terminated	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	054
b. CONTRIBUTING				
c. XXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)*

(U) Assessment of Cold Injury Susceptibility (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

002600 Biology;003500 Clinical Medicine;005900Environmental Biology;012900 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING		
	CURRENT 78	3.8	61

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* HAMLET, Murray P., D.V.M.

TELEPHONE: 955-2865

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME:

NAME: DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U) Cold Injury; (U) Cold Pressor Test; (U) CIVD; (U)Infrared Thermography

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Background characteristics of individuals suffering cold injury reveal differences in cold injury susceptibility in response to cold. Evidence to date suggests racial background, smoking habits, cold experience, cold injury, climatic origin, attitude and emotional characteristics represent important predictors. Cold hypersensitivity of these individuals may be detectable through simple temperature measurements either directly (thermocouples) or remotely (Infrared Thermography). From this research adequate medical screening and preventative training or instruction can be developed.

24. (U)A single hand cooling procedure will be used to define the onset of vasoconstriction and vasodilation in a normal and in a clinically identified abnormal population. Multi-point thermocouples and infrared thermography will be used. One hand will be cooled in air or water for a given duration to elicit vasoconstriction and CIVD. Subsequent temperature measurements and thermograms of both hands will differentiate centrally mediated vasoconstriction from local vasoconstriction.

25. (U)77 10 - 78 09 Computer analysis software is being developed which will allow for measurement of surface area and temperature by computer program. Preliminary work with 10 human test subjects indicates significant differences in hand cooling response as measured by infrared thermography. Analysis of the thermograms utilizing high speed computer techniques will allow for continuation of this study. This work unit is now cancelled. Work will be continued under a new work unit.

*Available to contractors upon originator's approval

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	054 Assessment of Cold Injury Susceptibility
Study Title:	Evaluation by Infrared Thermography of Susceptibility to Peripheral Local Cold Injury
Investigators:	Murray P. Hamlet, D.V.M. and John C. Donovan, CPT, VC

Background:

Historically, military operations have been compromised as a result of cold injury. Analysis of previous wars has indicated that there may be soldiers who are more susceptible to cold injury (1,2). The fundamental objective of this study was to determine whether or not such individuals can be identified.

A screening procedure to identify soldiers who are more susceptible to cold injury should be practical. Such practicality entails three elements: it must be rapid, limited to the minimal population size, and non-invasive. These three elements will be considered sequentially. To evaluate individual susceptibility, it is necessary first to have a standard method whereby moderate cold stress (exposure of an extremity either to cold air or cold water for a prolonged period, usually 15 minutes to several hours) can be simulated. If the assumption were made that the relative vascular reactivity to a moderate cold stress correlates with responses to a severe, injury-producing cold stress, the time of onset of vasodilation and the amount of heat flow to the extremity could be a measure of an individual's cold injury susceptibility. It is obvious that this method of testing is unsuitable for screening purpose since it requires exposure to cold for long periods.

The cold pressor test, which has been used classically to measure vascular reactivity in relation to hypertension may be a desirable test for mass screening since it requires extremity immersion for only one minute. It is postulated that the mechanism involved in rewarming responses following prolonged cold exposure and brief ice water immersion may be similar. If so, the cold pressor test may be suitable for mass screening for peripheral cold injury susceptibility. This will require experimental evaluation by comparing individual responses to the cold pressor test and prolonged cold exposure.

Whether or not the cold pressor test can be utilized in screening for cold injury susceptibility, it appears desirable to limit mass physiological screening to the minimal population size required to identify cold injury susceptible persons. Population size can be limited by identifying specific risk groups on the basis of background and psychological factors. Only these at risk groups would require individual physiological testing.

Finally, the measurement of the cold stress response of individuals should be done non-invasively and as rapidly as possible. Infrared thermography is such a rapid, non-invasive technique and may prove satisfactory for cold injury susceptible screening. Infrared thermography has been extensively employed in medical applications. The present state of the art of infrared thermography is the AGA Thermovision system (AGA, Aktiebolag) (3,4).

In summary, these three elements must be considered in planning a program to define cold injury susceptibility: rapid testing, non-invasive testing, and testing.

Progress:

Software development and testing to permit PDP-11/40 analysis of thermograms has been completed. Twenty-five thermograms can be stored on a video disk for later computer analysis. Reliable temperature profiles have been produced with good precision. The initial programs written involve defining the surface area represented by a given set of temperatures and comparing it to the total surface areas studied. Problems of calibration and non-linear camera output are being addressed. This has proven to be more difficult than first thought. Two methods (1) a linar regression and (2) can exponential regression are being developed to solve this problem.

A device for positioning human hands for thermography during cold pressor tests has been designed and is being fabricated. This device suspends the hands over a cold background with no compromise to blood flow.

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(83055)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
	DA OC 6121	78 10 01	DD DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
77 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES:	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	055
b. CONTRIBUTING				
c. XXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code) Fire Direction Center (FDC) Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operation...

12. SCIENTIFIC AND TECHNOLOGICAL AREAS 013400 Psychology; 016200 Stress Physiology; 005900 Environmental Biology; 007900 Occupational Medicine; 002300 Biochemistry

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER: NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	8	272
	CURRENT 79	8	381

19. RESPONSIBLE DOD ORGANIZATION
NAME: USA RSCH INST OF ENV MED
ADDRESS: Natick, MA 01760
RESPONSIBLE INDIVIDUAL
NAME: DANGERFIELD, HARRY G., M.D., COL, MC
TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
NAME: USA RSCH INST OF ENV MED
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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
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TELEPHONE: 955-2802
SOCIAL SECURITY ACCOUNT NUMBER
ASSOCIATE INVESTIGATORS
NAME: STOKES, James W., LTC, MC
NAME: 955-2822 DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Team Performance; (U)Environmental Stress; (U)Sustained or Continuous Operations; (U)Fatigue,Mental; (U)Psychomotor & Cognitive Functions; (U)Motivation.

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U)Opposing threat doctrine may require that the Army deploy to harsh climates to fight for five or more days without rest. This work unit quantifies, correlates and describes in a critical military context the interaction of: 1) harsh climatic conditions; 2) common military stressors such as mission demands, noise, crowded work space, and sustained operations with recurrent sleep disruption or deprivation; 3) the acute physiological, biochemical, symptomatic and psychosocial status of functioning team members; 4) individual and team operational effectiveness over time.

24. (U)FDC teams from line Field Artillery units are tested for extended periods in naturalistic combat simulations as a "model" command/control and communications system. Multi-disciplinary data collection and correlation is done to assess the operational as well as medical cost to teams functioning under stress, determine rates of recovery following exposure, identify predictors of operational degradation, establish mechanisms of action, and test prophylactic or therapeutic interventions.

25. (U)77 10 - 78 09 (1) Data analysis is being completed on the archival FDC records (RTO logs, computor record of fire forms, chart sheets) from the 1977 test of four 82d ABN Div teams. Changes in team member performances are being examined to determine individual and team compensatory strategies and the impact of individual dysfunction upon the timeliness and accuracy of system output. Measures of operational effectiveness are being integrated with the physiological and psychosocial data collected by collaborating institutes (NHRC, WRAIR). (2) Operational and epidemiological observations and WBGT measurements were made at Ft. Hood, TX (Jun-Jul) during two 5-day practice field exercises and a 96h continuous operations test (conducted by TCATA) of a self-propelled Field Artillery battalion organized under the Division Restructuring Study TO&E and equipped with TACFIRE. Preventive medicine input was provided to the battalion, TCATA, and USAFAS to minimize interference of heat disabilities with that test.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	055 Fire Direction Center (FDC) Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operations
Study Title:	Fire Direction Center (FDC) Team Efficiency and Well-Being in Simulated Sustained Operations
Investigators:	Louis E. Banderet, Ph.D., and James W. Stokes, M.D., LTC, MC

Background:

The Scenario Oriented Recurring Evaluation System (SCORES) European scenarios (1) and the Science & Technology Objectives Guide (2) establish requirements to define, and if possible to extend, the physiological and psychological limits of critical command/control and communications personnel engaged in sustained-intense combat. It was postulated that problems of such complexity could be studied in a laboratory simulation which would use actual Army teams performing their normal functions, yet would permit control and replication of environmental and situational conditions and measurement and correlation of mission effectiveness, behavior and biological processes (3,4).

The Army's common Field Artillery fire direction center (FDC) was simulated for initial experiments in 1974 which employed actual FDC teams in an environmentally controlled chamber at USARIEM (5). This approach capitalized on pre-existing training, professional pride, social support and military task organization. Such factors are critical in the study of group military task performance and the contribution of individual performance to system (team) output (6,7); they also influence physiological as well as psychological responses to stress (8,9). In 1977, multidisciplinary studies were conducted jointly by the US Army Research Institute of Environmental Medicine (USARIEM), the Walter Reed Army Institute of Research (WRAIR), and the Naval Health Research Center (NHRC). In brief, complete audio, video and archival records of task performance were obtained.

Other information collected or derived included: unobtrusive observations of non-task behaviors, biochemical indices, physical fitness measures, physiological assessments including EKG, wrist actograph, sleep EEG and EOG, and self-evaluation of sleep, mood and symptoms. The rationale, methods, conditions and some study findings are described in previous reports (10,11,12).

Much of the precision of conventional laboratory performance paradigms was applied to the complex mission demands of the Field Artillery to document changes in FDC performance and to reduce sources of extraneous variance. This methodology was embodied in a detailed script ("scenario") of radio messages, played by roleplayers, which depicted a battle played on terrain maps according to military doctrine. Other roleplayers provided the telephone communications of the gun crews and controlled the sound effects of the guns. The scenario was organized into equivalent 6-hour blocks in which matched events of different classes recurred in a similar sequence with sufficient frequency to permit pooling and analyses of performance by standard statistical techniques. The classes included: 1) Calls for new, unplanned fire missions which required immediate plotting of coordinates, computation and transmission of numbers (ballistic firing data) by the FDC to the guns. These tasks were basically externally driven demands which required a rapid response with serial and parallel task processing, although timeliness could be sacrificed to maintain accuracy. 2) Encoded lists of preplanned targets for which firing data were to be computed and sent to the guns ready for urgent use. These self-driven but high priority tasks involved use of special correction factors for precise accuracy. Preplanned targets were to be processed by the FDC team members working both serially and in parallel but not necessarily in concert amidst the ongoing fire missions. Occasionally the correction factors would change, generating a need to update work already completed. 3) Subsequent calls for immediate fire on 50-70% of the preplanned targets, probing and reinforcing the state of readiness achieved by performance of the preplanning tasks. 4) Lower priority administrative tasks and 5) Background radio noise and messages irrelevant to the FDC. The workload each 6 hours ranged from brief lulls to periods of very heavy mission input. Atypical events also occurred periodically, making the sequence of standard events less predictable and evoking special responses. Appropriate and consistent feedback from the simulation role players was given to the FDC for significant errors or tardiness.

