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US ARMY MEDICAL RESEARCH AND DEVELOPMENT ANNUAL PROGRESS REPORT--ETC(U)
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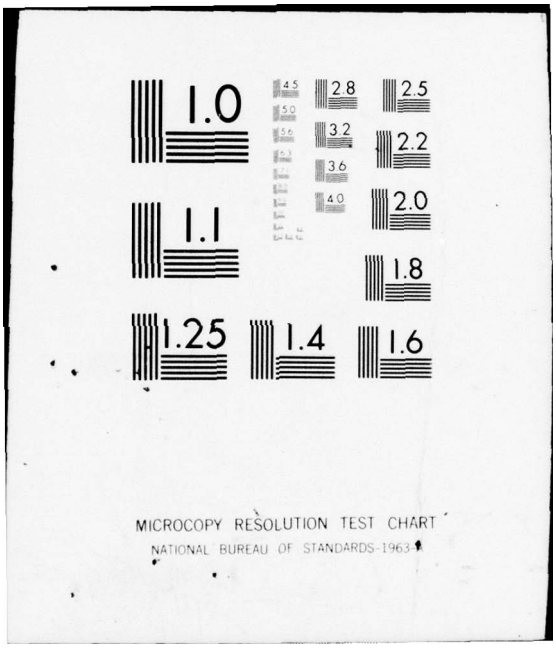
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RCS MEDDH-288 (R1)

ANNUAL PROGRESS REPORT
FISCAL YEARS 1976 and 7T
(1 July 1975 - 30 September 1976)

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

1 October 1976

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UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

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Acid-Base Status	Behavior	Cardiovascular
Activity-Rest Cycles	Biochemistry	Casualty Treatment
Altitude	Biophysics	Central Nervous System
Altitude Physiology	Blood Flow	CIVD (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 Years 1976 and 7T 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	3A161102B71R	05	Research in Biomedical Sciences - Environmental Medicine
6.27.58.A	3A762758A827	00	Military Environmental Medicine

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Cold Stress
Combat Effectiveness
Continuous Operations
Cryobiology
Disabilities
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Environmental Extremes
Environmental Medicine
Environmental Stress
Environmental Tolerance
Exercise Physiology
Facilitation of Work
Fatigue
Fatigue, Mental
Frostbite
Gas Exchange
Heat
Heat Disabilities
Heat Production
Heat Stress
Heatstroke
Heat Tolerance
Hepatic Ultra-structure
Human Subjects
Human Volunteers
Hypoxia
Liver Function at High Temperature
Metabolic Regulation
Metabolism
Microcirculation
Military Clothing
Military Disabilities
Military Doctrine
Military Heat Stress
Military Operations
Military Performance
Military Tactics
Military Tasks
Motivation
Muscle
Nonsedentary Analgesic
Pathology Model
Performance
Performance Decrement
Performance Limits
Perfused Liver
Peripheral Blood Flow
Pharmacology
Physical Exercise
Physical Fitness
Physiology
Protection
Psychomotor & Cognitive Abilities
Psychomotor Skills
Pulmonary Function
Regulation of Respiration
Sensory Processes
Simulation
Thermoregulation
Thyroid Function
Tolerance
Tolerance Prediction
Wind
Work
Work Stress

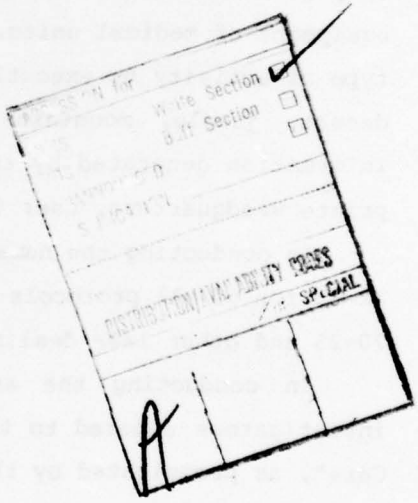
US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

NATICK, MASSACHUSETTS

ANNUAL PROGRESS REPORT

FISCAL YEARS 1976 and 7T

(1 July 1975 - 30 September 1976)



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FOREWORD

The research and progress reported herein were authorized and supported under the following DA Technical Projects: In-House Laboratory Independent Research (3A161101A91C); Research in Biomedical Sciences (3A161102B71R-05); and Military Environmental Medicine (3A762758A827). This report represents a statement of progress conducted in FY 76 and FY 7T.

During the last year members of USARIEM have taken on an additional challenge utilizing their expertise in military medical problems of harsh environments: studies of operational requirements produced by the operation of medical units serving in cold weather areas were initiated. The results were incorporated into a technical report which brought to light many potential shortcomings in force structure, doctrine, training, and equipment of medical units. It is the intent of USARIEM to continue this type of activity by executing similar operational research studies in the desert, jungle, mountains, high altitude and old environments. The information generated by these studies will be transferred to the appropriate Headquarters, user units, and combat developers of the Army.

In conducting the human studies reported herein, review, approval and execution of all protocols was obtained in consonance with Army Regulation 70-25 and other laws dealing with human experimentation.

In conducting the animal studies described in this report, the investigators adhered to the "Guide for Laboratory Animal Facilities and Care", as promulgated by the Committee on the Guide for Laboratory Animal Resources, NAS/NRC. The facilities are fully accredited by the American Association of Accreditation of Laboratory Animal Care.

HARRY G. DANGERFIELD, M.D.
Colonel, MC
Commander

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IN-HOUSE LABORATORY INDEPENDENT RESEARCH

PROJECT: 3A161101A91C

In-House Laboratory Independent Research

(81020)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
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76 08 20	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	020
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*

(U) An Analgesic for Use in Cold Environments (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 012900 Physiology; 016200 Stress Physiology; 0126 Pharmacology 003500 Clinical medicine; 005900 Environmental biology

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: Not Applicable EXPIRATION:

b. NUMBER:*

c. TYPE: d. AMOUNT:

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

18. RESOURCES ESTIMATE	a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
PRECEDING FISCAL YEAR 76(7T)	.1 (.1)	1 (3)
CURRENT FISCAL YEAR 77	1.7	22

19. RESPONSIBLE DOD ORGANIZATION

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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) Nonsedentary analgesic; (U) Cold Injury; (U) Casualty Treatment

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

23. (U)Morphine is the standard systemically-administered analgesic employed by the military in the treatment of battle casualties. One of the side effects of therapeutic doses of morphine is the lowering of body temperature. At low ambient temperatures, this effect of morphine deserves special consideration since it predisposes the casualty to the additional risk of cold injury. The administration of a combination of morphine and d-amphetamine has already been shown to be effective in eliminating the sedating and depressing effects of morphine while enhancing the level of analgesia. There is good reason to suppose that this drug combination will also negate the effect of morphine on body temperature, and thus reduce apprehension concerning its use in cold environments. To document the value of this drug combination, experiments on mice are needed to determine the effects of morphine plus amphetamine on rectal temperature, oxygen consumption, and activity.

24. (U)Groups of mice will be given the combination listed above and core temperature, oxygen consumption and level of activity will be recorded. Preliminary data gathering of this study will commence this quarter.

25. (U)76-04 76 10 Work on this project has consisted of a literature search to determine the proper animal model for this study. Resources utilized during FY 7T: Professional Man Years .1; Funds $3 (in thous).

*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:	020 An Analgesic for Use in Cold Environments
Study Title:	Rectal Temperatures of Mice as Affected by Morphine, d-amphetamine and their Combination
Investigator:	James Jaeger, CPT, MSC

Background:

In a cold environment, the depressant effect of morphine on body temperature reduces its appropriateness as an analgesic. This study is designed to determine if the administration of a combination of morphine and d-amphetamine will overcome the hypothermic effect observed following the administration of morphine alone.

Progress:

Work on this project has consisted of a literature search to determine the proper animal model for this study. To date, both the mouse and the rat have been rejected because their body temperature responses to low doses of morphine and/or d-amphetamine are not similar to that of humans.

Recommendations:

Continue the literature survey until a suitable animal model is found.

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6134	76 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. DISP'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 04 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	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;010100Microbiology

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: Not Applicable EXPIRATION:
b. NUMBER:*
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 76(7T)	.7 (.1)	30 (10)
FISCAL YEAR CURRENT 77	5.4	89

19. RESPONSIBLE DOD ORGANIZATION

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TELEPHONE: 955-2862
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ASSOCIATE INVESTIGATORS

NAME:
NAME:

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U) heatstroke; (U) perfused liver; (U) hepatic ultrastructure; (U) liver function at high temperature

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) 76-04 - 76-09 The surgical skills and perfusion apparatus have evolved to the extent that acceptable parameters can be obtained from livers perfused at normal temperatures. Current experiments involve accumulating control data on bile production, potassium release, release of GPT, glucose metabolism, and light and electron microscopic changes for comparison with that to be obtained at elevated temperatures. Resources utilized during FY 7T: Professional Man Years .1; Funds $10 (in thous).

*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:	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.; John T. Maher, Ph.D. and Milton Mager, Ph.D.

Background:

Pathological changes in the liver are among the most consistent findings in humans subsequent to heat overload. Centrilobular necrosis and hydropic swelling have been described in cases of heatstroke induced in cross country runners and individuals working in hot environments. Work in this laboratory with Hubbard's rat model for heatstroke in humans has demonstrated similar liver lesions after exposure to heat or to exhaustive exercise at or near room temperature. Although liver damage has frequently been observed subsequent to heatstroke, neither the mechanisms nor consequences have been established.

Rowell's demonstration that hepatic venous blood may reach 41.7°C (107°F) with a simultaneous rectal temperature of 40.2°C in normal men exercising in a hot environment suggests that metabolic oxidations in the liver may contribute to the heat load. It has also been suggested that a toxic substance, circulating in the blood as a result of exposure to elevated temperatures, may be more critical in the absence of normal liver function.

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The complexity of in vivo studies makes it difficult to assess the role of specific organs in the processes which result from heatstroke. The isolated liver perfusion system provides an approach which is readily adaptable to heat research and which may prove to be the system best suited to assess the role of individual parameters believed to participate in heat injury. Critical temperatures for cell injury can be established using light and electron microscopy, bile production, potassium release, dye clearance, release of GPT, glucose metabolism and oxygen consumption. The effects of the perfusate, heated to known temperatures, containing cellular fluids from heated animals or containing precise amounts of chemically pure substances, thought to play a role in heatstroke, can be ascertained.

Progress:

Adapting the isolated perfused rat liver system to heatstroke required several modifications most of which are based on the critical evaluation of the organ and a requirement for strict temperature control. The surgical skills and perfusion apparatus have evolved to the extent that acceptable parameters are obtained from livers perfused at normal temperatures. Current experiments involve accumulating control data to be compared with that obtained at elevated temperatures. Data on bile production, potassium release, release of GPT, glucose metabolism, light and electron microscopic changes are being collected.

(81022)

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. DISP'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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 — NOT APPLICABLE

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:*

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 76 (7T)	2 (.1)	53 (10)
FISCAL YEAR — CURRENT 77	3.6	45

19. RESPONSIBLE DOD ORGANIZATION

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NAME:* Maher, John T., Ph.D.

TELEPHONE: 955-2851

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME:

NAME:

21. GENERAL USE

Foreign Intelligence Not Considered

DA

22. KEYWORDS (Precede EACH with Security Classification Code)

(U) Altitude Physiology (U) Regulation of Respiration (U) Acid-Base Status (U) CSF

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. Additional studies to determine the relationship between the ventilatory controller and effector, as exemplified by influences of increased inspiratory flow resistance on the ventilatory response of man to hypoxia or hypercapnia, are included.

25. (U) 75-07 -76-09 Our studies have shown that the intracranical cerebrospinal fluid of man becomes alkaline during five days at 4.267m. Methods have been developed in this laboratory for indirect measurement of the ionic composition of cerebral interstitial fluid of goats during acclimatization to high altitude. Studies have been initiated to measure changes in the ventilation and cerebral blood flow of man during hypoxemia, seeking evidence for a medullary chemoreceptor contribution to ventilation during brief exposures to hypoxia. Resources utilized during FY 7T: Professional Man Years .1; Funds (in thous) $10.