The joint USARIEM/WRAIR/NHRC study involved four volunteer FDC teams from two battalions of the 82d Airborne Division. Each team consisted of five men: a lieutenant Fire Direction Officer (FDO), a sergeant Computer (COM), vertical and horizontal Chart Operators (HCO and VCO) and a Radio-Telephone Operator (RTO). All teams were tested on the same mission demands (scenario-scripts), but underwent one of two experiment designs (Figure 1). All teams received 4 days of familiarization and practice in the simulation to minimize subsequent training and novelty effects. Two teams (1 & 4) then underwent a single challenge which they were told could run 86 h. The other two teams (2 & 3) underwent two 38 h challenges separated by a 34 h rest; they were told the challenges would each run 36 to 42 h. All teams were instructed not to set shifts, rotate jobs or nap.

Each team's performance was evaluated for system accuracy and timeliness. Accuracy was defined as the concordance between the FDC team's firing data and the correct solution computed by the US Army Field Artillery School, Ft. Sill, OK. Timeliness was the latency between mission input and the team's (system) output. Accuracy and timeliness data were scored from an audio tape with time signal and compared with a second independent determination. Any discrepancies were resolved by further rescoring of the audio tapes. Accuracy criteria were established and utilized in all studies, i.e., ≤ 3 mils[1] was acceptable and ≥ 15 mils was unacceptable. Other indices of performance were analyzed as difference scores between matched pairs, quartile scores[2], percent of uncompleted tasks demands, percent of task demands satisfied, number of occurrences or cumulative occurrences.

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1 The mil (m̸) is a unit of angular measure used by the Artillery; 6400 $\text{m̸} = 360^{\circ}$. Three (3) mils is the approximate tolerance between two independently performed manual computations if no errors are committed at any step.

2 Q1 = 25th percentile score, Q2 = 50th percentile = median, and Q3 = 75th percentile.

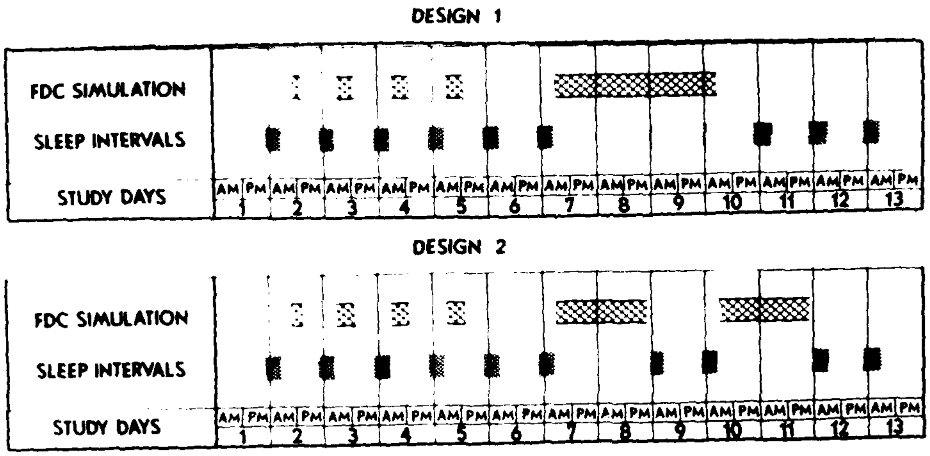

Figure 1. Schedules for the two experimental simulation designs are shown. Teams 1 and 4 were tested with design 1; Teams 2 and 3, design 2. Large cross-hatched areas represent simulated operations in the FDC. Small cross-hatched areas are times for scheduled sleep in the dormitory during nonoperational periods.

The teams differed substantially in social history, prior experience, mode of operation, and mastery of the simulated mission demands. Generally, Teams 1 & 4 (single open-ended design) showed less initial mastery and greater performance changes over time.

Team 1 exercised their right to withdraw from the study at 0700 h after 48 h. A chart operator had resolved to terminate, and the officer decided that the team should leave together. The team had also made several errors which "endangered friendly troops" during the prior 8 h and the officer was concerned that his team would soon be ineffective.

Team 4 withdrew voluntarily at 0400 h after 45 h. The younger enlisted personnel of this team had had the least field experience and were very fatigued. The highly experienced officer was especially fatigued from the continuous supervision he had been giving, but persevered until the sergeant prompted him for the decision to stop.

Team 2 completed both 38 h challenges. However, sleep data (13) indicated that the officer, sergeant and one chart operator slept very poorly the night before the second 38 h challenge. Urinary excretion of 17-hydroxycorticosteroids by the FDO, COM and RTO were markedly reduced during that second trial; the significantly increased oxygen uptake and heart rate during standard submaximal work at the end of the trial suggested that cumulative fatigue had decreased physical fitness (10).

Team 3 completed both 38 h trials even though one chart operator terminated after 6 h of the second trial. The remaining four men took this as a challenge and continued with the officer operating that chart.

The present report is concerned with describing group (system) and individual performance analyses and to demonstrate this approach has utility for the development of a stress-performance model. Group performance data will be presented for all studies, preliminary data for individual performance will only be presented for Team 4. Specific questions related to performance were: 1) Would the simulation yield meaningful group and individual performance data? 2) Which group and individual measures of performance are sensitive to time in the simulation and levels of training? 3) What are the time courses of various group and individual performance measures during a simulated, sustained intensive operation which does not provide opportunities for sleep? 4) What are the characteristics of mission tasks which are sustained or degraded with time? 5) What individual or group behaviors and actions sustain or degrade performance?

Progress:

For all teams, accuracy of firing data computed for the new (unplanned) fire missions was well maintained even until termination (Figure 2). Median times to accomplish the most standard subset of these tasks (the subsequent adjustments) increased more than 35% from initial values during sustained operations for Teams 1, 2 and 4 (Figure 3).

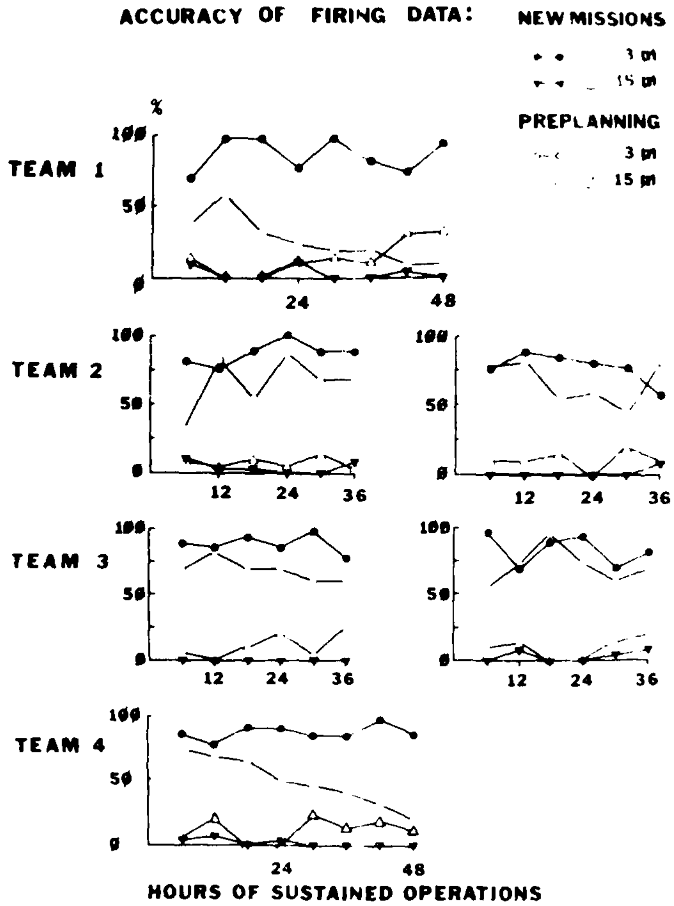

Figure 2. Accuracy of firing data as a function of hours in the simulation are shown for the four teams studied. Accuracy of ballistic data generated for new unplanned missions are shown in the solid symbols; accuracy data for preplanned targets, with the open symbols. Acceptable accuracy (≤ 3 mils) is shown by the circular symbols. Unacceptable accuracy, (≥ 15 mils) is shown by the triangular symbols.

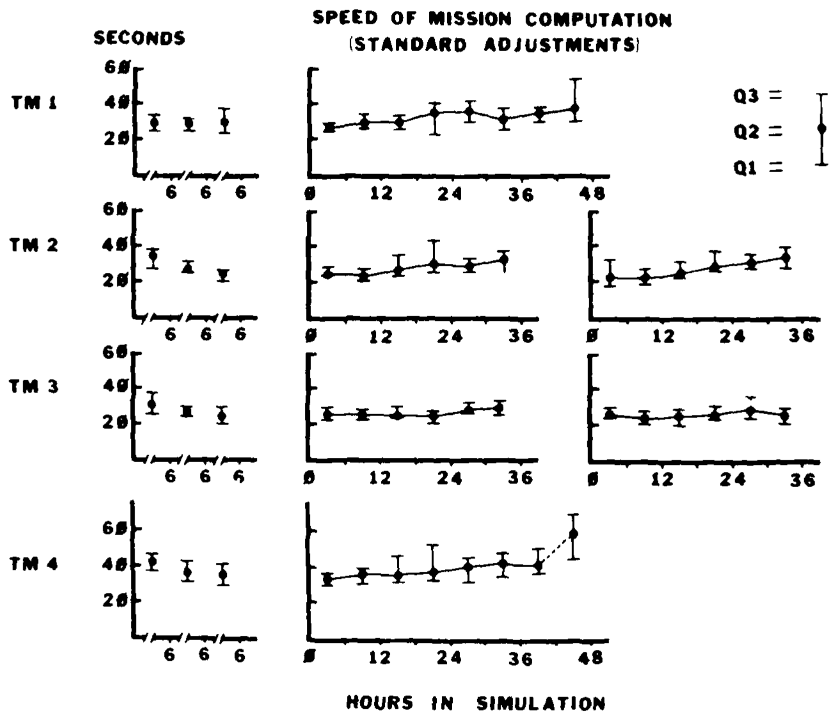

Figure 3. Speed of mission computations for standard adjustment sequences (new unplanned missions) is shown for all four teams studied. Each data point with lower and upper bracket represents the 50th, 25th, and 75th percentile scores.

The differences between initial and final 6 h performances are statistically significant ($P < .05$ for Teams 1 & 2, $P < .01$ for Team 3)[3]. These findings are as expected (6,7) for highly overlearned tasks: 1) initiated by arousing external cues, 2) accomplished during a brief period of mobilization, and 3) which receive prompt feedback for inadequate performance. It was apparent on the video record that accuracy was sometimes maintained at the expense of speed through increased individual latencies and demands upon team double-check procedures. However, this delay represents a tactically significant loss of combat effectiveness against moving battlefield targets and would increase the vulnerability of the FDC and its guns to detection and destruction by the enemy. Team 3 did not take significantly longer to compute these missions with time even during the second 38 h challenge after the VCO's withdrawal. The role of factors (perhaps related to motivation, prior training or team organization) which sustain performance are suggested as critical determinants of operational capability. Identification and management of such factors are critical in insuring that performance can be sustained under a variety of adverse conditions, even loss of personnel.