*Available to contractors upon originator's approval.

* U.S. GPO: 1974-540-843/8691

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: Alterations in pH and Bicarbonate Concentration of the Lumbar and Intracranial Cerebrospinal Fluid of Man After Five Days at High Altitude

Investigators: Richard B. Weiskopf, MAJ, MC; Ronald A. Gabel, M.D. and Vladimir Fencl, M.D.

Background:

Dempsey and Forster at the University of Wisconsin in recent years have presented evidence that there is a rise in pH of the cerebrospinal fluid of man during acclimatization to high altitude and that during altitude acclimatization the concentration of bicarbonate in cerebrospinal fluid falls only to the extent that plasma bicarbonate is reduced through renal excretion. These findings directly challenged the reasonable but unproved explanation for ventilatory acclimatization to high altitude which has been accepted by most physiologists. The acclimatization process was thought to begin with hypoxic stimulation of the peripheral chemoreceptors, which produces respiratory alkalosis when a person arrives at high altitude. Through free diffusion of carbon dioxide across the blood-brain barrier, pH of cerebral fluids is elevated. This was thought to initiate the active transport of bicarbonate from cerebrospinal fluid, which eventually reduces pH of the cerebrospinal fluid to normal sea level values. The respiratory depressant effects of early cerebral alkalosis are thereby counteracted, permitting unattenuated manifestation of the peripheral

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hypoxic drive to ventilation. Ventilatory acclimatization to high altitude, therefore, was considered to be the result of a decrease in pH of the cerebral fluids. Dempsey and Forster reasoned that the persistently alkalotic cerebrospinal fluid pH which they observed should be sufficiently depressant to ventilation that some stimulus to ventilation other than reduction of cerebral pH would have to be responsible for ventilatory acclimatization to high altitude. Before progressing further in our pursuit of details concerning the acclimatization process, it became crucial for us to confirm or refute the data of Dempsey and Forster.

Progress:

In six healthy young male volunteers, we anaerobically sampled lumbar cerebrospinal fluid and blood from an artery and from the jugular bulb at sea level and after five days in a chamber at barometric pressure 447 torr. We calculated pH of intracranial cerebrospinal fluid by using the bicarbonate concentration of lumbar cerebrospinal fluid along with an estimation of cerebral tissue P_{CO_2} (one torr greater than the arithmetic mean of arterial and internal jugular P_{CO_2}, as reported by Ponten and Siesjo). Both the directly-measured lumbar cerebrospinal fluid pH and the estimated intracranial cerebrospinal fluid pH were more alkaline after five days at high altitude than at sea level:

	Sea Level	High Altitude
Lumbar CSF	7.297 ± 0.005	7.327 ± 0.007
Intracranial CSF	7.318 ± 0.008	7.382 ± 0.014

Differences in the above mean values (± standard error) between sea level and high altitude are statistically significant at $P<0.01$. A further finding was that, during acclimatization, the reduction in bicarbonate concentration of lumbar cerebrospinal fluid was no greater than the reduction in bicarbonate concentration of blood plasma:

(mM/L)	Sea Level	High Altitude	Difference
Lumbar CSF	22.7 ± 0.4	17.7 ± 0.5	5.0
Arterial Blood	24.8 ± 0.4	19.3 ± 0.4	5.5
Jugular Venous Blood	26.8 ± 0.3	21.3 ± 0.6	5.5

Conclusions:

Our data, confirming and extending the findings of Dempsey and Forster, are not consistent with the widely-accepted concept that pH of the cerebrospinal fluid is returned to normal by active transport of bicarbonate during acclimatization to high altitude. Therefore, we must either seek a stimulus other than the hydrogen ion to explain the process of ventilatory acclimatization to high altitude or seek evidence that acid-base changes in the cerebrospinal fluid during acclimatization are not representative of those occurring at the intracranial chemo-receptors.

Future Plans:

We are developing an animal model with which to compare the ionic composition of the cerebral interstitial fluid with that of the intracranial cerebrospinal fluid during acclimatization to high altitude. This will permit us to evlauate changes in bicarbonate concentration at an intracranial site closer to the hydrogen-ion chemoreceptors, which probably constitute an important element in adaptation of the ventilatory control system during sojourn at high altitude.

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6125	76 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. DISP'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	6.11.01.A	3A161101A91C	00	023
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*

(U) Aminoacids, Monoamines and Temperature Regulation (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012600 Pharmacology; 002300 Biochemistry; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
73 07		DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: Not Applicable EXPIRATION:
b. NUMBER:*
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	76(7T)	.2 (0)	13 (0)
FISCAL YEAR CURRENT			

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL
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TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* Francesconi, Ralph P. Dr.
TELEPHONE: 955-2877
SOCIAL SECURITY ACCOUNT NUMBER:

21. GENERAL USE

Foreign Intelligence Not Considered

ASSOCIATE INVESTIGATORS
NAME: Mager, Milton Dr.
NAME: 955-2871 DA

22. KEYWORDS (Precede EACH with Security Classification Code)

(U) Thermoregulation; (U) Body Temperature; (U) Environmental Extremes; (U) Drugs; (U) Central Nervous System

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

23. (U)The current experiments are designed to clarify the thermoregulatory role of hypothalamic monoamines in order to understand more fully the biochemical and physiological mechanisms involved in the response of higher animals and man to environmental extremes. It is hoped that such increased understanding may ultimately be useful in pharmacological intervention for treatment of debilitating effects caused by exposure of man to adverse climatic conditions.

24. (U)The combination of specific environmental conditions along with the central administration of certain drugs, amino acids, monoamines, and inhibitory compounds can effect thermoregulatory responses in small animals. These responses will be interpreted to deduce the biochemical and physiological mechanisms affecting temperature set-point in higher animals. The major focus will be on direct central nervous system injection in rats by stereotaxic means with particular emphasis on the role of hypothalamic monoamines.

25. (U)75-07 - 76-09 By pharmacologically altering central monoamine levels, we have obtained data leading to important conclusions on the role of hypothalamic monoamines in thermoregulation. Thus, endogenous concentrations of monoamines are not as important in establishing a temperature set-point as an active fraction released at synaptic terminals. Thermogenic properties of both serotonin and norepinephrine were demonstrated by utilizing antagonists of both compounds. A serotonin antagonist, cyproheptadine, attenuated the hyperthermia induced by serotonin activators adding support to a thermogenic, rather than thermosuppressive, role for serotonin. In addition, oxygen consumption (O_2) studies have separated the central and peripheral effects of pharmacological intervention and formulated a rationale for more applied studies. This work unit has been terminated. No resources utilized during FY 7T.

*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:	023 Amino Acids, Monoamines, and Temperature Regulation
Study Title:	Pharmacological Intervention: Effects on Temperature Regulation Under Moderate Ambient Conditions
Investigators:	Ralph Francesconi, Ph.D. and Milton Mager, Ph.D.

Background:

The impetus for this work came from our observation that intraperitoneal administration of the amino acids tryptophan and tyrosine effected significant hypothermia in rats when the rats were maintained at ambient temperatures much below thermoneutral (4°C). In investigating the mechanism of these thermoregulatory responses, we found markedly reduced oxygen consumptions concomitant with significant increments of serotonin and norepinephrine in the hypothalamic area of the brain, a center which for several years had been recognized as a thermoregulatory effector in higher animals. Since tryptophan and tyrosine are precursors to serotonin and norepinephrine, respectively, and since the latter two monoamines had been closely implicated in temperature regulation, we felt that further research in the pharmacological control of hypothermic and hyperthermic responses was warranted. We particularly reasoned that information obtained by experiments of a rather fundamental nature in higher animals might ultimately lead to newer and more effective means of reversing either hyperthermic or hypothermic responses induced in humans by adverse environmental factors, exercise, or both.

For example, by utilizing small animals such as the laboratory rat experiments can be designed to differentiate central processes from peripheral in achieving adaptive responses to hot or cold ambient

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conditions. Although many descriptive reports have appeared ascribing thermoregulatory alterations in higher animals to a myriad of substances, relatively few have investigated either the mechanisms of response or the importance of central factors (temperature set-point, hypothalamic biochemistry, physiological role of the monoamines, pyrogens, ions, glucose, prostaglandins) and the relationship of these central phenomena to peripheral responses (thermogenesis in liver and muscles, sweating, vasoconstriction, vasodilation, hyperventilation). Because of their economy, ease of handling, analogies to human thermoregulatory responses, the number of animals required to verify thermal responses and the recent development of an adequate heat stroke model, the laboratory rat has been the experimental animal of choice in these studies.

Approach: For central thermoregulatory studies, rats were fitted with chronically implanted cannulae for lateroventricular injection. Peripheral effects were monitored after intraperitoneal injection of appropriate substances; rectal temperatures were sampled utilizing thermistors and tail skin temperature, where appropriate, by copper-constantan thermocouples. Rats were always handled frequently and allowed sufficient time after surgical procedures and experiments to offset any untoward thermoregulatory affects of the procedures. Oxygen consumption was monitored in expired gases to determine metabolic rates. Equipment and solutions for injection were carefully prepared to preclude non-specific pyrogenic effects.

Progress:

Although we had shown that intraperitoneal injection of salicylate, tryptophan or tyrosine had induced significant hypothermia in rats when they were maintained under cold ambient conditions, a combination of the three compounds was ineffective in eliciting an hypothermic response when

administered centrally. This was true despite the fact that both routes of administration had been successful in altering the concentrations of hypothalamic norepinephrine and serotonin. Similarly, when hypothalamic concentrations of these monoamines were decremented by intraperitoneal administration of depleting agents and reduced concentrations were confirmed by biochemical analysis of the hypothalamic area, we demonstrated that synergizers and potentiators were equally effective in inducing thermoregulatory responses even in these depleted animals.

By using various doses of monoamines and monoamine synergizers, we were able to show that the heretofore reported hypothermic responses were rapidly superseded by a more persistent hyperthermia. We hypothesized that both serotonin and norepinephrine can act as thermogenic substances in higher animals, and we added further evidence to this hypothesis with the following experiments. When rats were pretreated with the anti-serotonin compound called cyproheptadine and then injected intracerebroventricularly with the serotonin synergizer chlorimipramine, there occurred an attenuation of the normal hyperthermic response elicited by chlorimipramine alone. It is significant to note that past research had labelled serotonin as a thermodepressive compound in rats largely because of a rapid hypothermic response effected by high concentrations centrally administered. Our evidence indicated that this hypothermia was actually a pharmacological effect which was, in turn, superseded by a more physiological and persistent hyperthermia.

We further found that hyperthermia induced by these monoamines is probably due to conservation of heat loss mechanism because close examination of oxygen consumption data indicated no increases concomitant with increased rectal temperatures. If endogenous fuels are not being oxidized at a more rapid rate (as evidenced in increased O_2 consumption), then it is likely that conservation of heat loss (e.g. vasoconstriction) is responsible for the increased temperature.

Conclusions:

In the broad area of temperature regulation in high animals, a number of important conclusions can be drawn from these studies. Initially, since tryptophan, tyrosine, and salicylate, had virtually no thermoregulatory effects when administered centrally despite alterations in monoamine levels, we concluded that endogenous concentrations of monoamines were not so important in establishing a thermoregulatory set-point. This conclusion was substantiated when we demonstrated in monoamine depleted animals thermoregulatory responses similar to those of nondepleted animals. Thus, the set-point seems to be unaffected by endogenous levels of concentration and more dependent upon an active fraction released at synaptic terminals affecting neurons involved in establishing a setpoint of body temperature. This work was further corroborated in studies demonstrating an attenuated response by an anti-serotonin compound when administered prior to a potentiator of serotonin action.

In addition we feel that our work related to the acute hypothermic effects of serotonin and norepinephrine superseded by hyperthermia may help to clarify some of the apparently conflicting data in the literature pertaining to species specificity, dosage effects, time-course, etc. We hope that our work may have separated the pharmacological effects of central administration from the physiological effects which, to be recognized, require dose-response curves, adequate time course of study, investigations with agonists and antagonists, several routes of administration, etc.

Finally, we conclude that the central and peripheral response to thermal effector substances should be studied mechanistically to appreciate fully the role of central and peripheral physiological responses in establishing thermoregulatory responses. For example, we initially felt that tryptophan administration was effecting its

hypothermic effects centrally through a serotonergic mechanism. However, we later found that although central administration similarly affected serotonin concentrations, no thermoregulatory effects ensued. Then through O_2 consumption studies, we concluded that this amino acid was having its effects peripherally and directly on the sites of heat production by a thermo-suppressive (possibly toxicological) mechanism. Likewise, with serotonin agonists we found no effects on O_2 consumption thus forcing us to conclude their effects upon peripheral heat loss, rather than thermogenic, centers.

Future Plans:

Since the final results of these studies in the broad area of thermoregulation have been presented and published, we deemed this an appropriate time to transfer these studies to the Heat Work Unit. Our future plans call for inducing hyperthermia in experimental animals (rats) either by elevated environmental temperature, exercise, or both. Then, it is our objective to study means by which animals which have become hyperthermic can effectively reduce rectal temperature by pharmacologically reducing thermogenesis or increasing heat dissipation processes. We are hypothesizing that agents which are effective in accomplishing these ends will be likewise effective in reducing the cellular and organ lesions associated with hyperthermia, heat exhaustion, or heatstroke.

(81024)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6131	76 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. DISP'N INSTR'N	8b. SPECIFIC DATA - CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	024
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*

(U) Pulmonary gas exchange during exercise at sea level and altitude (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology; 05900 Environmental Biology; 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: Not Applicable EXPIRATION:
b. NUMBER:*
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 76(7T)	1 (.2)	51 (10)
FISCAL YEAR CURRENT 77	1.6	35

19. RESPONSIBLE DOD ORGANIZATION

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20. PERFORMING ORGANIZATION

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

NAME:* Maher, John T., Ph.D.

TELEPHONE: 955-2852

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: James T. Sylvester, M.D., MAJ, MC

NAME: 955-2894 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U) Exercise Physiology; (U) Altitude Physiology; (U) Gas Exchange; (U) Pulmonary Function

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

23. (U) To determine how exercise and exposure to high altitude affect the transfer of oxygen from the atmosphere to the blood in the lung.

24. (U) In the normal lung, O_2 transfer depends mainly upon the relationship between flow of air and blood through the lung. Techniques will be finalized for the accurate assessment of this relationship and apply them to animals in order to determine how the relationship between lung blood and air flow changes during alterations in body physiology simulating exercise and altitude exposure.

25. (U) 75-07 - 76-09 Experiments conducted on pigs have resulted in a refined surgical procedure for the isolation of the lungs from the rest of the body. Chromatographic methods have been perfected for the measurement of dissolved anaesthesia gases in blood and expired air. A quantitation program for the accurate determination of the A-aDO_2 gradients has been completed. Control data has been amassed; analysis is underway. Resources utilized during FY 7T: Professional Man Years 1.6; Funds $10 (in thous).

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*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:	024 Pulmonary Gas Exchange during Exercise at Sea Level and Altitude
Study Title:	Pulmonary Gas Exchange at Sea Level and Altitude - Phases I and II.
Investigators:	Jimmie T. Sylvester, MAJ, MC and Allen Cymerman, Ph.D.

Background:

During high intensity muscular exercise at sea level, the ability of the lung to transport oxygen into the blood from the inspired air deteriorates, and deterioration is even greater at high altitude. The reasons for this are unknown, but it has been long suspected that the major cause is the manner in which air flow and blood flow are distributed in the lung. Until the present, however, there has been no way to assess these distributions. In 1974, Wagner, Saltzman and West published an ingenious method to measure blood and air distribution in the lung, which is simple to perform and low-risk. The method involves infusion of trace amounts of six inert gases into the venous system while simultaneously collecting samples of arterial blood and expired air. Sophisticated computer analysis of this data enables the determination of lung blood and air flow distribution. We plan to utilize this method in animals, firt to attain expertise with the technique, and second, to gain understanding of basic nature of gas exchange. For example, at altitude and during exercise, blood and gas flow and blood and gas volume in the lung all change simultaneously. Therefore, to interpret changes in gas exchange occurring with altitude exposure, we need to know what effect each of these factors exerts by itself. Experiments in animals will allow this determination

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because we can change, say, blood volume while maintaining blood flow, air flow, and air volume constant. The final stage of the experiments will be the assessment of oxygen transport (in human subjects) using the inert gas technique during rest and exercise at sea level and at altitude. Hopefully, the insight we gain from these studies will allow some pharmacological or environmental intervention that will improve pulmonary oxygen transport and thereby improve the soldier's ability to accomplish his mission at altitude.

Progress:

1) The laboratory is now completely equipped.

2) The animal preparation (an *in situ* perfused pig lung) has been perfected.

3) The chromatographic techniques for measurement of the six inert gases have been perfected. We are currently conducting detailed studies of the reproducibility and accuracy of these measurements.

4) Through collaboration with Dr. Edward Ross of NARADCOM, we are exploring new theoretical approaches to the analysis of the inert gas data. Since this technique was originally published by Wagner, Saltzman, and West, questions have been raised regarding the acceptability of the method by which the inert gas measurements were converted into distribution functions of blood and air flow in the lung. Our current approach, while still in the exploratory stage of development, appears to have an advantage over the original approach in that confidence limits may be placed on the distribution. The collaboration with Dr. Ross has proven exceedingly fruitful and we hope to present our new method within the year.

5) We are also performing experiments to determine the "biological reproducibility" of the measurements in the intact anesthetized pig.

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6128	76 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. DISS'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	6.11.01.A	3A161101A91C	00	025
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*

(U) Metabolic Aspects of Thermoregulation (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

002300 Biochemistry; 012500 Pharmacology; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
73 07		DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: Not Applicable EXPIRATION:

b. NUMBER:*

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	76(7T)	.3	46 (10)
FISCAL YEAR — CURRENT			

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

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20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST ENV MED

ADDRESS:* Natick, MA 01760

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

NAME:* Mager, Milton Dr.

TELEPHONE: 955-2871

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME:

NAME:

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Thermoregulation; (U)Body Temperature; (U)Environmental Extremes; (U)Metabolism; (U)Drugs; (U)Central Nervous System

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

23. (U)The development of chemicals for the treatment and/or prophylaxis of thermal injury is dependent on elucidation of the biochemical mechanisms of central temperature regulation. The purpose of these studies is to elucidate the relationship between availability of metabolic fuels and maintenance and regulation of body temperature. These findings will aid in better understanding man's responses to environmental extremes.

24. (U)Research will be performed on small animals and will involve the administration of agents which are known to alter both the levels of circulating substrates and body temperature, e.g. 2-deoxy-D-glucose, insulin, norepinephrine, etc. Assessment of the concomitant thermal (rectal, tail, liver, and muscle temperatures) and the peripheral metabolic responses (plasma glucose, free fatty acids, etc.) individually, and in conjunction with a variety of blocking agents, will provide the primary documentation required for this investigation.

25. (U)75-07 - 76-09 2-deoxy-D-glucose (2-DG) was administered centrally to rats via cannulae implanted in their ventricles, and with thermocouples surgically glued to the liver and shoulder muscles. Results of these experiments performed at both 15 and 20°C indicated that a disruption of the normal thermoregulatory processes had occurred, as well as a generalized decrease in heat production at various sites in the body. From the data obtained at 15°C, it was concluded that the rat is still able to make additional heat to maintain body temperature even when exposed to this acute cold stress. Additionally, we have documented basic similarities in the thermoregulatory responses between rats and mice as they pertain to 2-DG, to a variety of blocking agents, and to prostaglandin E_1 fever. This work unit has been terminated. Resources utilized during FY 7T:Professional Man Years .2; Funds $10 (in thous).

*Available to contractors upon originator's approval.

* U.S. GPO: 1974-540-843/8691

Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	025 Metabolic Aspects of Thermoregulation
Study Title:	Metabolic Aspects of Thermoregulation
Investigators:	Milton Mager, Ph.D.; Candace B. Kelly, M.A.; and Sumner M. Robinson, Ph.D.

Background:

Thermoregulatory dysfunction or failure is manifested by a number of disabilities potentially affecting a variety of military activities. Included are those disabilities caused by heat, e.g., heat stroke, heat exhaustion, heat syncope. Rational therapy is hindered by a lack of knowledge of the mechanisms underlying these syndromes, particularly of the biochemical and neurochemical relationships.

Our interests have been directed to defining the impact of the metabolic milieu on thermoregulation, with emphasis on the hypothermia noted in man with hypoglycemia, particularly insulin hypoglycemia. In addition, we have investigated in man the marked hypothermic response following intravenous infusion of 2-deoxy-D-glucose (2-DG). Reductions in core temperature with this competitive inhibitor of glucose utilization were accompanied by elevations of plasma glucose, growth hormone, immunoreactive insulin, and urinary catecholamines. Metabolic responses to 2-DG were characterized and determined in the mouse and compared to effects produced by administration of insulin and norepinephrine (NE) into the cerebral ventricles. From these data, we postulated that glucopenia in the central nervous system affects centers that are involved with the control of peripheral heat production, and is accompanied by a decreased utilization of peripheral substrate. Our current investigations were designed to further elucidate the phenomenon of 2-DG hypothermia in the

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rat, and to compare it with previous observations noted with mice.

Progress:

To determine the specific organ site of decreased heat production resulting from centrally administered 2-DG, copper-constantan thermocouples were surgically glued to the liver and shoulder muscles of rats and a cannula implanted in their lateral cerebral ventricles. Results of these experiments performed on groups of conscious animals at both 15 and 22°C indicated that a disruption of the normal thermoregulatory processes, and a generalized decreased heat production had occurred at various sites in the body. Thus, while there was a decrease in the temperature of the liver, the site for approximately one-third of the total heat produced by the body, there was no single site which was primarily responsible for the observed reduction in core temperature. However, from experiments performed at 15°C, it was concluded that even with 2-DC administration, the rat is still able to make additional heat when challenged with an acute cold stress.

In an attempt to elucidate partially the central mechanisms which control peripheral heat production, a variety of central blocking agents were administered to the rat alone and in conjunction with 2-DG, as well as prostaglandin E_1 (PGE_1). The results of these experiments are summarized below.

a. Administration of 5 ug of phentolamine HCl did not alter the hypothermia usually induced with 8 mg of 2-DG. This is consistent with the observations previously noted with mice.

b. Administration of 5 ug of propranolol HCl also did not alter the hypothermia usually induced with 8 mg of 2-DG. This is in contrast to what had previously been noted in mice, where an enhanced hypothermic affect was observed.

c. The administration of 10 mg/kg of desipramine HCl (DMI) 2 hours prior to the administration of 8 mg of 2-DG, partially blocked the usually observed hypothermic effect. However, this blockade was not as complete as previously observed with mice.

d. The administration of PGE_1 resulted in a dose related hyperthermic response at levels from 25 to 150 ng, which are approximately one-sixth of that required to elicit equivalent rises in core temperature in mice. The central injection of 8 mg of 2-DG with 100 ng of PGE_1 was sufficient to prevent the usual dramatic hyperthermic response. This is similar to our previous observations with mice.

Thus, we have documented basic similarities in the thermoregulatory responses between rats and mice as they pertain to 2-DG, to a variety of blocking agents, and to PGE_1. However, the central mechanisms which control peripheral heat production in the rat are yet to be determined, as well as the altered metabolic pathways and the resultant decrease in heat production which occur during the phenomenon of 2-DG hypothermia.

(81026)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6133	76 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. DISP'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	026
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)* (U) Heat production and heat loss in chronic overweight 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: Not Applicable EXPIRATION:
b. NUMBER:*
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 76(7T)	.5 (.1)	50 (60)
FISCAL YEAR CURRENT 77	.7	49.3

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST ENV MED
ADDRESS:* Natick, MA 01760
RESPONSIBLE INDIVIDUAL
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TELEPHONE: 955-2811

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: 955-2831
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: Danforth, Elliot, M.D.
NAME: 090-26-2209; Un of VT College of Med
Tel:(802) 656-2530 DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)
(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)75-07 - 76-09 Four naturally overweight men, after 18 days excess carbohydrate (2000 kcal/day above maintenance levels), increased body weight 4% and surface area 2%, but raised basal metabolism a disproportionate (based on size) 15%. Working heat production increased 16%, 1/4 due to increased BMR and 1/5 to higher cost of moving the added body weight. The remaining 55% is apparently the same response to excess carbohydrate seen in normal men. An increased turnover of T_3 and a suggestion of increased peripheral conversion of T_4 to T_3, which support the increases in metabolic production, were observed. Resources utilized during FY 7T: Professional Man Years .1 ; Funds $10 (in thous).