By contrast with the new, unplanned fire mission tasks, firing data for those preplanned targets actually fired upon was less accurate for all teams and deteriorated progressively over time in Teams 1 and 4 (Figure 2). These preplanning tasks required increased effort in comparison to new unplanned mission calculations, e.g., decoding of grid coordinates, addition and updating of correction factors, etc. Many errors reflected omissions or misapplications of the correction factors and produced errors > 3 ₥ but < 15 ₥ deviations. Although the greatest disparity between new and preplanned mission accuracy occurred with Team 1, this was probably due to inadequate instruction regarding the precision expected. There were also increased serious (≥ 15 ₥) errors in the latter hours of the sustained operations, resulting from gross errors in decoding or plotting the target's coordinates, using the wrong algebraic sign for correction factors, or transposing digits.

[3] T-test for matched pairs, 2 tailed

Median times to execute on-call responses to preplanned targets (Table 1a) increased significantly ($P < .01$) after 42 h in Team 1 and after 30 h in Team 4. These delays would have serious tactical consequences in combat, where delivery of artillery fire within seconds on preplanned targets is essential to suppress hostile wire-guided weapons.

Teams 2 and 3 did not show a progressive deterioration in accuracy (Figure 2) or speed of response (Table 1b) on these calls for preplanned targets, although there is a period of slower on-call responses ($P < .05$) from hours 18 to 30 h during Team 2's second challenge. It is interesting that the accuracy of Team 3 improved when the officer took over one chart following the voluntary withdrawal of a chart operator.

Examination of preplanning performance shows how these differences in team effectiveness occurred. Operationally, this task required processing target lists and sending the resulting firing data for each target to the guns as soon as it was ready. Ideally, this was well before a target was called for, if indeed it ever was. Functionally, the task involved all team members; an individual had to complete his portion of the task before others could proceed (serial processing). Finally, unless completed quickly, other fire mission events would inevitably interrupt the process.

Preplanning latencies (the time between input of the target list and output of ballistic data for an individual target) are presented in Figure 4. Teams 1 and 4, who expected the test to go for 86 h, showed increased latencies after 18h which were most pronounced from hours 36 to 48. Latencies during the latter interval were more variable, response times were longer, and performance was characterized by a failure to process a large number of preplanned targets. The observed loss of effectiveness (time taken to respond when targets were called for) clearly was a consequence of not preprocessing the data, while the loss in accuracy resulted largely from either legitimate trade-offs of accuracy for speed in urgent situations or from accidental lapses due to haste.

TABLE 1a

Latency of on-call responses for preplanned targets engaged by Artillery. Data are arrayed for each 6 h in the simulation for FDC Teams 1 and 4. Q1, Q2, Q3 are 25th, 50th (median) and 75th percentile values; Max is the longest latency observed. All data are in seconds.

SIMULATION CONDITIONS

Statistic	Practice Sessions (h)			Sustained Operation (h in simulation)							
	0-6	0-6	0-6	0-6	6-12	12-18	18-24	24-30	30-36	36-42	42-48
				Team 1							
Max	26	41	50	26	44	80	55	121	39	64	233
Q3	18	21	20	15	15	18	12	21	16	17	95
Q2	14	15	13	10	11	12	10	14	15	13	40
Q1	11	12	11	5	7	8	8	9	10	9	9
				Team 4							(42-45h)
Max	56	65	62	24	97	47	116	50	94	149	(86)
Q3	12	23	19	12	14	15	19	16	36	70	(48)
Q2	9	10	11	10	10	10	14	11	17	22	(44)
Q1	6	6	5	7	5	5	5	6	10	11	(16)

TABLE 1b

Latency of on-call responses for preplanned targets engaged by Artillery. Data are arrayed for each 6 h in the simulation for FDC Teams 2 and 3. Q1, Q2, Q3 are 25th, 50th (median) and 75th percentile values; Max is the longest latency observed. All data are in seconds.

SIMULATION CONDITIONS

Statistic	Practice Sessions (h)			Sustained Operation #1 (h in simulation)						Sustained Operation #2 (h in simulation)					
	0-6	0-6	0-6	0-6	6-12	12-18	18-24	24-30	30-36	0-6	6-12	12-18	18-24	24-30	30-36
Team 2															
Max	92	22	73	18	15	21	28	29	18	13	14	24	18	67	173
Q3	40	19	13	12	12	11	12	12	12	9	9	9	11	29	17
Q2	23	8	11	7	9	9	9	6	11	6	8	8	10	10	10
Q1	16	6	6	4	6	5	5	4	5	4	4	4	5	7	9
Team 3															
Max	51	77	18	19	38	22	57	40	21	18	26	15	56	49	27
Q3	10	17	13	12	14	12	20	15	17	11	11	12	12	19	12
Q2	5	14	10	10	4	9	14	9	11	9	9	10	8	14	9
Q1	4	6	4	4	3	4	4	4	6	5	2	5	5	4	3

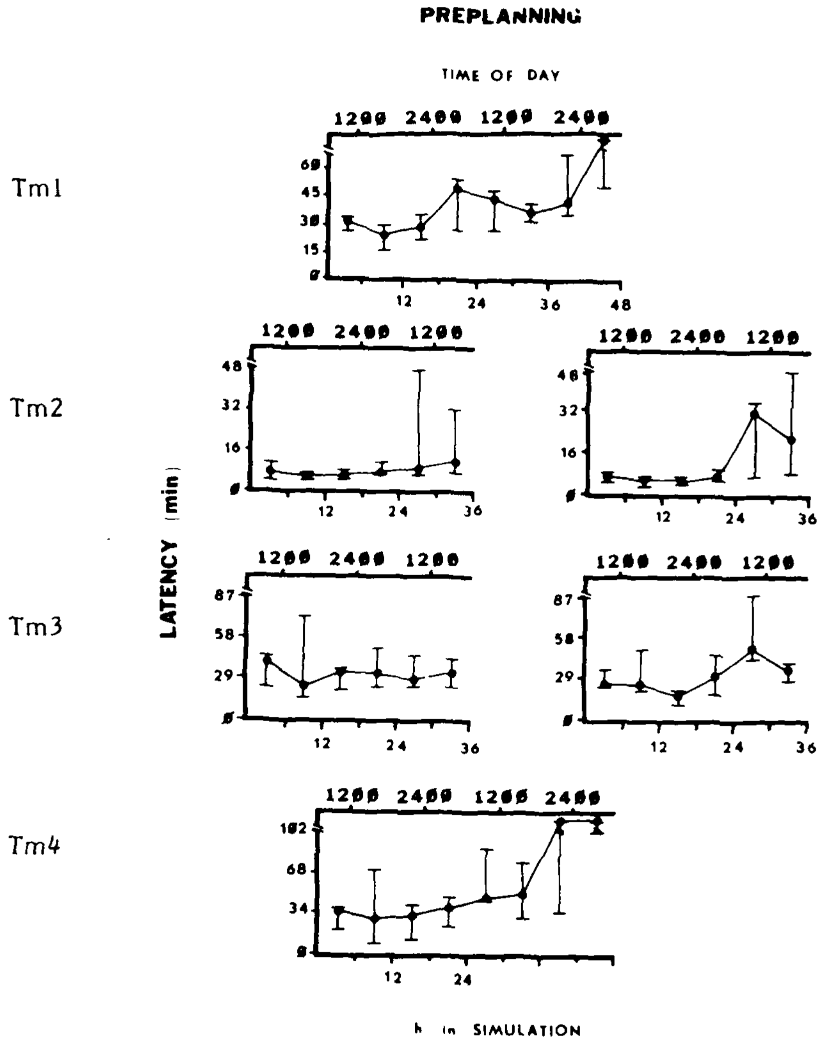

Figure 4. Latencies for preplanned target processing for all four teams studied are shown as a function of hours in simulation. Each data point shown with lower and upper bracket indicates the 50th, 25th, and 75th percentiles, respectively. Values plotted above the breakpoint on each ordinate indicate targets for which no ballistic data were ever sent to the guns.

Team 2 (two 38 h challenges) was very proficient at the preplanning tasks; their latencies were approximately 1/4th those of other teams. The latencies of Teams 2 and 3 did not change during the first 38 h challenge (Figure 4) although processing for Team 2 was more varied after 24 h. During the second challenge, processing time increased after 24 h for Team 2; processing times for Team 3 also increased after 24 h but declined from 30 to 36 h.

Figure 5 shows the prioritizing aspect of preplanned target activity for the different teams. This task involved indicating to the guns which preplanned target was of greatest importance to the forward observer at that time and calling ballistic data to the guns, if not communicated previously. In the Field Artillery and from a task analysis viewpoint, this activity provided an emphasis and focus for preplanning activities. As more and more of the preplanning tasks were not completed by Teams 1 and 4, increased latencies for prioritizing were observed, since ballistic data had to be computed before the FDC could specify the priority target to the guns. Teams 2 and 3 were more stable in their prioritizing performance, although some periods were characterized by increased variability. Consistent with the preplanning trend, prioritizing by Team 2 was also impaired after 24 h in the second challenge.

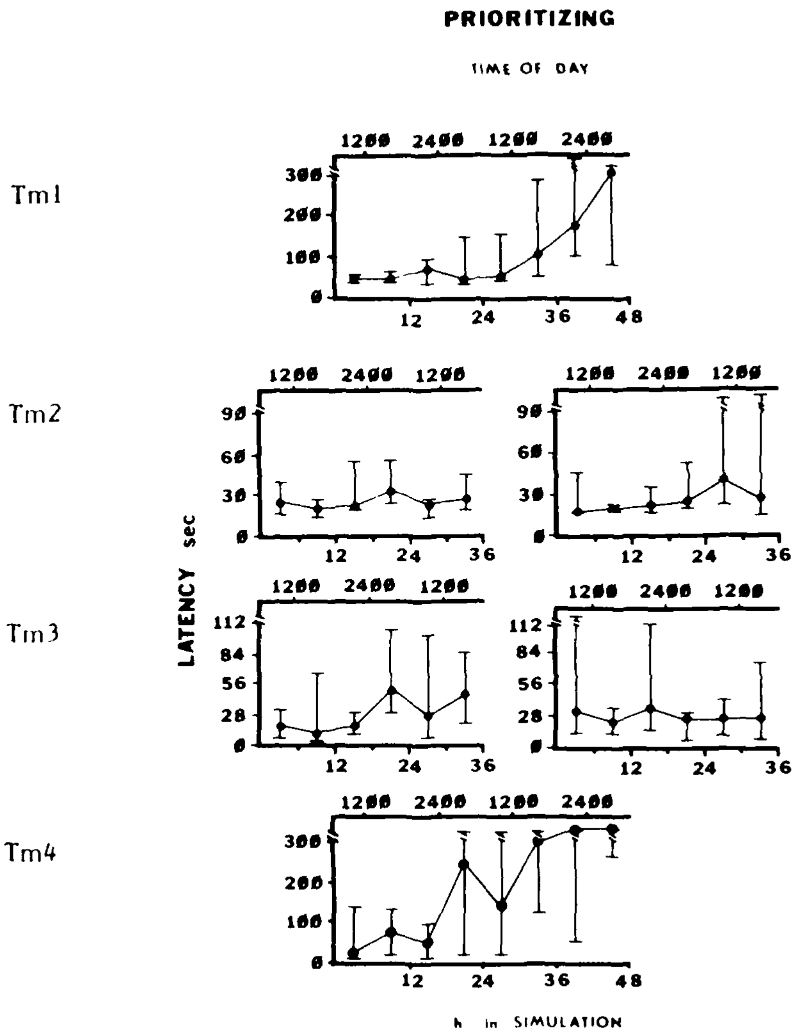

Figure 5. Latencies for prioritizing of preplanned targets for all four teams are shown as a function of hours in the simulation. The data point with lower and upper bracket indicates the 50th, 25th, and 75th percentiles, respectively. Any values plotted above the broken portion of the ordinate indicate targets for which no ballistic data were even sent to the guns.