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*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:	026 Heat Production and Heat Loss in Chronic Overweight as a Function of Endocrine Patterns
Study Title:	Heat Production and Heat Loss in Individuals Considered "Easy" as Opposed to "Hard" Gainers
Investigators:	Ralph F. Goldman, Ph.D. and Staff, in collaboration with the Univ. of Vermont Clinical Research Unit

Background:

It has been shown in previous work by Miller et al., (1967); Durnin and Norgen (1969), and more recently in a preliminary phase of this investigation by Goldman, Sims et al., that overfeeding of carbohydrate for a prolonged period can increase heat production and metabolism beyond the normal increase expected simply from the accompanying gain in body size.

This study involved four subjects, all of whom have a history of obesity and were considered "easy-gainers." Since previous tests were on more normal subjects, the question here is does this response to carbohydrate overfeeding exist in the obese, or is lack of this mechanism for excess caloric consumption a contributory cause of these subjects' obesity?

In looking for a mechanism for this effect, we studied heat production-heat loss; RQ factors; respiratory responses; corrected metabolic measures. In conjunction with our studies, Dr. Eliot Danforth (Univ. of Vermont Medical Center) is conducting tests on hormone production, particularly involvement of the thyroid, using radioactive tracers in analyzing blood samples.

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Progress:

The 4 subjects were tested on two occasions, separated by 18 days of carbohydrate overfeeding of 2000 kcal per day. As a result of this overfeeding, body weight increased 4%, surface area 2% and basal metabolism 15%, exceeding that expected from increased body size. Working heat production increased 16%; of this increase, the increased basal metabolism accounted for about 1/4 and the energy cost of moving the increased body weight 1/5. The remaining 55% of the increase is apparently the same thermogenic response to intake of excess calories seen during work in individuals of normal weight.

Post-prandial resting metabolic rates were consistently (but not significantly) higher after overfeeding. Basal and resting respiratory quotients (RQ) did not change, but RQ during work increased from 0.79 to 0.93, suggesting an increased carbohydrate metabolism. There was definitely increased turnover of T_3 in the body after overfeeding, and a suggestion of increased peripheral conversion of T_4 to T_3, which support the metabolic findings of increased basal and working energy expenditure.

Future Plans:

Additional hormone assays are underway at the University of Vermont concerning pre- to post-overfeeding differences in levels of insulin, glucagon, growth hormone and thyrotropic stimulating hormone, to determine their patterns of response.

Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	026 Heat Production and Heat 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. (Univ. of Vermont)

Background:

Previous studies (Miller et al., 1967; Durnin and Norgen, 1969; Goldman, et al., 1974; Burse, et al., 1976) have shown that overfeeding of carbohydrate for periods ranging from 1-3 weeks results in metabolic heat production which is in excess of that expected from the increases in body weight. However, when fat is overfed for prolonged periods, metabolic heat production is not in excess of that expected as an accompaniment to the weight gain (Goldman, et al., 1974). Because the various studies comparing excess intake of fat and carbohydrate calories were conducted at different times, one cannot be assured that conditions were controlled to the extent that the studies were strictly comparable. Accordingly, the heat production and heat loss responses were measured pre- and post-prandially before and after a 3-week overfeeding of either fat or carbohydrate. The hypothesis is that ingestion of excess carbohydrate calories will result in greater thermogenesis, and lower weight gain, than ingestion of the same number of calories of fat.

Progress:

Initially a group of six subjects were maintained on an isocaloric diet for 10-14 days at the University of Vermont Medical Center. Their thermogenic responses at rest and during work were evaluated at USARIEM, following which they returned to Vermont for a 3-week period of overfeeding either carbohydrate or fat calories (3 subjects on each diet). They then returned to USARIEM for the post-test of their thermogenic responses. To insure reproducibility of findings, and an adequate sample size, the study was replicated on another group of 6 subjects (3 overfed carbohydrate, 3 overfed fat).

The study involved measurements of heat production - heat loss, effects on respiratory responses, RQ and metabolic measures; dietary intake, and tests of hormone production and thyroid involvement in all responses, will be conducted by Dr. Eliot Danforth and his associates at the University of Vermont Medical Center using radioactive tracers and blood analysis.

Data collection has been completed on 11 subjects before and after 18 days of overfeeding (6 on carbohydrate, 5 on fat). The results are being analyzed.

(81027)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6136	76 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. DISP'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	027
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*

(U) The Squirrel Monkey as a Model for Peripheral Cooling (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology 016200 Stress Physiology

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: Not Applicable EXPIRATION:
b. NUMBER:*
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 76(7T)	.1 (.1)	1 (3)
FISCAL YEAR CURRENT 77	.5	17

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST 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 ENV MED

ADDRESS:* Natick, MA 01760

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

NAME:* Roberts, Donald E., Dr.

TELEPHONE: 955-2893

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME:

NAME:

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U) CIVD; (U) Thermoregulation; (U) Peripheral Blood Flow

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

23. (U)The aim of this study is to evaluate the feasibility of using the monkey as a model for peripheral thermoregulation in response to cooling.

24. (U)The peripheral response to local cooling will be assessed by blood flow (plethysmograph) and temperature (thermocouple) measurements. Alterations in the rate of cooling and/or production of CIVD will be examined. The squirrel monkey is being used because its thermoregulation is similar to that of humans and the anatomical relationships of the monkey tail to the human hand is closer than a dog's or cat's paw would be. The types of studies being considered are pressure-flow relationships, nutritive flow vs. bulk flow, and the effects of flow-alterating drugs during cooling.

25. (U)76-04 - 76-10 Protocol has been prepared and submitted for approval. Resources utilized during FY 7T: Professional Man Years .1; Funds $3 (in thous).

*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 The Squirrel Monkey as a Model for Peripheral Cooling
Study Title:	The Squirrel Monkey as a Model for Peripheral Cooling
Investigator:	Donald E. Roberts, Ph.D.

Background:

The vascular responses associated with cooling of the extremities are currently being looked at in several studies using human subjects. The limitations imposed by the use of human subjects makes the development of an animal model necessary.

It has been reported that the squirrel monkey has the necessary hypothalmic control and the peripheral vasomotion to be considered as a possible model. One other requirement is a minimal stress response to restraint. The monkey can be trained to tolerate a restraint chair very well.

The terminal vascular beds in the tail and the hind feet will be considered in this study to ascertain if this model can be used for more definative studies into the mechanism of vascular responses to cooling.

Progress:

This protocol has not been started, but a review of the literature is in progress.

Future Plans:

This protocol should be starting this fall with an expected completion of the first phase within a few months.

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PROGRAM ELEMENT: 6.11.02.A

DEFENSE RESEARCH SCIENCES, ARMY

PROJECT: 3A161102B71R

Research in Biomedical Sciences, Army

TASK: 05 Environmental Medicine

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(82001)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OA 6142	76 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. DISP'N INSTR'N	8a. SPECIFIC DATA - CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	6.11.02.A	3E161102BS08	00	001
b. ~~XXXXXXXX~~	6.11.02.A	3A161102B71R	05	057
c. ~~XXXXXXXX~~	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U)Development of Cold Models and Characterization of Frostbite, Non-Freezing Cold Injuries and Whole Body Heat Loss Common to the Soldier(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: Not Applicable EXPIRATION:
b. NUMBER*
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 76(7T)	3.5 (.7)	176 (50)
	CURRENT 77	2.4	70

19. RESPONSIBLE DOD ORGANIZATION
NAME* USA RSCH INST 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 ENV MED
ADDRESS* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME* Denniston, Joseph C.,VMD,Ph.D.,MAJ,VC
TELEPHONE: 955-2852
SOCIAL SECURITY ACCOUNT NUMBER

ASSOCIATE INVESTIGATORS
NAME: HAMLET, Murray P., D.V.M.
NAME: 955-2865

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)
(U)Cold Injury; (U) Frostbite; (U) Thermoregulation; (U) Arctic Military Operations; (U) Cryobiology; (U) Human Subjects

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 recooperation of frostbite victims will be included in an animal model. Mild frostbite lesions will be produced and sequential radiographs taken to identify the production of the radiographic changes. The ability to measure temperature from deep within the tissue would be advantageous in the clinical evaluation of frostbite lesion. Attempts to utilize the microwave radiometer on an animal model will progress this quarter.

25. (U)75-07 - 76-09 Eight animals in four groups, fasciotomy and non-fasciotomy plus dialators have shown an increase in tissue cells which with fasciotomy dialators over non-fasciotomy injuries. Blood flow and angiography and thermographic studies support this tissue slavage data. Edema and compartment pressures rose dramatically the first 45 minutes after thaw. Fasciotomy markedly decreased these pressures. Daily whirlpool therapy also inhanced tissue salvage. External and internal rewarming of the squirrel monkey, dog and pig favors internal methods. Resources utilized during FY 7T: Professional Man Years .7; Funds $50 (in thous).

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*Available to contractors upon originator's approval

☆ U.S. GPO: 1974-540-843/8691

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3A161102B71R Research in Biomedical Sciences, Army
Task:	05 Environmental Medicine
Work Unit:	057 Development of Cold Injury Models and Characterization of Frostbite, Non-Freezing Cold Injuries and Whole Body Heat Loss Common to the Soldier
Study Title:	Evaluation of Fasciotomy for Treatment of Frostbite in the Dog
Investigators:	David R. Franz, D.V.M., CPT, VC, Joel J. Berberich, Ph.D., CPT, MSC

Background:

Fasciotomy has been successfully used in man for such problems as massive soft tissue injury, arterial and venous occlusion, and arterial spasm. Fasciotomy, in conjunction with a vasodialator, has been used in a small number of human frostbite patients with apparent favorable clinical results. It is thought that the vascular stasis and ischemia found in frostbite may be related to increased compartment pressures following thaw. Failure to relieve these tissue pressures may explain why, historically, treatments for frostbite have been relatively ineffective.

Results:

Severe frostbite was produced in 28 mongrel dogs, divided into four treatment groups, and maintained for 14 days. All laboratory work has been completed, and the data are being analyzed. Major findings include the following: Max edema and compartment pressures were noted within 30-45 minutes post thaw. Compartment pressures dropped and deep foot temperatures (a function of blood flow) increased by 3–9°C within 15

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minutes following fasciotomy. A significant difference in deep foot temperatures persisting to at least 5 days post thaw was noted in the vasodilation plus fasciotomy treated group versus the control group. Tissue survival at 14 days post thaw generally followed an all or none pattern in fasciotomy dogs; i.e., severe tissue loss occurred earlier than in control dogs or tissue survival was greatly increased over controls. Chronic orthopedic changes are being observed radiographically in one fasciotomy dog with complete tissue survival. Pilot and study data support importance of daily whirlpool therapy in the chronic treatment of frostbite.

Recommendations:

Recommend further study be initiated to attempt to sort out "warming" vs. "nutritive" blood flows. Recommend blood gas and certain key humoral factors be analyzed in blood flow to and from injured extremity. Recommend same dog model be used for the above, as injury and control data is now well established.

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3A161102B71R Research in Biomedical Sciences, Army
Task:	05 Environmental Medicine
Work Unit:	057 Development at Cold Injury Models and Characterization of Frostbite, Non-Freezing Cold Injuries and Whole Body Heat Loss Common to Soldier
Study Title:	Evaluation of Venous Effluent Following Frostbite in the Dog
Investigator:	David R. Franz, D.V.M., CPT, VC

Background:

Several theories have been proposed to account for the death of tissue following frostbite. Most theories can be classified into two categories: (1) direct cellular damage from the cold; and (2) hypoxia and cell death resulting from destruction of the supportive vascular bed at the site of injury. In vivo studies indicate the presence of obstructive embolic platelet aggregates. Electron microscopic studies reveal a destruction of the microsvascular endothelium.A systemic review of selected humoral factors in the arterial and venous systems of the injured canine hind leg could provide insight into the mechanics of what is observed grossly and microscopically.