Queueing theory was also applied to the preplanning and prioritizing performance of the four teams. For these analyses, the FDC can be viewed as a service organization to which users send orders to be processed; once processed these orders are held ready for use "on-call" (defined here as "coverage"). As shown in Figure 6 orders were always sent in groups of 4 targets as predetermined by the scenario. The potential number of targets, available on-call, increased to a maximum of 16; thereafter, users cancelled their four oldest targets when sending new ones. The area within the stepped boundary of Figure 6 therefore represents the total demand for coverage placed by users on the service center. The new orders (target lists) entered a queue in which each waited until either it was processed or the user withdrew it. The queue is shown by the shaded area. Therefore, the shaded area is the total user demand which has not yet been satisfied.

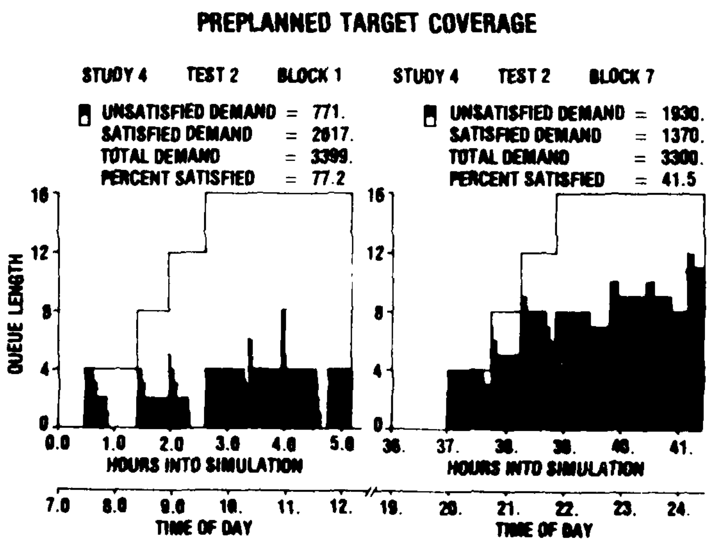

Figure 6. Queue analysis of Team 4's preplanned target coverage is shown for the first and last 6 h of sustained operations. The total area for a 6 h period represents the total demand for target "coverage", while the shaded and unshaded portions represent unsatisfied and satisfied demand, respectively.

The ratio of unshaded area to total area multiplied by 100 is the percentage of active orders over time which are "covered" and could be picked up without waiting by the customer. If percent coverage is divided by 100, it gives the probability that a customer, coming at random to pick up any one of his pending orders, would find it ready. As Figure 6 shows, the percent of satisfied demand is much less (42%) from 36 to 42 h of Team 4's sustained operation than in their first 6 h (77%).

Figure 7 shows the percent of preplanned target coverage over time for the four teams, considering: 1) all preplanning, i.e., all suppressive targets send in encoded lists, and 2) only prioritizing, i.e., those targets designated for a time as having priority. All teams showed increased efficiency after the pretraining. During the sustained operations, the preplanning coverage provided by Team 1 fell from a maximum of 77% to 33%, with 70% of that drop in the last 6 h. For Team 4, the decrease was more gradual from 77% to 42% over 42 h, then falling to 18% in the last 3 h before termination. Team 2, on the other hand, processed their preplanned targets efficiently from the onset. Although some decrease in readiness was observed with time on task for Team 2 (max of 95% to a min of 76%) they were rarely unprepared. Hence, they were less likely to omit correction factors deliberately or to make errors in haste when called upon. Team 3 maintained consistent coverage between 75% and 68% throughout their first challenge, but were more variable (85% to 61%) in the second trial when functioning with only four men.

For the subtask of prioritizing, the queue analysis indicates that in most cases, the teams maintained better coverage than for the total population of targets. This would be expected given the greater importance (priority) of those targets. The exception is Team 4, the least experienced team, who actually performed the priority task less adequately than the overall task from 18 h to 42 h.

The importance given to a task, either by the initial instructions to the team or by the task's manifest consequences, generally did have a strong influence on the performance observed. Even initially, a third aspect of the total preplanning function, i.e., Updating (Table 2) was rarely completed by Teams 1 and 4 and was ignored by Teams 2 and 3 more than other preplanning tasks. Thus, updating was the preplanning task most frequently not completed by all four teams. It is of interest that, in contrast to the other preplanning tasks, the updating task was done by a single team member, was not solicited or probed by external or internal forces, and had the least consequences for inadequate performance (approximately a 7 % deviation from the correct solution).

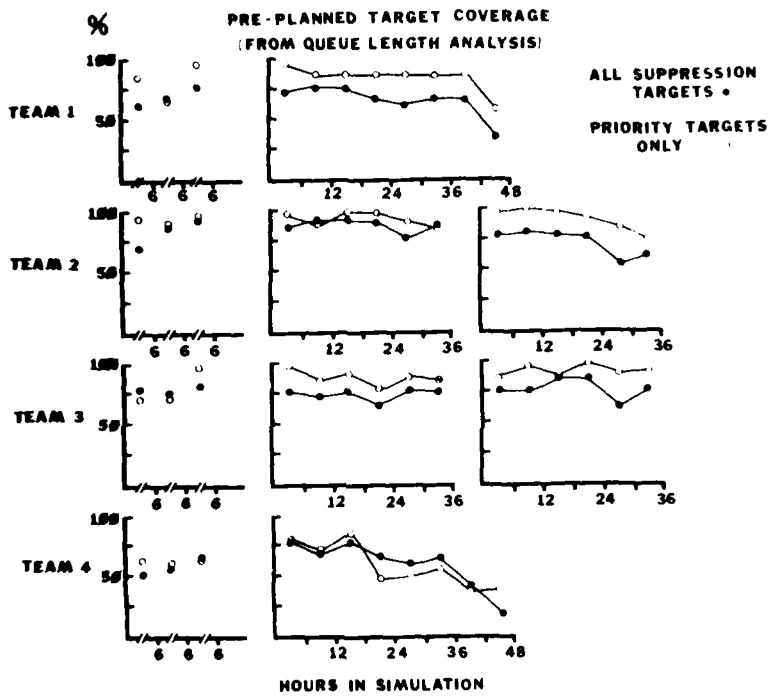

Figure 7. Percent coverages of preplanned targets from queue analysis are shown for all four teams as a function of hours in the simulation. Coverage of all preplanned (suppression) targets is shown by the solid symbols. Coverage of targets designated as having priority is shown by the open symbols. Data plotted on the left hand side of the figure represent values determined for three separate pretraining days before the sustained operations challenges.

TABLE 2

Percent uncompleted, preplanned target tasks are shown for the four teams studied. All values without parentheses may be compared across studies since they represent data for comparable durations, i.e. 36 h. Values inclosed within parentheses for Teams 1 and 4 represent the percent of uncompleted task demands over the entire 48 h duration of the longer simulation challenges, unique to these studies. Team 4 values from 45-48 h (interval after Team 4's termination) were extrapolated.

Team	Interval	Preplanning	Prioritizing	Updating
1	1st 36 h	4	8	100
	(all 48 h)	(11)	(14)	(95)
2	1st 36 h	2	5	12
	2nd 36 h	2	11	11
3	1st 36 h	9	10	36
	2nd 36 h	12	7	19
4,	1st 36 h	9	27	86
	(all 48 h)	(19)	(34)	(88)

It is axiomatic that group performance will be some complex interaction of the performances of each of the team members (14,15). To understand these interactions and factors which maintain or degrade team performance, we have begun to look intensively at individual task performance. The remainder of this report will describe preliminary data on individual task performance derived from archival records (RTO log book and chart grid sheets) from Team 4.

Prior discussions of system performance data from Team 4 have shown that this team took longer to complete many mission demands than the other teams studied. On several measures after 18 h in the simulation, these trends were prevalent. The number and percent of unprocessed preplanned targets for each FDC team member are shown in Table 3.

TABLE 3

Unprocessed preplanned targets for each individual FDC team member in Team 4. The number and percent of unprocessed preplanned targets per 12 h interval are shown for each individual team member. The Fire Direction Officer (FDO) is not included in this analysis since in a supervisory, leadership role he does not generate any specific output. The rows in this table show uncompleted targets for each individual team member as a function of 12 h increments in the simulation. Examination of the columns allows one to infer which members of the team were responsible when no group output (ballistic firing data) was generated for a particular preplanned target. Values from 45-48 h (interval after Team 4's termination) were extrapolated.

	Hours in the Simulation (Study 4)				
Team Member	0-12	12-24	24-36	36-48	
Radio-Telephone	0	0	4	0	No. unprocessed
Operator (RTO)	0	0	7	0	% Task
Chart Operator	3	0	7	27	No. unprocessed
1 (HCO)	5	0	12	48	% Task
Chart Operator	3	0	8	34	No. unprocessed
2 (VCO)	5	0	14	61	% Task
Computer	5	2	9	34	No. unprocessed
	9	4	16	61	%

All team members showed the greatest performance deterioration on preplanned target processing from 24 to 48 h, except for the radio-telephone operator (RTO). The performance of the chart operators up to 30 h was identical and rarely asymptotic. This correspondence suggests the role of social and organizational factors in sustaining behavior. From 36 to 48 h, 61% of the preplanning task, a task essential for rapid delivery of artillery fires, was left uncompleted by chart operator 2 and the computer. In this team the RTO did not limit this aspect of preplanning performance. The computer does appear a critical limiting factor since he completed less of the task than other members of the team and he allowed his performance to be limited (driven) by the performance of the chart operator who processed fewer targets. Thus, the present level of analysis enables one to infer differing organizational styles and determine for a particular team how different team members influence and set limits upon the ultimate system (group) performance.