Progress:

The protocol is nearly complete. Electromagnetic flow measurements will be made from the femoral artery and vein, before, during, and after freeze and thaw of the canine hind foot. Initial evaluation of arterial and venous samples will include detection and quantitative analysis of complement, histamine, white blood cell counts, hematocrit platelets, lactate, cholesterol, total lipids, hemoglobin, PO_2, PCO_2, and pH.

Findings will then be used in an attempt to modify the pathophysiology by means of drugs or other treatment.

Recommendations:

This study should greatly increase the value of the present dog frostbite model. Preliminary data from the dog support the theory that the present model, with the addition of flow and 0_2 consumption measurements, could become extremely valuable in the evaluation of various frostbite treatment systems and techniques.

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3A161102B71R Research in Biomedical Sciences, Army
Task:	05 Environmental Medicine
Work Unit:	057 Development of Cold Injury Models and Characterization of Frostbite, Non-Freezing Cold Injuries and Whole Body Heat Loss Common to the Soldier
Study Title:	Preliminary Investigation of Microwave Radiometry in Dog Animal Model
Investigators:	Joel J. Berberich, CPT, MSC, Ph.D.; Danney L. Wolfe, CPT, VC; and David R. Franz, D.V.M., CPT, VC

Background:

Frostbite therapy has been confounded by the lack of good prognostic measures of degree of injury, anatomical limit of injury, and response to therapeutic measures. It was felt that a prototype microwave radiometer developed for NASA and the National Cancer Institute by Radiometrics Technology, Inc., might help correct this deficiency. A microwave radiometer non-invasively measures the energy radiated in the microwave spectral band; since these longer waves are less diminished by tissue, subsurface radiation, and hence temperature, is measured. A pilot study was proposed to evaluate the utility of this device. Blood flow would be occluded differentially at the iliac artery in the dog. Changes in blood flow measured by electromagnetic probe at the femoral artery would be correlated with surface temperatures measured by microwave radiometry and thermistors. The experimental hypothesis to be answered is whether or not the microwave radiometer can detect these blood flow changes accurately.

Progress:

A protocol has been written, submitted, and approved by the Animal Use Committee, USARIEM, on 27 May 1976 for a pilot study. The microwave radiometer has been received from NASA Ames Laboratory (Moffett Field CA). Unfortunately, initial evaluation showed the radiometer to be malfunctional. The necessary repairs have been made by the subcontracting agency for NASA and the instrument subsequently has been found to be operational. Experimental techniques for surgical implantation and for calibration of the blood flow probes have been initiated.

Recommendations:

Actual data collection for this pilot study begin approximately 15 October 1976. Recommendations for future use of microwave radiometry will be based on results of the pilot study.

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
DA 0B 6149	76 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. DISP'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	H. Terminate	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	3A161102B71R	05	058
b. CONTRIBUTING				
XXXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code): (U) Development of Performance Measures for Simulated and Real Military Team Tasks (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS: 013400 Psychology; 005900 Environmental Biology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
73 07		DA	C. In-House

17. CONTRACT/GRANT: NOT APPLICABLE
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:
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	76 (7T)	3 (.5)	160 (50)
FISCAL YEAR — CURRENT			

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: Evans, Wayne O., LTC, MSC
TELEPHONE: 955-2822
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) Human Volunteers; (U) Psychomotor & Cognitive Abilities; (U) Motivation; (U) Performance; (U) Simulation; (U) Military Tasks; (U) Environmental Stress.

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

23. (U) To develop psychophysiological, biochemical, motivational, behavioral state, group process, and task proficiency measures which are relatable to operational indices of military team performance. These measures will be used to determine the impact of environmental extremes upon group performance and individuals functioning within the group so that performance alterations and subclinical illnesses can be identified and means of treating these disorders can be evaluated.

24. (U) Emphasis was placed upon developing methodology for testing real Army fire direction center teams performing their critical military tasks in the laboratory with conditions similar to those in the field.

25. (U) 75-07 - 76-09 Plans have been made for a collaborative study of actual FDC teams during simulated sustained operations, involving USARIEM, WRAIR, and NHRC. The scenario-script which regulates the mission demands was designed and tested on two FDC teams at Ft. Bragg, NC. The exercise provided an initial data base, confirmed the doctrinal and technical acceptability of the scenario mission content to the "users", and tested control procedures needed to assure scientific performance assessment of multiple levels of function. Simulation and data recording technology for the in-laboratory study is being tested; and computer software for scenario-script generation and data analysis is in final development. This research will be continued under a new work unit. Resources utilized during FY 7T: Professional Man Years .5; Funds $50 in thous.

*Available to contractors upon originator's approval.

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3A161102B71R Research in Biomedical Sciences, Army
Task:	05 Environmental Medicine
Work Unit:	058 Development of Performance Measures for Simulated and Real Military Team Tasks
Study Title:	Development and Application of a Methodology to Assess Effects of Extreme Natural Environments and Operational Conditions on Individual and Group Performance Fundamental to Complex Military System Operation
Investigators:	John L. Kobrick, Ph.D. and Bernard J. Fine, Ph.D.

Background:

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. This methodology embodies the following criteria:

a. high face validity - (1) use of real military systems; e.g., field artillery fire direction center, command/staff operations, and others; (2) use of actual military equipment and procedures.

b. precise definition and measurement of tasks; systematic manipulation of environmental exposures and operational conditions.

c. predictive validity - ability to generalize findings to actual Army operational field situations.

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The findings will provide guidelines to determine Army medical and performance doctrine related to operations in extreme natural environments and sustained duty, develop medical and psychological indices to aid selection of specifically qualified personnel for particular operations, provide a model to study performance improvement through biologic intervention techniques, and guide Army field commanders concerning personnel capabilities in extreme environments.

Progress:

First study completed. Both altitude and hot-wet conditions produced highly significant impairments of all tasks. Although the peak impairments were about equal for heat and altitude, their patterns of development differed. Altitude effects occurred sooner than for heat and showed some later recovery, whereas heat effects developed more slowly and did not recover. Omission errors exceeded commission errors. Considerable differences in individual response to each stressor were noted.

Data collection has been completed in a second study using the same stress conditions but involving more varied and demanding tasks. Data analysis is underway.

Preparations are in process for a third study of artillery fire direction center performance under the environmental exposure conditions used previously combined with experience of the conditions involved in rapid translocation of personnel to a tactical operation.

(82009)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
DA OB 6120	76 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. DISS'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	6.11.02.A	3E161102BS08	00	009
b. [redacted]	6.11.02.A	3A161102B71R	05	059
c. [redacted]	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: Not Applicable EXPIRATION:
b. NUMBER:
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 76(7T)	4 (1)	100 (50)
	CURRENT 77	3.5	95

19. RESPONSIBLE DOD ORGANIZATION

NAME: USA RSCH INST 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 ENV MED
ADDRESS: Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME: VOGEL, James A. Dr.
TELEPHONE: 955-2878
SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS
NAME: HORSTMAN, Donald H. Dr.
NAME: 955-2879

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Work; (U)Endurance; (U)Fatigue; (U)Cardiovascular; (U)Military Performance; (U)Blood Flow; (U)Muscle

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) oxygen transport and hemodynamics of the exercising limb; (2) biomechanical changes in skeletal muscle during training of various intensities and frequency; (3) muscle blood flow as a limitation to maximal exercise and modes of facilitating muscle blood flow during exercise; (4) cellular respiration as a limitation to maximal exercise and (5) the interrelationship between maximal oxygen consumption and endurance capacity.

25. (U)75-07 - 76-09 (1) In situ dog gastrocnemius-plantaris preparation experiments indicate that muscle temperature does not affect the energy cost of contractions, but significantly lowers initial muscle performance as indicated by isometric tension and may also contribute to muscle fatigue. (2) In a similar dog muscle preparation it was found that increased blood flow produced by adenosine infusion increased oxygen utilization of working muscles by shifting from anaerobic metabolism. (3) The determination of anaerobic threshold has been found to be a sensitive and feasible measure of aerobic fitness and may therefore be a valuable additional measure of overall physical fitness. Resources utilized during FY 7T: Professional Man Years 1; Funds $50 (in thous).

*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.
* U.S. GPO: 1974—540-843/8691

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3A161102B71R Research in Biomedical Sciences, Army
Task:	05 Environmental Medicine
Work Unit:	059 Biological Processes that Limit Heavy Physical Work Ability of the Soldier
Study Title:	Determining Anaerobic Threshold by Lactate Curve Plots
Investigators:	Donald Horstman, Ph.D., John F. Patton, Ph.D., and James A. Vogel, Ph.D.

Background:

The relative work intensity (i.e., % $\dot{V}O_2$ max) at which steady state muscle lactate production rises above resting values is defined as anaerobic threshold. Anaerobic threshold represents the intensity of work above which aerobic mechanisms cannot completely meet energy requirements for muscular contraction and a commitment of anaerobic pathways is initiated. This has important implications in that anaerobic glycolysis is the primary consumer of muscle glycogen stores, and total depletion of muscle glycogen stores is a primary cause of true physiological exhaustion. The higher the intensity at which one can work before initiating anaerobiosis is a good measure of aerobic efficiency, a contributing factor to overall cardiorespiratory fitness and to the potential to perform heavy work for prolonged periods of time.

The purpose of this study was to develop the methodology for determining anaerobic threshold in average people, and to determine the reproducibility of this methodology.

Progress:

Initially, eight subjects performed work at 10 to 12 different

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intensities, ranging between 20 and 100% of $\dot{V}O_2$ max. For each subject, blood lactate concentration was plotted as a function of relative work intensity (% $\dot{V}O_2$ max); the extrapolated point at which blood lactate concentration deviated from resting was taken as the anaerobic threshold. Blood lactate concentration was an exponential function of relative work intensity (this has been previously reported by numerous investigators); and the mean anaerobic threshold was 47.4 ±2.1% $\dot{V}O_2$ max. Because of the exponential relationship, semilog plots of blood lactate concentration as a function of relative work intenisty were also performed for each subject. Anaerobic threshold was taken as the relative work intensity point of intercept for blood lactate concentration of 10 mg/100 ml (Lac_{10}), the mean of which was 49.4± 2.0% $\dot{V}O_2$ max. Rank order correlation analysis yielded a coefficient of 0.94 between the two techniques for establishing anaerobic threshold.

Next we chose to establish the reliability of determining anaerobic threshold by the semilog plot technique using blood lactate concentrations obtained at only three submaximal work intensities. Maximal work was also performed to establish $\dot{V}O_2$ max. Total testing consisted of work at five separate work intensities, interspaced by one hour rest periods, a regiment which can easily be accomplished in one day. Test-retest analysis for 20 subjects yielded mean Lac_{10} values of 52.5 ± 1.6 and 52.6 ± 1.9% $\dot{V}O_2$ max for test 1 and test 2, respectively. The standard error of the difference between test 1 and test 2 was only 1.0% $\dot{V}O_2$ max and the coefficient of correlation was 0.89.

Conclusions:

We concluded that anaerobic threshold can be accurately determined by a relatively simple procedure, which is highly reproducible, requiring only one day to administer.

Future Plans:

Manuscript for publication is being prepared. Since the measure of anaerobic threshold is an indicator of aerobic efficiency, we may incorporate it as part of our method of assessing physical fitness. Secondly, the measure of anaerobic threshold will be used to assess the effectiveness of various experimental interventions (such as training programs, diets, drugs) designed to increase the physiological potential for prolonged work (i.e., to prevent physical fatigue).

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3A161102B71R Research in Biomedical Sciences, Army
Task:	05 Environmental Medicine
Work Unit:	059 Biological Processes that Limit Heavy Physical Work Ability of the Soldier
Study Title:	The Effects of Adenosine Infusion on Metabolic and Hemodynamic Factors Related to Endurance
Investigators:	Donald Horstman, Ph.D. and Danny Wolfe, CPT, VC, V.M.D.