TABLE 4

Radio-telephone operator (RTO) performance on various indices. The number of occurrences for various RTO performance deficiencies are shown in this table. The first three performance indices were determined by post study review of the RTO's log book, a natural archival record maintained in the FDC. The last two measures shown were established by monitoring audio recordings of the radio traffic. Values from 45-48 h (interval after Team 4's termination) were extrapolated.

	Hours in Simulation (Study 4)			
Performance Measures	0-12	12-24	24-36	36-48
Call Sign Omissions in Logbook	0	2	6	4
Undecoded Position Reports	17	27	34	36
Logbook Entry Changes	1	1	4	11
Radio Retransmissions to FDC	1	7	8	6
RTO "Say Again" Requests	1	12	28	27

With one exception shortly before a battery move (4 targets from the same list), the RTO always decoded preplanned target grids from the radio messages and conveyed this information to the chart operators. In contrast, other aspects of RTO performance deteriorated as h in the simulation increased (Table 4). On most measures this trend was most marked after 24 h. The number of undecoded positions reports shown represents approximately 30 to 80% of uncompleted task demands. This task, like the computer's updating of preplanned data, is done by a single team member and the consequences for inadequate performance are usually minimal. Some performance measures (e.g. number of times the radio operator failed to respond to his call sign and the sender retransmitted the call sign) appear from observation of the video tape record to have reflected lapses into microsleep. Failure of the RTO to record the sender's call sign in his log book even though he responded to the mission also increased after 24 h and may indicate "slow starting" after arousal from microsleep. It must be emphasized that numerous measures of RTO performance do not show changes with time; the data arrayed show only some measures that do. This is an important observation since it suggests that when many of the real-world variables are incorporated into a performance study, i.e., task feedback, opportunities for "say again" requests, social and group support, double-check procedures, and error detection capabilities, performance is more robust than that predicted by more traditional approaches to performance assessment.

The performances of the chart operators are shown in Table 5. The target plots of chart operator 1 were less accurate and his probability of an inaccurate target plot varied greatly with time (P=0.08 to 0.36). The site computation performance of chart operator 2 was greatly degraded 36 to 48 h in the simulation and indicates a failure to complete this computation. The apparent difference between the chart operators on this measure is because this task is normally performed by a single chart operator and the computer. It was demonstrated earlier that the accuracy of the firing data for preplanned targets as well as the number of preplanned targets processed deteriorated markedly with time in both Teams 1 and 4. This analysis of individual chart operator performance suggests these trends in Team 4 are partially accounted for in the uncompleted site computations of chart operator 2 and the failure of both chart operators to plot numerous targets after 36 h in the simulation. Thus, failure of the chart operators to plot the preplanned targets and of the VCO to calculate this correction factor degraded the ultimate group (system) output.

In conclusion, the types of performance decrement observed in these studies using actual Army teams performing their military occupational specialty (MOS) conforms well with those predicted from the scientific literature and field experience. The robustness of several performance measures under these study conditions suggests one must be cautious in generalizing results from traditional laboratory studies of performance to real-world settings which include social and military task organization, task feedback, double check procedures, and error detection capabilities. Analyses of individual performance and non-task behaviors are proceeding. Soon, it will be possible to specify if the principles described for Team 4 generalize to the other teams. When the analyses of individual task performance and non-task behavior are completed, the sleep, biochemical, and physical measures will be arrayed with these indices. The possible relationships between these multidisciplinary measures on actual Army teams will then be determined.

TABLE 5

Target plotting accuracies and unfinished site computations for each FDC chart operator in Team 4. These data were determined from post study analysis of acetate sheets used for target plotting each 6 h in the simulation. These data indicate that chart operator 2 was a more proficient operator than chart operator 1. Values from 45-48 h (interval after Team 4's termination) were extrapolated.

	Hours in the Simulation (Study 4)							
Performance Measures	0-12	12-24	24-36	36-45	0-12	12-24	24-36	36-48
	Chart Operator 1 (HCO)				Chart Operator 2 (VCO)			
Cumulative No. of Inaccurate Target Plots	5	15	29	47	4	7	10	13
% Inaccurate Target Plots	8	16	26	36	6	4	6	10
N	69	64	56	37	69	64	54	28
% Unfinished Site Computations	100	100	98	97	15	18	20	63
N	93	88	80	55	93	88	78	47

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	055 Fire Direction Center (FDC) Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operations
Study Title:	Environmental and Epidemiologic Observations of a Live Fire Field Artillery Test in Hot Weather
Investigators:	James W. Stokes, M.D., LTC, MC and Louis E. Banderet, Ph.D.

Background:

The Division Restructuring Study (DRS) conducted by Training and Doctrine Command (TRADOC) (May 1976) recommended a number of changes in the table of organization and equipment (TO&E) of the Army division to make it better able to fight on the anticipated high technology battlefield against a numerically superior opponent who wages continuous (round the clock) combat. A brigade of the 1st Cavalry Division at Ft. Hood, TX was reorganized according to the DRS TO&E and trained for over a year to take part in field tests of the new concept. Planning for and analyzing the results of those tests was the responsibility of the TRADOC Combined Arms Test Activity (TCATA, previously known as MASSTER) at Ft. Hood. Personnel from USARIEM's Health and Performance Division (FDC Team Project) became involved when it was learned that the field test of the restructured direct support Field Artillery battalion was to be conducted in July 1978 as a 96 hr sustained operation, live fire, with mission demands and frequency of unit moves approaching those predicted by TRADOC's SCORES (Scenario Oriented Recurring Evaluation System) Europe I Sequence 2A scenario.

The restructured FA battalion differed from the current TO&E in the following ways: 1) it had four batteries of 8 guns each instead of three batteries of 6 guns; 2) each howitzer battery normally operated as two 4 gun elements separated by 500 to 1500 m and moving by alternate bounds; 3) each duo of 155 mm self-propelled howitzer and tracked ammo carrier had only 9 men instead of 10: 4) mess and ammunition resupply resources were taken away from each battery and consolidated in a Service Battery; 5) maintenance was consolidated in a Maintenance Battery; 6) Headquarters battery continued to maintain the battalion operations center and also the battalion fire direction center (FDC), which was equipped with the TACFIRE computer system.

While not inherently linked with the DRS concept, use of TACFIRE had a number of implications of its own. Forward observers normally transmitted fire missions to TACFIRE by digital radio messages. TACFIRE assigned the mission to one or more firing elements, computed the firing data for those guns, and transmitted the commands digitally to a Battery Display Unit in the FDC. In theory, the battery FDC needed to compute firing data only when the Battalion FDC was moving or otherwise out of communication. Questions for the DRS field test included whether digital and voice traffic would interfere with each other, and whether each element of a battery needed a complete FDC or could function adequately with only a relay station. The battalion TACFIRE TO&E did provide personnel for two complete 3-man shifts; the battery FDC was allowed duplication for all personnel except the officer.

Underlying many of TCATA's field test issues was whether the reorganized TO&E left the units with sufficient "robustness" to be able to sustain adequate operations for more than 5 days under heavy work loads. Under the conditions of the SCORES scenario, it was assumed that personnel would be able to get only severely fragmented sleep and that fatigue might have a significant effect on performance.

Although heat stress was not called for under the European scenario, scheduling contraints required that the test of the FA battalion be held at Ft. Hood in late July. TCATA and the 1st Cavalry Division participants, therefore, welcomed consultation from USARIEM to minimize interference of heat-related disabilities with the test and to assist in evaluating the extent to which environmental factors influenced the test results.

Progress:

Two observers from USARIEM (a Medical Corps physician and a civilian Behavioral Psychologist) lived with the troops in the field for two week long practice exercises (June 26-30, July 10-14) and throughout the DRS test (July 24-28). Periodic measurements of the Wet Bulb Globe Thermometer (WBGT) index were made using the newly available kit NSN 6665-00-159-2218 under several standard conditions: 1) in the open; 2) under the Lightweight Screening System (LWSS) camouflage nets at the gun positions; 3) inside the self-propelled howitzers and armored Fire Direction Center vehicles when they were operating with hatches open or, 4) when operating with hatches closed. In addition, we obtained the "official" Ft. Hood WBGT measurements taken hourly each day between 0930 and 1630 by the Health and Environment Activity, MEDDAC, adjacent to Darnall Army Hospital; those records were provided to TCATA for inclusion as an appendix to the DRS test report.

As a result of our observations during the first training week, the medics (MOS 91B) available to the battalion were augmented to provide one with each 4-gun firing element instead of one per battery; subsequently, this has been recommended as a permanent change in the DRS TO&E. During the test, each medic was provided with a form on which to record the MOS, actual duty position, time of day, chief complaint and disposition of all patients seen in the field. Darnall Hospital records were also obtained for personnel evacuated from the field to the emergency room during the test.

Medical coverage relied upon prompt evacuation of serious or uncertain cases by helicopter to the Darnall Hospital emergency room and was adequate for the test situation. Four medics (MOS 91B) were levied from other Artillery battalions to supplement those of the 1-77th's TO&E so that one medic was present with each of the eight firing elements. However, as three of the 1-77th FA's medics were on leave or otherwise occupied, only one medic was left over to cover all of Service, Maintenance and Headquarters Batteries. Quality of the medics ranged from outstanding and exemplary to so negligent that a DRS evaluator initiated court martial proceedings. The adequacy of the DRS TO&E to provide first aid and initiate evacuation under SCORES Europe I scenario combat conditions was not tested, but deserves critical examination.

TABLE I

Daily Mean Daytime & Peak WBGT Values (°F)

at Ft. Hood, TX Before and During DRS Test

TRAINING:	26 JUN	27 JUN	28 JUN	29 JUN	30 JUN
$\bar{X}$ WBGT	----	----	85.3*	85.2	84.1
Hi WBGT	----	86.2	87.3	86.8	86.5
REHEARSAL	**10 JUL**	**11 JUL**	**12 JUL**	**13 JUL**	**14 JUL**
$\bar{X}$ WBGT	85.6	86.4	85.1	86.7	88.6
Hi WBGT	87.6	88.0	87.4	91.9	91.4
DRS TEST	**24 JUL**	**25 JUL**	**26 JUL**	**27 JUL**	**28 JUL**
$\bar{M}$ WBGT	87.1	89.5	88.5	----	88.9
Hi WBGT	89.6+	92.7	93.2	89.4	92.0

Original data courtesy of Health and Environment Activity, MEDDAC, collected at Darnall Army Hospital, Ft. Hood, Texas

Heat illness did not have a major influence on the conduct of the test. Table I shows that daytime average and peak temperatures were only moderately higher during the test than during the practice weeks. This gradual progression provided physiologic and behavioral acclimatization for the physically active battalion personnel, while the less well acclimatized evaluators and controllers of the test were able to remain relatively sedentary. However, there were still frequent times when conditions were above the cut-off point of 90° WBGT at which the Post's Hot Line Policy calls for all non-mission-essential training to cease and for commanders of units performing mission-essential work to take special precautions. Special measures were taken to get sufficient water to the batteries, detached elements and outposts (a lesson learned at one observation post in June, when 2 members of FIST teams were medevac'd for temporary heat exhaustion). The officers and men had learned not to rely on thirst but to drink small amounts of water often. They had been instructed to use extra salt with their meals, and to get more if they needed from the medics. A unit-wide policy of unblousing fatigue shirts and trousers when the Ft. Hood wet bulb reading reached 84^{o} had been instituted. From experience, the troops knew how to pace themselves and catch sleep whenever they could. Even with these precautions, four men were evacuated from the field for minor heat-related during the test. Two of these occurred on the same day in the same Fire Direction Center team due to a combination of disrupted food and water resupply, working conditions and psychological factors; both returned to duty within 24 hours.