Background:

In recent experiments with in situ dog muscle, we found that adenosine infusion resulted in vasodilation and hyperemia; leading to an increase in oxygen consumption ($\dot{V}O_2$) and a decrease in lactate production ($\dot{V}_{lac}$) at high, yet submaximal contraction rates, i.e., between 60 and 90% $\dot{V}O_2$ max. Adenosine-induced hyperemia resulted in increased O_2 availability which we postulated enabled the muscle to increase aerobic metabolism in lieu of anaerobic metabolism. Anaerobic metabolism is primarily dependent upon muscle glycogen as energy substrate. Endurance performance is closely related to initial muscle glycogen levels and rate of muscle glycogen utilization, with true physiological exhaustion occurring when muscle glycogen stores are depleted. Therefore, decreased anaerobic metabolism should result in preservation of muscle glycogen and a concommitant increase in endurance performance. The purpose of this study was to test the efficacy of adenosine to serve this function in intact, exercising dogs.

Progress:

Ten splenectomized dogs ran on a motor driven treadmill at 7 mph.

Comparisons were made between arterial infusions of saline and adenosine while running at 0, 5, 10 and 15% grades of incline. Cardiac output (Q) was between 10 and 15% greater at all work grades with adenosine, evidence of adenosine's effectiveness in inducing additional vasodilatation and hyperemia. At 0, 5 and 10% grades, $\dot{V}O_2$ was slightly higher (2%) with adenosine than with saline. At 15% grade, $\dot{V}O_2$ was 5% greater with adenosine than with saline. Blood lactate concentration (LAC), an indicator of $\dot{V}_{lac}$, was near resting values at 0 and 5% grades for both adenosine and saline. At 10% and 15% grades, LAC was 25% greater and 33% lesser, respectively, with adenosine than with saline.

Conclusion:

The results of this study are inconclusive. There are slight indications that aerobic metabolism ($\dot{V}O_2$) was increased with adenosine infusion, however, the varied responses of LAC are not supportive of this contention.

Future Plans:

The use of vasodilators to increase endurance performance is still a reasonable area of inquiry. With the thought that perhaps the intact, exercising dog is not a suitable model for testing in this instance, we are considering the use of a different specie with the same protocol. We are also considering oral administration of adenosine to man and its effect on both direct and indirect indices of endurance performance.

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OA 6143	76 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. DISP'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	6.11.02.A	3A161102B71R	05	060
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)* (U) Development and Characterization of Models of Heat Injuries and Disabilities and Other Heat Responses of the Soldier (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
70 07		DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: Not Applicable EXPIRATION:
b. NUMBER:*
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 76(7T)	3.5 (2.1	500 (100)
FISCAL YEAR CURRENT		

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST 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 ENV MED
ADDRESS:* Natick, MA 01760
PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* Mager, Milton, Dr.
TELEPHONE: 955-2871
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: Hubbard, Roger W., Dr.
NAME: 955-2873 DA

21. GENERAL USE
Foreign Intelligence Not Considered

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) Develop and characterize models, i.e., experimental equivalents or analogues, of heat stress and heat-induced injuries and disabilities in the soldier.

24. (U) Models will be produced using experimental animals, mathematical and physical simulation, or human subjects. The injury, disability or response will be induced directly by heat, work or indirectly by chemicals or other agents. Physiological, pathological, biochemical, behavioral or other studies will then determine the nature and usefulness of the model in examining methods of prevention, amelioration, and treatment.

25. (U) 75-07 - 76-09 The working and/or sedentary heated rat has been used to develop a model to study both the incidence and cause of heat illness and fatal heatstroke. The results demonstrate: 1) A continuous and increasing risk of thermal death exists from heat exhaustion (104°F) to heatstroke (106°F) levels of body temperature. 2) The existence in rat populations, as in humans, of heat sensitive individuals and 3) that the hyperthermia induced by work is more lethal than an equivalent heat load at rest. Utilizing our recently developed dog heatstroke model, we have demonstrated the relative efficacy of peritoneal dialysis over surface cooling as a method for reducing elevated core temperatures. Additionally, we have documented that bacterial invasion of the liver, increased endotoxin activity, and elevation of humoral factors such as T_3 and angiotensin II and components of dog heatstroke. This work unit has been terminated and work will be continued under a new work unit. Resources utilized during FY 7T: Professional Man Years 2.1; Funds $100 (in thous).

*Available to contractors upon originator's approval

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Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3A161102B71R Research in Biomedical Sciences
Task:	05 Environmental Medicine
Work Unit:	060 Development and Characterization of Models of Heat Injuries and Disabilities and Other Heat Responses of the Soldier
Study Title:	A Dog Heatstroke Model
Investigators:	Gaither D. Bynum, MAJ, MC, John F. Patton, CPT, MSC, Jerry M. Brown, MAJ, MSC, Wilbert D. Bowers, Ph.D., Erwin Leav, D.V.M., Danney L. Wolfe, CPT, VC, Murray P. Hamlet, Ph.D., SP4 Mark Marsili, SP5 Ben Caleb, and Dave Dubose

Background:

Because of the lack of accepted animal heat stroke models we have virtually no description of the pathophysiology of heat stroke. This stands in stark contrast to insightful and in depth analysis of the precipitating environmental factors of heat stroke and the exhaustive clinical descriptions of heat stroke morbidity and mortality. By recognizing precipitating environmental factors and restricting activity accordingly the incidence of heat stroke has been dramatically reduced. The wealth of clinical data provides the experience necessary to anticipate patterns of morbidity. However, the basic treatment of the acute event of heat stroke remains external cooling as initially suggested by Coates in the mid 19th Century. This is due in large part to a lack of data which can be obtained only from animal models of heat stroke.

The current series of studies in this laboratory are intended to develop an in depth dog heat stroke model providing information in the following three areas: 1) A description of the physiologic events leading up to and immediately following heat stroke. 2) The definition of those factors which are key to the etiology of heat stroke. 3) The definition and evaluation of therapy modes for heat stroke.

Progress:

A dog model for untreated heat stroke has been developed which describes events leading up to, through and following heat stroke with the following parameters: Survival rate (25%): mean weighted skin temperature; mean weighted surface heat loss; rectal, brain, liver, kidney temperatures; oxygen consumption and metabolic rates; cardiac output; heart rate; EKG; clinical chemistry and hematology parameters, platelet count, fibrinogen, Na, K, Cl, CO_2, Ca, PO_4, Gluc, BUN, UA, Chol, T. Pro., Alb., T. Bili., Cr, SGPT, Alk. Phos., LDH, Amylase; autopsy, histological and electron microscopic observations; microbiologic. The model was then utilized with subprotocols directed at developing therapy modes and pathophysiologic data.

1. The dog heat stroke model was utilized to demonstrate an increased short term survival (75%) if cold (6-10^{o}C) peritoneal dialysis is utilized to reduce the elevated body temperatures of heat stroke. This is a statistically significant increase from survival rates of 25% in untreated animals and animals packed with plastic bags containing ice slush.

2. A synthesis of the data recovered from the untreated and dialysis treated heat stroked dogs, suggested morbidity patterns similar to that seen in shock particularly endotoxic shock. Endotoxemia has been implicated in a number of forms of shock and is thought to be involved in the evolution of the "irreversible" or second stage of shock. To document whether endotoxemia or sepsis are associated with canine heat stroke tissue samples were taken from control and heated dogs. E. coli were demonstrated in the liver of heated animals and not in control animals. There was no evidence of hematogenous spread. Utilizing a lymulus lysate assay, increased endotoxin activity was demonstrated in dogs experiencing heat stroke.

3. Working under the hypothesis that humoral factors may precipitate or alter the event of heat stroke, we have evaluated the role of humoral constituents such as angiotensin, and T_3, T_4, TSH. Efforts to date suggest that Angiotensin and T_4 levels vary with heat injury in anesthetized dogs.

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3A161102B71R Research in Biomedical Sciences
Task:	05 Environmental Medicine
Work Unit:	060 Development and Characterization of Models of Heat Injuries and Disabilities and Other Heat Responses of the Soldier
Study Title:	A Rat Model of Acute Heatstroke Mortality
Investigators:	Roger W. Hubbard, Ph.D., Wilbert D. Bowers, Ph.D., and Milton Mager, Ph.D.

Background:

Historically, there have been two opposing views regarding the pathophysiology of heatstroke. The classical work and concept is generally attributed to Malamud et al. 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, who believed heatstroke to be the result of circulatory failure also leading to shock. With either hypothesis, shock was the critical end-point. The uncertainty surrounding the central or peripheral causes of heatstroke (neural versus cardiovascular) is evident in the following statement by Leithead and Lind: "The primary physiological failure in an unacclimatized man suddenly exposed to high heat stress probably lies in the failure of the sweating mechanism but it is also true that in such conditions any heat disorder that develops is most frequently cardiovascular in origin."

However, the extent to which direct thermal injury to tissue and circulatory collapse combine to produce fatal heatstroke shock can be determined. If direct thermal injury to tissue is the primary factor in the pathogenesis of heatstroke shock, then the work-induced hyperthermia of running rats should not be more lethal than equivalent heat loads in the absence of physical effort.

Purpose and Goals: The purpose of this research has been to refine the use of the rat heat illness model as a research tool and to measure the extent to which work factors contribute to heatstroke death.

Progress:

A total of 252 untrained, unacclimatized and unanesthetized laboratory rats weighing between 485-545 g were fasted and either run to exhaustion at 5, 20, 23 or 26°C or were restrained and heated at an ambient temperature of 41.5°C. The incidence of mortality associated with a wide range of work-induced hyperthermias was compared to the lethality of equivalent heat loads in the absence of physical effort. The severity of hyperthermia was calculated in degree-minutes above a baseline core temperature of 40.4°C. Mortalities within 24 hours occurred following exhaustive work over the entire range of individual hyperthermias from baseline levels to 185 degree-minutes. With passive heating, mortalities were not observed below a thermal area of 20 degree-minutes, and no rat enduring a thermal area above 125 degree-minutes survived.

Dose-response curves plotted as percent mortality versus hyperthermic area in degree-minutes demonstrated: 1) A continuum of increasing incidence of death with increasing severity of hyperthermia, i.e. the existence within this population of both heat-sensitive and heat-resistent animals. For example, there was an apparent fourteen fold difference in heat tolerance between an exhausted animal that succumbed to a 5 degree-minute exposure and one that survived over 120 degree-minutes of hyperthermia. 2) A dissociation of the effects of heat plus work from the effects heat alone, i.e. an experimental demonstration that the hyperthermia induced by working to exhaustion can be lethal to some individuals while enduring an equivalent heat load at rest is not. Obviously, certain animals can withstand tremendous heat stress before collapsing whereas others cannot. Since, in both cases, exhaustion was the end point, these results indicate why in some cases the most fit, highly

motivated individuals often suffer the severest heat injury. Under these circumstances, the point of collapse does not insure similar chances of survival amongst different individuals. The LD 25's of run versus restrained rats were 16.8 and 30.1 degree-minutes, respectively.

These results provided an objective method of classifying the severity of hyperthermia based upon the incidence of mortality within the total population. Thus, each animal was retrospectively assigned to one of five groups whose limits were described by intervals in degree-minutes along the dose-response curve: 1) LD 0-25, 2) LD 25-50, 3) LD 50-75, 4) LD 75-94, 5) LD 94-100. The LD 94 was chosen as a limit because it represents: a) the point where the two dose-response curves converge and b) the approximate mid-point in the total range of thermal exposures. This classification made it possible to compare 1) groups of run and restrained rats whose reaction to experimental treatment resulted in a similar probability of death and 2) to compare survivors versus fatalities over a wide range of thermal exposures.

An analysis of the heating and cooling areas of the hyperthermic curves indicated that: (1) in general, the heating and cooling portions of the total hyperthermic curve were nearly equal under these conditions and (2) significant heat injury can occur after exhaustion and/or withdrawal from the heat. Thus, any attempt to limit the duration of the hyperthermia after collapse should reduce the death rate. This has been clearly demonstrated in South Africa, where the incidence of fatal heatstroke was reduced by the early application of therapeutic cooling.