Accidents and injuries associated with operating the potentially hazardous equipment under field conditions during the DRS test were similar to the previous practice weeks, and did not have major effect on unit effectiveness.

The WBGT measurements taken in the field provide some evidence on the differences in thermal stress exposure for those working in different locations and functions within the batteries. The Lightweight Screening System (LWSS) camouflage nets provided up to 10^{o}F protection for the WBGT against solar load, although erecting the nets in the open around midday was one of the major heat stress situations encountered by the gun batteries and tended to be neglected as the test proceeded. Vehicles buttoned up after dark for light discipline (especially FDC's in the M577 with their radios and computor hardware) remained uncomfortably hot throughout the night. This was less a problem during the DRS test than in the practice weeks because the tailgates were usually kept open to accommodate the observing evaluators. Our observations on heat stress during the test will be reported to the Field Artillery community in a letter to be published in the Field Artillery Journal (Mar-Apr 1979).

The WBGT measurements taken in the field using the NSN kit were consistently higher than those obtained at Darnall Army Hospital, Ft. Hood, by the Health and Environment Activity, in one case 13.4^{o}F higher (27 June 1230h) but on the average 4.2^{o}F higher. This could be due to actual local differences in wind speed, humidity, air temperature, solar load and albedo, perhaps magnified by placement of the kit (although we attempted to elevate it several feet off the ground on branches or on an LWSS). However, when the NSN kit was compared with the prototype Wexler kit, the two were equivalent when solar load was low but the NSN gave increasingly higher readings as solar load increased. This may be due to the olive drab metal case of NSN kit, which became perceptably hotter than the grey plastic of the Wexler kit.

We observed that most units and individuals were able to obtain adequate, although uncomfortable and disrupted sleep. Only a few key personnel were obliged to function without relief to the point where this per se may have impaired function. However, it was recognized by TCATA that the number of fire missions and unit displacements actually imposed during the test was less than planned, and that difficulties in coordinating and executing so many live fire missions resulted in each firing element having several periods of over an hour each per day during which no mission demands occurred. Perhaps this situation may be a closer approximation of true average conditions in combat, even for the defender during a continuous operation, but the data obtained from the test should not be interpreted as answering the questions raised by a worse case analysis.

We discussed our observations with the staff at TCATA and with the Doctrine Team, Directorate of Combat Developments, US Army Field Artillery School (USAFAS), who then had us brief the Assistánt Commandant, USAFAS. These agencies and the field experiments and computor simulations which they conduct may provide an avenue for introducing environmental and occupational medical considerations at an early stage into planning and doctrine development.

Animal Care and Animal Modeling

Investigator, Chief, Animal Care Facility:

Danney L. Wolfe, CPT, VC (1 Oct 77 - 31 May 78)

John C. Donovan, CPT, VC (1 Jun 78 - 30 Sep 78)

Background:

Over the years, the position of Chief, Animal Care Unit has expanded to include several areas of responsibility. These responsibilities include:

1) surgical development of new and unique animal models to support the research mission of the US Army Research Institute of Environmental Medicine (USARIEM).

2) performance of both chronic and acute aseptic surgical techniques and procedures to produce statistically significant numbers of healthy animal models,

3) administrative management of the Animal Care Facility to include the physical plant and animal care personnel in accordance with standards of the American Association for the Accreditation of Laboratory Animal Care (AAALAC).

4) maintenance of the health of the laboratory animal population through a sound conditioning program, a preventative medical program for all animals and the observation, diagnosis and treatment of medical/surgical problems occurring in the laboratory animal population, and

5) chairing of USARIEM's Animal Use Committee to review and make recommendations to the Commander for his approval or disapproval of proposed research protocols utilizing laboratory animals.

Progress:

During the course of fiscal year 1978, the Animal Care Facility experienced a change of personnel in the position of Chief, Animal Care Facility. With the loss of CPT Danney Wolfe, CPT John Donovan, CPT, VC filled the vacancy. A significant portion of the eight months prior to CPT Wolfe's departure was spent in training CPT Donovan in the methods, and procedures commonly used in support of animal modeling and research here at USARIEM. Some of the techniques covered included: 1) preparation of the goat animal model to include carotid loop preparation and the surgical procedures used for the implanting of cisternal and ventricular guide tubes, 2) preparation of permanent tracheostomies, 3) special radiographic techniques for contrast angiography and venography, 4) use and placement of flow directed Swan-Ganz catheter, 5) application of electronic flow probes around both peripheral vessels and the great vessels of the heart and thoracic cavity, and 6) chronic catheterizations of various abdominal and thoracic vascular cavities. The skills and knowledge achieved through this training will insure continued high quality veterinary support of research at USARIEM.

The Animal Use Committee, continuing in its responsibility to: 1) oversee the use of laboratory animals and to insure that the information sought by the use of laboratory animals is sufficiently important to warrant their use, 2) insure that the maximum amount of information consistent with good scientific research practices is obtained, 3) use the minimum number of animals necessary for scientific validity, 4) after adequate consideration of the experimental design, laboratory limitations and alternative species, select the species most suitable, and 5) insure that the description of the procedures is reasonably complete and *minimizes pain and discomfort* to the greatest extent possible without compromising the objectives; reviewed the following protocols:

1) "An Evaluation of Various Methods of Rewarming Hypothermia Victims" -Dr. Roberts

2) "Heat and Exercise Induced Injury; Preventative Measures" - Dr. Francesconi

3) "Ionic Composition of Cerebral Interstitial Fluid in Acute Lactic Acidosis and Hypocapnia" - Dr. Fencl

4) "Role of Cerebral Fluids in Respiratory Adaptations to Acute Acid Base Imbalance" - Dr. Fencl

5) "Development of an In Vivo Animal Model to Study Cold Induced Vascular Changes and Post-Frostbite Hemostasis" - CPT Trusal

6) "Role and Significance of Endotoxin in Heatstroke" - Mr. David DuBose

For each of these protocols recommendation for the approval, modification or disapproval were made to the Institute commander, prior to the initiation of any experimentation.

A number of surgical procedures were performed in support of USARIEM protocols. Those procedures, their numbers, the species involved, and the nature of their use (acute or chronic) are listed in Table 1.

TABLE 1

Surgical Procedures Performed to Support Research During FY 78

Surgical Procedure	Species, Number of Procedures Acute or Chronic Preparations			
	Canine		Caprine	
	Acute	Chronic	Acute	Chronic
Cerebral Surface Exposure for Ph Measurements	18			
Tracheostomy				1
Carotid Loop				6
Cisternal Magna Cannula Implantation				6
Lateral Ventricle Cannula Implantation				5

All surgical procedures were accomplished under Work unit 022 and were performed in support of the following protocols:

1) "Role of Cerebral Fluids in Respiratory Adaptations to Acute Acid-Base Imbalance" - Dr. Fencl

2) "Ionic Composition of Cerebral Interstitial Fluid In Acute Lactic-Acidosis Hypocapnia" - Dr. Fencl

To maintain and guarantee health of the laboratory animals, we have conducted a preventative medicine and conditioning program for each of the species. Incoming canines were examined, tatooed and dewormed upon arrival. A routine blood work-up on each dog consisted of a CBC, heartworm exam and 16 parameter biochemical screen. Routine fecal analyses were performed on the dogs at six month intervals and appropriate anthelmintic therapy institutued. Rats were routinely histologically screened for the presence of pneumonitis and examined for pinworm infection. Newly arrived goats were examined, deloused, dewormed and routine blood work consisting of a CBC and 16 parameter biochemical screen was performed.

Publications:

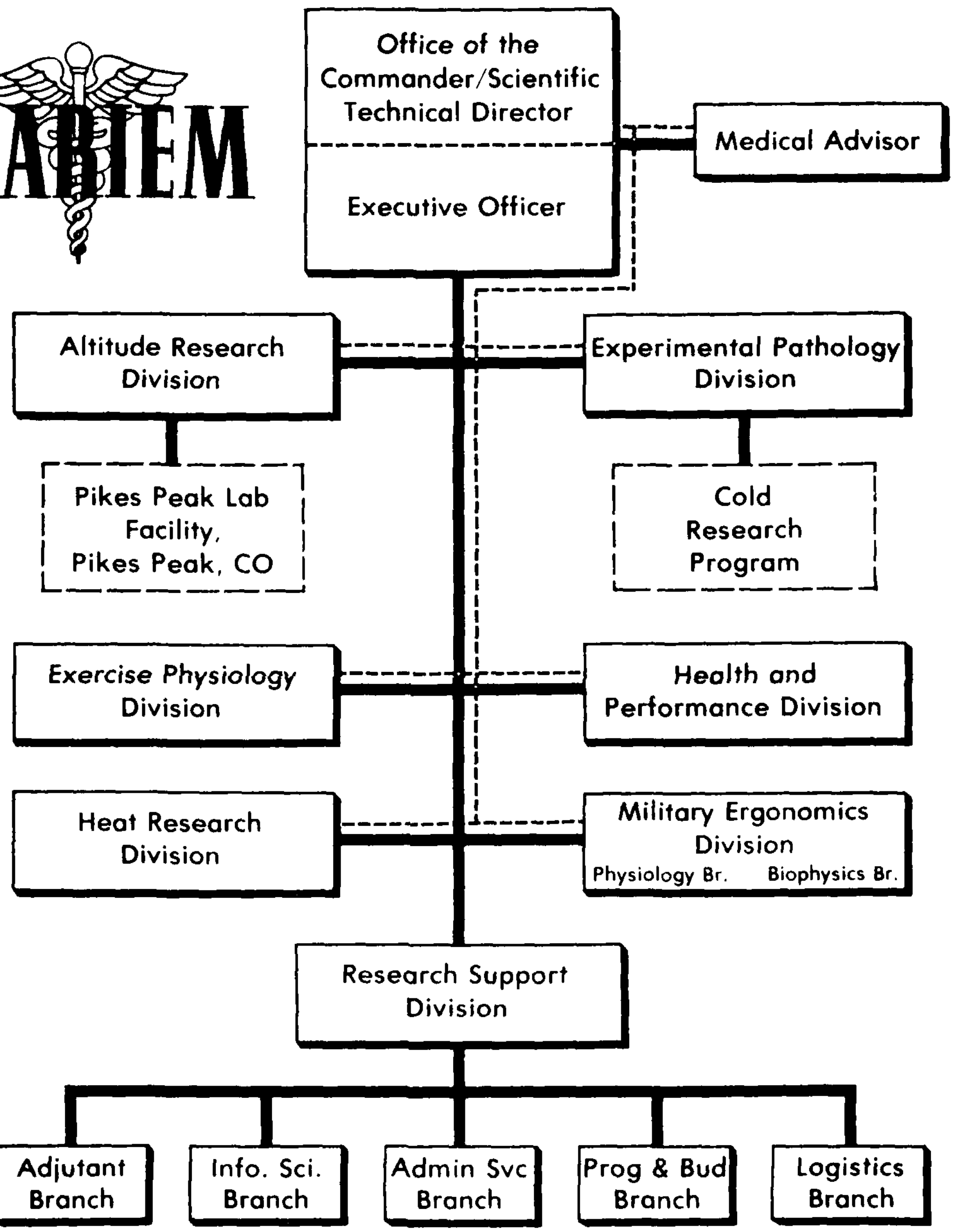
1. Fencl, V., R. A. Gabel and D. O. Wolfe. Role of cerebral fluids in respiratory adaptations to acute acid base imbalance. (In preparation).