The pattern in survival times suggest that the pathophysiology of fatalities in Group 1 might be different from that in Group 5. By this method of retrospective analysis, it should be possible to determine which non-critical biochemical or physiological factors increase with thermal load independently of mortality rates. Conversely, by examining Group 1 mortalities, it should be possible to determine which vital biochemical or physiological factors change rapidly in some susceptible individuals with

a low thermal load. Thus, it should be possible to carry the analysis of heatstroke beyond the dose-response relationship indicating how many will die to the point of resolving for the clinician who will die and why.

When the reactive hyperemia of work is added to the burden of superficial dilatation provoked by hyperthermia, an intense splanchnic vasoconstriction must occur or shock would intervene. As shown by the mortality data, this combination of heat plus work is much more dangerous at low, comperable thermal loads than is acute exposure to excessive heat at rest. The proposed series of events leading to profound peripheral vascular collapse is currently under investigation. In this regard, the cooling rate of run survivors is significantly less than heated survivors. This may indicate an increased rate of heat production or, more likely, a serious impairment of cardiovascular function in heat dissipation mechanisms.

Finally, with this model it is possible to evaluate the work component of heat illness in a way consistent with the "hyperthermic area concept of thermal stress." The difference in thermal areas in degree-minutes (heated minus run) within each of our five groups are an estimate of the thermal equivalency of work stress. Since no fatalities occurred below an end of run core temperature of 40.4C, only work done above this threshold core temperature should be relevant to the calculation of degree-minute per kilogram-meter factor. The value of this ratio was calculated to be 0.44 $\pm$ 0.11 degree-minutes per kilogram-meter of work above a core temperature of 40.4C. The use of this factor would allow the direct addition of work stress, expressed in degree-minutes, to the thermal stress in order to predict and test their combined effects on mortality rates or tissue injury in various experimental paradigms.

(82002)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
				DA 0A 6144	76 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. DISP'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	6.11.02.A	3A161102B71R	05	061
XXXXXXXXX	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: NOT APPLICABLE
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:
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 76 (7T)	5 (2)	150 (50)
FISCAL YEAR CURRENT 77	6.8	230

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
Natick, MA 01760
ADDRESS:

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic institution)
NAME: Maher, John T., Ph.D.
TELEPHONE: 955-2851
SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS
NAME:
NAME:

21. GENERAL USE: Foreign Intelligence Not Considered

DA

22. KEYWORDS (Precede EACH with Security Classification Code): (U) Altitude; (U) Hypoxia; (U) Mountain Sickness; (U) Acclimatization; (U) Military Operations

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 allowing for the elucidation of the physiological and biochemical adaptations which occur in response to the stress of high terrestrial elevations.

24. (U) Models will be developed and/or used for investigating 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; (4) related functional deficits and disabilities; and (5) factors affecting recovery in order to identify new approaches for improving military effectiveness at high terrestrial elevations.

25. (U) 75 07 76 09 The ventilation of goats did not correlate with cerebrospinal fluid pH at high altitude as it did at sea level. A correlation between cerebrospinal fluid bicarbonate and ventilation existed at both sea level and high altitude. This suggests that the sensitivity of the central chemoreceptors is determined by the CSF bicarbonate concentration. (2) Both a negative chronotropic and negative inotropic response of the heart to beta adrenergic stimulation were observed at high altitude. (3) Although a slight decrease in myocardial contractility seems to occur with chronic hypoxia, the decrease is not significant. Resources utilized during FY 7T:2 Professional Man Years ; Funds (in thous) $ 50 .

*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. 77

* U.S. GPO: 1974—540-843/8691

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Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3A161102B71R Research in Biomedical Sciences, Army
Task:	05 Environmental Medicine
Work Unit:	061 Development and Characterization of Models to Study Acute Mountain Sickness and High Altitude Pulmonary Edema in Military Operations
Study Title:	The Effects of Hypoxia on Cardiac Performance in Conscious Goats: Mechanisms of Altered Myocardial Contractility.
Investigators:	Joseph C. Denniston, MAJ, VC; John T. Maher, Ph.D.; Danney L. Wolfe, CPT, VC; Ronald E. Jackson, MAJ, MC; Allen Cymerman, Ph.D.; George Pettit, CPT, MSC; and Tadataka Yamada, MAJ, MC.

Background:

Acute exposure to hypoxia is associated with a transient increase in cardiac output, resting heart rate, and in urinary and plasma catecholamines. After several days of hypoxia the cardiac output falls to below sea-level values. The decrease in cardiac output is attributed to both a progressive decrease in stroke volume and a return of heart rate toward sea-level values. Noteworthy is the fall in heart rate at a time when circulating catecholamines continue to rise, implying altered chronotropic responsiveness to adrenergic stimulation.

Although an altered chronotropic response of the heart has been demonstrated in sedated dogs during chronic hypoxic exposure, the evidence for altered inotropic responses is not clear. Stroke volume has not been restored to sea-level values by the infusion of dextran even though ventricular filling pressures were increased. This has led to the suggestion of altered myocardial function. In fact, one group has reported

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myocardial depression (reduction in the maximum velocity of contractile element shortening) in goats during 15 days exposure to an altitude of 4300m. However, others have not been able to report similar findings in dogs.

Available evidence suggests that the effects of hypoxia on the heart may be mediated via the autonomic nervous system. Both the chronotropic and inotropic effects of the autonomic nervous system on humoral interventions have complicated interpretations. The infusion of acetycholine has only a slight negative inotropic effect on the ventricular myocardium; however, the same infusion with increased sympathetic activity or norepinephrine infusion results in pronounced myocardial depression. Thus, an increase in vagal tone which may occur with hypoxia in the presence of increased plasma catecholamine levels could lead to depressed myocardial activity.

Hypoperfusion of the splanchnic bed has been reported to occur during chronic hypoxia and this hypoperfusion might also play a role in myocardial depression at altitude. Prolonged hypoperfusion of the splanchnic bed, as might be expected at altitude, may contribute to lysosomal and zymogen granule disruption, proteolysis, and production of a myocardial depressant factor (MDF). MDF released from the pancreatic and splanchnic beds during ischemia (shock-induced) has been shown to significantly depress myocardial contractility.

The present study was designed to examine the relationships between myocardial performance, plasma catecholamines and myocardial depressant factor during acute and chronic hypoxia. A better understanding of the mechanisms involved in the altered cardiovascular response to hypoxia would open the way for improving performance as well as providing answers to basic and important questions relating to hypoxia.

Progress:

Observations were made in ten goats at sea-level and daily during 10 days of altitude exposure (4300 meters). Both a negative chronotropic and negative inotropic response of the heart to beta adrenergic stimulation (isoproterenol infusion) was observed. Importantly, parasympathetic blockade (atropine sulfate) had little effect in alleviating the observed negative chronotropic and inotropic response to isoproterenol infusion.

Although a slight decrease in myocardial contractility (V_{max}) seemed to occur over time the decrease was not significant. Similarly, Drs. Pettit and Yamada of USAMRIID were unable to demonstrate any significant change in MDF activity in any of the goats during the course of the study.

The use of atropine sulfate (1.0 mg/kg) to produce parasympathetic blockage in awake goats is not recommended for future studies. Definite CNS effects were observed at this dose level and resulted in substantial loss of data. Atropine methylbromide does not traverse the blood brain barrier and would be the agent of choice in producing parasympathetic blockade duirng future studies with goats.

Conclusions:

A negative chronotropic and inotropic response of the heart develops during chronic hypoxia. The negative inotropic and chronotropic responsiveness of the heart to beta adrenergic stimulation is not alleviated by parasmypathetic blockade. Myocardial contractility did not appear to be depressed at any time during the study. In addition, there was no significant change in MDF activity during the course of the study.

These findings suggest that the attenuated responses due to hypoxia may be related to the basic enzyme systems involved in the metabolic transformation of catecholamines.

Future Plans:

Additional work in this area must await review and updating of both the computer data acquisition program and analysis program.

Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3A161102B71R Research in Biomedical Sciences, Army
Task:	05 Environmental Medicine
Work Unit:	061 Development and Characterization of Models to Study Acute Mountain Sickness and High Altitude Pulmonary Edema in Military Operations.
Study Title:	Effect of Metabolic Alkalosis during High Altitude Acclimatization
Investigators:	Julio C. Cruz, M.D.; Danney L. Wolfe, CPT, VC; Allen Cymerman, Ph.D.; and John T. Maher, Ph.D.

Background:

Respiratory alkalosis is evident in sea level residents exposed to high altitude. This acid-base disturbance is initiated by the resultant hyperventilation caused by the hypoxemia. An altered state of equilibrium is achieved by the elimination of bicarbonate via the kidney. The effects of disturbances in acid-base balance on respiration are mediated by changes in the hydrogen ion concentration (pH) of cerebral interstitial fluid. The present study was designed to alter the normal pathway of ventilatory acclimatization by exposing goats, which exhibit ventilatory changes quantitatively similar to man, to altitude. With the production of chronic metabolic alkalosis prior to altitude exposure the normal renal compensation of respiratory alkalosis is reduced or avoided and the cerebrospinal fluid (CSF) bicarbonate concentration altered since plasma bicarbonate levels account for some of the changes in CSF bicarbonate levels caused by respiratory acid-base disturbances.

Progress and Conclusions:

Eight unanesthetized goats were studied at sea level and after two hours, 1.5 and eight days of chronic hypoxia in a hypobaric chamber (P_B 447 torr). Four goats were used as controls and four were made chronically alkalotic. The animals were surgically prepared with carotid loops and cisternal cannulae to sample arterial blood and CSF, respectively. Alveolar ventilation was measured simultaneously with arterial pH, P_{O_2}, and P_{CO_2}. CSF was sampled several minutes afterward for pH and P_{CO_2} measurements. Results indicated that ventilation and acid-base changes at sea level were similar to those previously described in the goat. With altitude exposure it was found that ventilation did not correlate with CSF pH, as was the case at sea level. However, a correlation between CSF bicarbonate and ventilation was observed in both groups, both at sea level and at high altitude. Since ventilation is controlled by CSF pH and since there was no difference in CSF pH between the two groups despite the difference in ventilation, the data suggest that the sensitivity of the central chemoreceptors is determined by the CSF bicarbonate concentration.

Future Plans:

None are contemplated.

PROGRAM ELEMENT: 6.27.58.A

MILITARY MEDICAL INVESTIGATIONS

PROJECT: 3A762758A827

Military Environmental Medicine

(83046)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
DA OC 6149	76 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. DISP'N INSTR'N	8b. SPECIFIC DATA - CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	3E762777A845	00	046
b. C[redacted]	6.27.58.A	3A762758A827	00	046
c. C[redacted]	CARDS 114f			

11. TITLE (Precede with Security Classification Code): (U) Prevention of Military Environmental Medical Casualties by Improved Information Transfer (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: Not Applicable EXPIRATION:
b. NUMBER:
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 76(7T)	3 (0)	89 (0)
	CURRENT 77	4.5	200

19. RESPONSIBLE DOD ORGANIZATION
NAME: USA RSCH INST 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 ENV MED
ADDRESS: Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME: Goldman, Ralph F., Ph.D.
TELEPHONE: 955-2831
SOCIAL SECURITY ACCOUNT NUMBER:

21. GENERAL USE
Foreign Intelligence Not Considered

ASSOCIATE INVESTIGATORS
NAME: Hamlet, Murray P., Dr.
NAME: Stroschein, Leander A., Mr.
NAME: Pandolf, Kent B., Dr. DA

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) Training films and wallet cards on cold and heat injury, plus films on mountain and high altitude operations, were prepared. Major collaborative studies with field units on problems of casualty handling in the Arctic, of mission performance in CW clothing in the heat, and of staging to altitude, were conducted. Information exchange for "Jack Frost","Alpine Warrior" and "TACVAL I," plus pre-deployment briefings on protective precautions, took place. Similar exchanges on physical fitness and training for women and older men have helped guide Army policy and USARIEM research. Resources utilized during FY 7T: Professional Man Years 0 ; Funds $ 0 (in thous).