2. Fencl, V., R. A. Gabel and D. L. Wolfe. Ionic composition of cerebral interstitial fluid in acute lactic acidosis and hypocapnia. (In preparation).

APPENDIX A

US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE
NATICK, MASSACHUSETTS 01760

USARIEM



APPROVAL: ______________________
HARRY G. DANGERFIELD, M. D.
Colonel, MC
Commanding

DATE: 6 June 1978

COMMAND ————
TECHNICAL - - - - - - -
COORDINATION

APPENDIX B

PUBLICATIONS

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APPENDIX C

ABSTRACTS AND PRESENTATIONS

Berberich, J. J. Impact of cold on the patient: dehydration. USARIEM/ONR Joint Working Group on Problems of Medical Evacuation in Cold Weather. Boston, MA, 31 October 1977.

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Philo, L. M., E. H. Follmann and H. V. Reynolds. Comparison of two techniques for surgical implantation of temperature-sensitive radio-transmitters in arctic grizzly bears (Ursus arctos). 29th Alaska Science Conference, Fairbanks, AK, 15-17 August 1978.

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Strauss, R. H., E. R. McFadden, R. H. Ingram and J. J. Jaeger. Effects of heat and humidity on exercise-induced asthma. American Physiological Society Fall Meeting, Hollywood, FL, 9-14 October 1977. The Physiologist 20:92, 1977.

Trusal, L. R. and C. J. Baker. Development of a suitable in vitro system to study freeze-thaw damage to endothelial cells in monolayer culture. Tissue Culture Association Annual Meeting, Denver, CO, 4-8 June 1978. In Vitro 14:378-379, 1978.

Vogel, J. A. and J. F. Patton. Evaluation of fitness in the US Army. NATO Symposium on Physical Fitness with Special Reference to Military Forces. Toronto, Canada, April 1978. NATO Report DS/DR (78)98:29, 1978.

Waggener, W., P. Brusil, R. Kronauer and R. Gabel. Strength and period of ventilatory oscillations in unacclimatized humans at high altitude. 28th Annual Fall Meeting of the American Physiological Society, Hollywood, FL, 9-14 October 1977. The Physiologist 20:98, 1977.

APPENDIX D

CONSULTATIONS

Requesting Individual/Agency	Subject	Month
AFEES Stations, New York and Chicago, IL	Design and modification of muscle strength apparatus	October
Guest Speaker, Fall Symposium of R&D Associates for Military Food and Packaging, USANARADCOM Natick, MA	Nutrition and physical fitness	October
MAJ Donald Price, Headquarters Company TECC, Twenty-nine Palms, CA	Overhydration	October
COL Lamax Roberts, British Liaison Medical Officer LTC John MacDougall, Canadian Liaison Medical Officer LTSG, Washington, DC	USARIEM research program	October
COL Fitzgerald, USMC, Deputy for Development, US Marine Corps, Quantico, VA	USARIEM research program	October
Community Health and Environmental Sciences Course, Academy of Health Sciences, Ft. Sam Houston, TX	Research in environmental stress	November
THE BOSTON GLOBE Boston, MA	Article on heat--"Ask the Globe" article	November
CPT David Hauler, USN, HQ Marine Corps Washington, DC	New development in Army physical fitness program	January
LT. L. Mainini, US Army Armor Center, Ft. Knox, KY	Remedial physical training	January
Ms. Carol Barbato, D.W.J. Association New York, NY	Wa_er requirements and human heat tolerance	January

Mr. M. Breakstone, Refrigiwear, Inc., Inglewood Long Island, NY	Guarded hot plate method	January
Dr. Andy Mossa, Los Angeles, CA	Cold weather information	January
Commander, MEDDAC, Health & Environment Activity Ft. Belvoir, VA	Manual dexterity in cold environment	January
Colonel J. D. Bartley MEDDAC, Health & Environment Activity, Ft. Benning, GA	Cold weather guidelines	January
Mr. Larry Penberthy, Mountain Safety Research, Inc., Seattle, WA	Consultation on treatment of acute mountain sickness in mountaineers	January
MAJ John Stacy, Enterprise, AL	Cold weather information	January
LTC Roberts US Army Admin. Center Ft. Benjamin Harrison, IN	Women in the Army (WITA) project in determining percentage of Army female population capable of performing work tasks in various MOS	January
Aerospace Medical Research Lab, Wright-Patterson AFB, OH	Extent of environmental physiology research effort ongoing at AMRL	January
Ms. Nancy Connor, Annandale, VA	Protein metabolism in environmental extremes	January
Mrs. Marcucelli, Medical Clinic, Wellesley College Wellesley, MA	Strenuous work guidelines for older individuals	January
CPT Garrett, Human Engineering Lab, Aberdeen Proving Ground, MD	Heat tolerance...Prediction for aircrewman dressed in 78^{o} and 85^{o}F, 30% RH (Environmental Control Unit in Copter)	February
Mr. Gary Kessler, Department of Epidemiology & Environmental Health, University of Vermont Burlington, VT	Computer simulation of hypoxia in man	February

MAJ Rakiewicz, Health & Environment, Ft. Belvoir, VA	Protection of personnel working in confined spaces at temperature around 100°C	February
CPT Mark S. Carroll, Commander Medical Company, USA MEDDAC Ft. Huachuca, AZ	Concepts of mountain evacuation	February
Mr. Henry M. Martens, Jr. Prudenville, MI	Windchill	February
F. R. Smith, M.D., Exxon Corporation, New York, NY	Prevention and treatment of altitude-induced disabilities	February
Mr. Kenneth Kopecky, Ames, IA	Windchill	February
MAJ R.Harasick, Academy of Health Sciences, Ft. Sam Houston, San Antonio, TX	Medical problems during mountain operations	February
Mr. William Prenski, Ft. Detrick, Frederick, MD	Characteristics of flexitherm auxiliary cooling layering system	February
Ft. Devens, MA	Cold weather	March
Ms. C. DuPre, Womens Equity Action League, Education & Legal Defense Fund, Washington, DC	Physical fitness capacity of women for sports	March
Mr. Jagdish Nazareth, Marketing Division, Indian Petrochemicals Corp., Ltd., Gujarat, India	Cold weather research	March
Mr. N. Perkins, President Safariland Ballistics, Inc. Monrovia, CA	Body armor	March
Dr. George Smith, F.A.A., Civil Aeronautics Washington, DC	Acceptability of an abstract for presentation at the Aeromedical Meetings. Discussed various aspects of the biomedical bases of performance	March

Ms. Jackie Goldenberg, Woman's Day, New York, NY	Comfort and heat transfer in the heat	March
LTC George Lindroth, Ft. Leavenworth, KS	Performance problems of soldiers and equipment at high terrestrial elevations	March
Mr. J. Dawson & Associates Training Development Directorate USA Infantry School, Ft. Benning, GA	MOS Clustering Selection of representative (limiting) physical tasks for the clusters	March
AFEES Stations, New York and Chicago, IL	Design and modification of muscle strength apparatus	March
Mr. Swatzchild, US Justice Department, Washington, DC	Physical fitness capabilities of women	March
LT Jim Hodgdon, Naval Health Research Center, San Diego, CA	On-line measurement of oxygen consumption using the Pneumonscan to determine ventilation	April
MSG Victor Stanley, Huntsville, AL	Heat injury	April
AFEES Stations, New York and Chicago, IL	Design and modification of muscle strength apparatus	April
Abraham Alfaro, Department of Health Sciences, Sargent College of Allied Health, Boston, MA	Discussion and demonstration of on-line oxygen consumption methodology	April
Mr. Peter Judd, National Enquirer, Wash, DC	Heat illness	April
CPT Carver Wilcox, MC CPT Frank Churchill, MC CPT Henry Scagliola, MC CPT Philip Lewis MC WRAIR, Washington, DC	Medical problems at high altitude	May
William R. Clark Army Health Planning, Health Facility, HQDA-SG FPDD Washington, DC	Air conditioning requirements for lightly clad hospital patients in environments of 80-84°F, 60% RH and winds to 15 mph	May

COL J. D. Bartley, Health & Environment Activities Medical Department Activity, Ft. Benning, GA	Human studies for determining safe exposure times for river/swamp crossings	May
US Army Infantry School Ft. Benning, GA	Army physical fitness program	May
MAJ Michael R. Janay, USMC Liaison Officer at DARCOM and LTC J. C. Berezowski, USMC, Canadian Liaison Marine Corps Officer at HQ, DARCOM, Alexandria, VA	USARIEM research program	May
CPT R. Rounds, Telecom Systems Staff Office School, 3395th Tech Training Squadron, Keesler AFB, Beloxie, MS	Cold weather operations and protection of individual soldier	May
COL Cadigan, Biomed Research Lab Edgewood Arsenal, Aberdeen Proving Ground, MD	How long an inactive man in an M3 suit could remain in room at 76°F without rectal temperature exceeding 100°F	May
Robert F. Grover, M.D., Ph.D. Director, Cardiovascular Pulmonary Research Laboratory, University of Colorado Medical Center, Denver, CO	Measurement of environmental symptoms	May
USANARADCOM, Natick, MA	US Marine nutrition/alchohol/ drug abuse program	May
USAF 6570th Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH	Review of contract report on fitness test battery	June
Dr. Dyer, Army Research Institute, Ft. Benning, GA	Physical fitness study proposals	June
Mr. Farley, DCASMR, Defense Logistics, Boston, MA	Designing testing procedures at elevated environmental temperatures	June

LTC D. Bittle, Air Force Civil Engineering Center, Kendall AFB, FL	Work-rest cycles for performance of various tasks by Air Force personnel in toxic environments	June
LTC Casey, Combat Development Agency, Academy of Health Sciences, Ft. Sam Houston, San Antonio, TX	Heat stress problems for tank crewmen	June
Framingham Union Hospital, Framingham, MA	Exertion induced heatstroke	June
MAJ Ron Porta, USAAUS, Ft. Rucker, AL	Heat illness	June
TRADOC Combined Arms Test Activity (TCATA), Fort Hood, TX	Interaction of heat stress and fatigue during a planned 96 h field test of a Field Artillery battalion organized according to the Division Restructuring Study.	June
Charles E. Brodine, M.D., Assistant Medical Director for Environmental Health & Preventive Medicine, Office of Medical Services, Department of State, Washington, DC	Assignment restrictions for high altitude posts	July
Ms. Barbara Moffitt, National Georgraphic News Service Washington, DC	Heat illness	July
TCATA, 1st Cavalry Division Artillery, and 1-77th FA Battalion, Fort Hood, TX	Prevention of heat casualties during the 96 h artillery field test at Fort Hood, 23-29 July	July
Jerome A. Dempsey, Ph.D., Department of Preventive Medicine, University of Wisconsin, Madison, WI	Cannulation of cisternum magnum in goats	July
1LT Alan L. Moloff, MSC, Medical Operations Officer, HQ, 7th Special Forces Group (Airborne) 1st Special Forces, Ft. Bragg, NC	Medical problems at high altitude	July
Congressman Berkley Bidell, Sioux City, IA	Request for information on wind chill and man working in cold air	July

Dr. Oliver, MacDill AFB, Tampa, FL	C-4, and Army plastic explosive	July
Mr. Charles Barb, WESTVACO, Luke, MD	Heat illness	September
COL Robert Holmes, M.D., Ft. Myer, VA	Jogging with T-shirts in the heat	September
Dr. Harry Frankel, Dept. of Physiology, Rutgers University, New Brunswick, NJ	Research projects in environmental physiology of mutual interest	September
Dr. Sidney Solomon, Professor and Chairman, Physiology Department University of New Mexico School of Medicine, Alburquerque, NM	Environmental physiology research of mutual interest	September

APPENDIX E
BRIEFINGS

Hamlet, M. P. Cold weather training, Ft. Carson, CO, 10-13 Oct 1977.

Hamlet, M. P. Medical evacuation in cold weather, USARIEM/Office of Naval Research Joint Working Group, Boston, MA, 31 Oct-3 Nov 1977.

Hamlet, M. P. Briefing on physiological effects of cold weather on troop performance and impact of those effects on planning and operations. HQ Fleet Marines Atlantic, Norfolk, VA, 17 November 1977.

Hamlet, M. P. Presented cold weather preventive medicine briefings to units scheduled to participate in Empire Glacier & Arctic Express, Camp LeJeune, NC, 1-2 Dec 1977.

Hamlet, M. P. Conducted cold weather classes for HQ 194th Armored Bde., Ft. Knox, KY, 18-20 Dec 1977.

Hamlet, M. P. Briefed National Science Foundation personnel on Antarctica trip, Washington, DC, 8 March 1978.

Vogel, J. A. In-Process Review of MOS fitness requirement project, HQ, Training & Doctrine Command, Ft. Monroe, VA, 28 February 1978.

Vogel, J. A. USARIEM's AFEES Project, Army DCSPER, HQDA, Washington, DC, 20 April 1978.

APPENDIX F

LECTURES

Berberich, J. J. Effect of dehydration on hand cooling in man. Brandeis University, Waltham, 7 November 1977.

Berberich, J. J. Frostbite & hypothermia prevention and treatment. Ada Agricultural Junior College, Danvers, MA, 11 January 1978.

Berberich, J. J. Frostbite & hypothermia prevention and treatment. Needham High School Adult Education Program, Winter Sports Program, Needham, MA, 28 January 1978.

Berberich, J. J. Cold weather immersion hypothermia. Outward Bound School, Maine at Boston University Care Center, Boston, MA, 29 January 1978.

Burse, R. L. Renal physiology. Boston University School of Allied Health Professions, Boston, MA, November-December 1977.

Burse, R. L. Thermoregulatory physiology. Boston University School of Allied Health Professions, Boston, MA, February 1978.

Dangerfield, H. G. Course in Environmental Medicine for WRAIR Preventive Medicine Residents, Natick, MA, 16-17 May 1978.

Dangerfield, H. G. Research in environmental stress - community health and environmental sciences course. Academy of Health Sciences, Fort Sam Houston, TX, 19 May 1978.

Goldman, R. F. Clothing and comfort. M.I.T., Cambridge, MA, 21 March 1978.

Goldman, R. F. Clothing comfort. DuPont, Wilmington, DE, 23 March 1978.

Goldman, R. F. Physical fitness, anthropometry. Sargent College, Boston University, Boston, MA, 6, 11, 18 April 1978.

Goldman, R. F. Metabolism and energetics. University of Massachusetts, Worcester, MA, 1 December 1977.

Goldman, R. F. Assessment of body composition. Workshop on Nutrition, Boston University School of Nursing, Boston, MA, July 1978.

Goldman, R. F. Tropical Medicine Course. Walter Reed Army Institute of Research, Walter Reed Army Medical Center, Washington, DC, 23 August 1978.

Goldman, R. F. Military ergonomics; definition of the environment, physical work, load carriage, clothing. Uniformed Services University School of Medicine, Washington, DC, 1, 2, 8, 9 May 1978.

Hamlet, M. P. Cold injury (hypothermia & frostbite). University Health Services, University of Vermont, Burlington, VT, 3 November 1977.

Hamlet, M. P. Cold weather preventive medicine. University of Canterbury; National Science Foundation Personnel VXE6 (Navy flight organization); Scott Base (New Zealand base), McMurdo, Antarctica, 14 January-7 February 1978.

Hamlet, M. P. Cold weather preventive medicine. New England College, Henniker, NH, 22 February 1978.

Hamlet, M. P. Cold weather preventive medicine. Dartmouth Medical Center, Hanover, NH, 3 March 1978.

Hamlet, M. P. Cold weather preventive medicine. Nordic Ski Patrol, Northfield, MA, 12 March 1978.

Hamlet, M. P. Cold weather preventive medicine. Cold Weather and Isolated Medicine Conference, NRMC, San Diego, CA, 10 August 1978.

Hamlet, M. P. Hypothermia and winter cold problems. Committee on Wilderness Medicine and First Aid of the Boston Chapter of the Appalachian Mountain Club, Boston, MA, 13 September 1978.

Horstman, D. and R. W. Hubbard. Exertion induced heatstroke. Grand Rounds, Framingham Union Hospital, Framingham, MA, 20 June 1978.

Mager, M. and D. Horstman. Heat disorders and first aid measures to treat these in the field. Committee on Wilderness Medicine and First Aid of the Boston Chapter of the Appalachian Mountain Club, Boston, MA, 21 September 1978.

Hubbard, R. W. Experimental model of human heatstroke. Brown University, Providence, RI, 15 November 1977.

Hubbard, R. W. Medical problems in the heat. Course in Environmental Medicine for WRAIR Preventive Medicine Residents, USARIEM, Natick, MA, 16-17 May 1978.

Mager, M. Medical problems in the heat. Course in Environmental Medicine for WRAIR Preventive Medicine Residents, USARIEM, Natick, MA, 16-17 May 1978.

Maher, J. T. Medical problems of high altitude. Course in Environmental Medicine for WRAIR Preventive Medicine Residents, Natick, MA, 16-17 May 1978.

Pandolf, K. B. The influence of hot environments on human performance of muscular exercise. York University, Toronto, Canada, 5 April 1978.

Pandolf, K. B. Influence of environmental factors on human performance of muscular work. University of Louisville, Louisville, KY, 20 April 1978.

Vogel, J. A. Physical fitness. Worcester State College, Worcester, MA, 9 May 1978.

APPENDIX G

SEMINAR PROGRAM

DATE	LECTURER	SUBJECT
5 October 1977	Helmut Weicker, M.D. Director, Division of Metabolism & Sports University of Heidelberg Heidelberg, Germany	Incidence of Motor Activity on Metabolic Regulation & Body Performance Medicine in Diabetes Mellitus
3 November 1977	Samuel Fox, III, M.D. Georgetown University School of Medicine Washington, DC	Place of Exercise Testing in Evaluating a So-Called Healthy Population
15 November 1977	Dr. Kurt Jorgensen August Krogh Institute University of Copenhagen	Physiological Problems in Lifting
12 December 1977	Dr. Adrian Williams Children's Hospital Boston, MA	Pathology Aspects of "Sudden Infant Death" Syndrome
13 January 1978	Ronald A. Gabel, M.D. Department of Anesthesia Peter Bent Brigham Hospital Boston, MA	Epidemiological & Experi- mental Evidence of Toxicity of Anesthetic Agents
2 February 1978	Division Staff USARIEM Natick, MA	Assessing the Effects of Sustained Operations Stress on Field Artillery FDC Teams
23 February 1978	Major Robert E. Richley William Beaumont Army Medical Center El Paso, TX	Work Efficiency Calcula- tions Using Oxygen Consumption at Rest & During Steady-State Exercise
24 February 1978	Division Staff USARIEM Natick, MA	Military Ergonomics Research Program

8 March 1978	Regius McFadden, M.D. Pulmonary Disease Division Peter Bent Brigham Hospital Boston, MA	Role of Air Temperature & Water Content in Exercise-Induced Asthma
9 March 1978	David E. Leith, M.D. Associate Professor Harvard School of Public Health Physiology Department Boston, MA	Ventilatory Muscle Training, Loaded Breathing, and the Control of Respiration
22 March 1978	Peter Raven, Ph.D. Associate Professor Department of Physiology North Texas State University Health Sciences Center Denton, TX	Physiology Effects of Combined Stressors: Heat, Exercise, & Air Pollutants
31 March 1978	Andrew Szent-Gyorgyi, M.D. Chairman, Department of Biology Brandeis University Waltham, MA	Biophysics of Muscle Function
6 April 1978	Vladimir Fencl, M.D. Department of Anesthesia Peter Bent Brigham Hospital Boston, MA	Selected Topics in Control of Breathing
18 April 1978	Jack H. Wilmore, Ph.D. Professor and Chairman Department of Physical Education & Athletics University of Arizona Tucson, AZ	Physiological Basis of Maximal Performance in Females: Strength, Endurance and Body Composition
26 April 1978	Division Staff USARIEM Natick, MA	Alitude Research Program
11 May 1978	LTC George S. M. Cowan, Jr. Chief, Clinical Investigation Service Dwight David Eisenhower Army Medical Center Ft. Gordon, GA	Anemia in Basic Combat Trainees

1 June 1978	Division Staff USARIEM Natick, MA	Cold Research Program
15 June 1978	Division Staff USARIEM Natick, MA	Exercise Physiology Research Program
19 June 1978	Martin T. Orne, M.D., Ph.D. Professor and Head Experimental Psychiatry The Pennsylvania Hospital Philadelphia, PA	The Nature of Hypnosis
7 September 1978	William McCabe, M.D. Professor of Medicine & Microbiology Boston University Boston, MA	Cross Reactive Antigens of Enterobacteriacea: Their Potential for Induction of Protection
21 September 1978	Division Staff USARIEM Natick, MA	Experimental Pathology Research Program

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