*Available to contractors upon originator's approval

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Program Element: 6.27.58.A MILITARY MEDICAL INVESTIGATIONS

Project: 3A762758A827 Military Environmental Medicine

Work Unit: 046 Prevention of Military Environmental Medical Casualties by Improved Information Transfer

Study Title: Prevention of Military Environmental Medical Casualties by Improved Information Transfer

Investigators: Ralph F. Goldman, Ph.D. and ARIEM staff

Background:

There are three general foci for the work of this Institute, which deals with the effects of heat, cold, work and high terrestrial elevations on the soldier and his ability to perform his mission. These foci include: (a) carrying out necessary and sufficient research to answer militarily significant environmental medical problems; (b) reporting these results in the appropriate technical and/or scientific publications; finally, (c) insuring that military planners, logisticians and tacticians, have available to them the latest information, since publication of technical bulletins or scientific papers does not necessarily insure its availability to and/or use by the appropriate military users. Work under this work unit is directed to fulfilling this latter objective and thus involves a continuing series of information exchanges with line elements, with the various schools and boards, with clothing and equipment developers and with government contractors.

Progress:

Four training films have been completed: (1) TF8-4879 - Prevention of Cold Injury; (2) TF8-4914 - Prevention of Heat Injury; (3) TF8-4915 - Medical Problems of Military Operations in Mountainous Terrains, and (4)

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TF8-4916 - Medical Problems of Military Operations in High Altitude Terrains. Wallet sized, "fact cards" on windchill and cold injury, and on WBGT and heat injury are also now available for distribution.

Major collaborative studies with line units have provided field demonstrations of: (a) the need for improved medical evacuation capabilities in Arctic operations; (b) the continuing need for acclimatization to heat, and for revision of training and tactics for military effectiveness during hot weather operations, particularly with protective uniform systems, and (c) the potential of staging to altitude for reducing the problems of acute mountain sickness.

Consultations and briefings have been provided, and in some cases USARIEM observers have participated in planning, for operations "Jack Frost", "Alpine Warrior" and "TACVAL I". While a small scale operation was carried out on TACVAL I during the summer, following safety guidelines we furnished, most was deferred until colder weather. Briefings have been presented to Army elements from Fort Lewis, Fort Campbell, Fort Bragg, Fort Devens and elsewhere, prior to their deployment for cold weather training, and for Army and Marine units considering hot weather training. In addition, with women increasingly coming into the service in larger numbers and increased concern for physical training for older men, major information exchanges have taken place between the USMA, West Point, the WAC Center, Fort McClellen, the MEDAC's at Fort Dix and Fort Benning and The Surgeons at TRADOC Hqtrs. and at 18th Corps at Fort Bragg; these exchanges have helped guide both current Army policies and the USARIEM research program on physical fitness assessment and training for older men and for women.

Guidance was furnished on use of pack animals in unconventional warfare, and on evaluations of heat stress in Vietnamese relocation centers (and instrumentation was furnished). Tri-Service and international information exchanges on environmental protective clothing and equipment has improved, with participation in Cold Climate Clothing Survival Equipment Workshops, and evaluations of Air Force, and certain Navy clothing systems, in addition to our continuing dialogue with the US DARCOM developers, the NATO Combat Clothing and Equipment Working Group and the Commonwealth Conference on Operational Combat Clothing and Equipment. USARIEM staff have played a major role in the development of a NATO STANAG on Methods for Physiological Evaluation of Combat Clothing and Equipment, and have set up systems for direct comparisons of thermal protection afforded by all NATO country sleeping systems and by the materials used in their uniforms.

International and Inter-Service programs on casualty protection and evacuation in the Arctic, on development of techniques for maintaining medical fluids, ointments, etc., and their administration in the Arctic have also been pursued, along with the medical lessons learned from the Mid East conflict.

A formal training course, Current Concepts in Environmental (Climatic) Medicine was presented as well as a special training course for military medical reservists, and Institute staff continue to participate in training programs at the Academy of Health Sciences, TRADOC, WRAIR, AFEB and the like. In addition, major information exchanges with civilian agencies have taken place with mutual benefit: Civil Defence (shelter tolerances); Police departments (heat stress with body armor); Fire departments (heat casualties, and the role of fitness); NIOSH (Standards for Cold and for Manual Materials Handling), and the Federal Energy Agency (energy conservation and the role of clothing and thermostat settings).

Future Plans:

A film is to be prepared on this Institute and its capabilities to provide information. Liaison will be expended in an attempt to extend the current program of formal lecture presentations on the effects of heat, cold, protective clothing and high terrestrial elevations, to additional Army elements as well as to other appropriate DoD groups. Information exchange with line units will be continued.

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
DA OA 6145	76 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. DISP'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	H. Terminate	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	6.27.58.A	3A762758A827	00	047
b. CONTRIBUTING				
c. XXXXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code): (U) Effects of Environmental Stress on Military Performance; Interactions with Extended Operations, Unusual Activity Rest Cycles. (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
70 07		DA	C. In-House

17. CONTRACT/GRANT: NOT APPLICABLE
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:
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: 76 (7T)	8 (3)	$340 ($70)
FISCAL YEAR — CURRENT		

19. RESPONSIBLE DOD ORGANIZATION
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Natick, MA 01760
ADDRESS:

RESPONSIBLE INDIVIDUAL
NAME: Dangerfield, Harry G., M.D., COL., MC
TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
NAME: USA Rsch Inst of Env Med
Natick, MA 01760
ADDRESS:

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME: Evans, Wayne O.,LTC, MSC
TELEPHONE: 955-2822
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)Human Volunteers; (U)Activity-Rest Cycles; (U) Heat; (U) Cold; (U)Altitude; (U)Fatique, mental; (U) Continuous and Operations

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

23. (U) Many environmental stresses produce prodromal and subclinical disorders prior to frank casualty occurrence. The purpose of these studies is to identify these subclinical disorders and to utilize critical military individual and team tasks to assess the decremental effects of adverse climatic conditions tested singly or in combination. To identify and evaluate means to minimize potential decrements in performance effected by such stressors.

24. (U) Critical military tasks will be simulated in the laboratory and performed by military personnel under environmental and working conditions similar to those encountered in the field. Group interactions, stress responses and decrements in performance will be characterized on an interdisciplinary basis bringing to bear physiological, behavioral, and biochemical studies. Tolerance limits will be established so that more effective means for reducing performance disabilities can be evaluated.

25. (U) 75 07 - 76 09 First study completed. Both altitude and hot-wet conditions produced highly significant impairments of all tasks. Although the peak impairments were about equal for heat and altitude, their patterns of development differed. Altitude effects occurred sooner than for heat and showed some later recovery, whereas heat effects developed more slowly and did not recover. Omission errors exceeded commission errors. Considerable differences in individual response to each stressor were noted. Data collection has been completed in a second study using the same stress conditions but involving more varied and demanding tasks. Data analysis is underway. Work to be continued under new work unit. Resources utilized duirng FY 7T: Professional Man Years 3 ; Funds (in thous) $ 70.

*Available to contractors upon originator's approval

Program Element: 6.27.58.A MILITARY MEDICAL INVESTIGATIONS

Project: 3A762758A827 Environmental Medicine

Work Unit: 047 Effects of Environmental Stress on Military Performance: Interactions with Extended Operations, Unusual Activity-Rest Cycles

Study Title: The Separate Effects of Altitude and Heat on Soldiers Performing Selected Communication and Computation Tasks Under Standardized (Non-Operational) Conditions

Investigators: Bernard J. Fine, Ph.D. and John L. Kobrick, Ph.D.

Background:

This research is concerned with the separate effects of heat and altitude on individual performances of several selected cognitive tasks which have been extracted from a more complex military team operation, the artillery fire direction center (FDC). The FDC is the nerve center of the artillery system, and, as such, is responsible for the collection, integration, and processing of a complex body of information which ultimately determines the precision with which the weapons acquire their targets. Both extreme heat and altitude have been shown to decrease the efficiency and accuracy of certain kinds of mental functions, some of which are involved in the performance of FDC tasks. The state of the art indicates that, on the average, most mental performance begins to deteriorate above 85° effective temperature or at altitudes above 4,000 meters. The implications for the military are significant because such limiting conditions will be exceeded in many areas of the world where tactical operations take

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place. There is very little research directly linking the scientific psychological literature to military tasks involving mental activity. The purpose of this research is to bridge this gap by using as dependent variables performance of actual FDC tasks, rather than laboratory analogs, yet retaining and working with the psychological conceptions of the tasks.

Progress:

Data analysis has been completed in a study previously reported in which 30 subjects in groups of 6 were given 1 week of intensive training on 4 selected FDC-type tasks and then performed the tasks on four consecutive days while exposed to the following conditions: Day 1 (control) - sea level, 70°F, 35% RH; Day 2 (altitude) - 14,000 feet, 70°F, 35% RH; Day 3 (control) - sea level, 70°F, 35% RH; Day 4 (heat) - 95°F, 90% RH, sea level. These tasks were: (1) fire missions, involving reception and notation of range, elevation, and adjustment data relevant to hypothetical targets and the calculation of site, one factor involved in vertical alignment of the guns which required the use of a graphical site table, a slide rule device routinely used by FDC personnel: (2) reception, notation, and decoding of encoded map-grid coordinates using a standard Army code wheel device; (3) reception, notation, and decoding of encoded military-type messages using a typical Army code book; and (4) reception and notation of meteorological data in the standard format used by FDC teams.

Conclusions:

The results indicate the following:

(1) In general, both altitude and heat produced highly significant impairments in performance of all tasks, and in direct relation to the length of exposure.

(2) Although the peak impairments for altitude and heat exposures were approximately the same, the patterns of development were noticeably different. Altitude impairments occurred sooner, and showed some subsequent recovery, whereas heat impairments developed more slowly and showed little or no recovery.

(3) Errors of omission greatly exceeded errors of commission under both heat and altitude exposure.

(4) While the two stress conditions produced similar group decrements, they did not affect the performances of all subjects in the same way. Some subjects were strongly affected by altitude and only minimally by heat, while others were affected in the opposite manner. Very few subjects were either unaffected or incapacitated by both stress conditions.

(5) Performances during the two control conditions were very similar and showed no evidence of improvement due to practice, or of deterioration due to fatigue or lack of motivation. This verifies the effectiveness of the training procedures, and further supports the validity of these results as true stress effects.

The research was reported at the 1976 Army Science Conference.

Data collection has been completed in a second study involving similar stress exposures and an increased work load consisting of the previous performance tasks as well as a demanding task involving the use of maps in target plotting. Additional cognitive and perceptual measures were also included.

Future Plans:

Data analysis will be completed, and plans are underway to study environmental stress effects upon other military tasks.

Program Element: 6.27.58.A MILITARY MEDICAL INVESTIGATIONS

Project: 3A762758A827 Environmental Medicine

Work Unit: 047 Effects of Environmental Stress on Military Performance: Interactions with Extended Operations, Unusual Activity-Rest Cycles

Study Title: Fire Direction Center (FDC) Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operations

Investigators: James W. Stokes, LTC, MC, Louis E. Banderet, Ph.D. and James E. McCarroll, MAJ, MS

Background:

The biological reactions of Army team members working under debilitating environmental and operational conditions become especially critical as units with reduced tables of organization and equipment must meet the unprecedented demands of continuous combat envisioned by TRADOC. The operational cost which must be planned for includes not only the evacuation of casualties and allotment of recovery time, but also the degraded mission capability of those approaching their human limits. Command/control and communications personnel are of particular concern because they may be especially vulnerable, and their mistakes can have far reaching consequences. The medical research issues are ones of biological and psychiatric resistance to multiple stressors when men work in closely knit, disciplined teams.

The FDC Team Project utilizes actual Field Artillery (FA) teams performing for extended periods in naturalistic simulation of combat mission demands to (1) quantify the effects of harsh environments in combination with common situational stressors on the acute physiological,

biochemical, medical and psychosocial well-being of the team members; (2) relate the signs and symptoms of stress-induced illness and its antecedents to changes in operational efficiency at the multiple levels of function represented in this "model" command/control and communications setting; (3) identify dysfunctions which can be generalized to other teams and settings; (4) amass a data base from which to assess the cost effectiveness of alternative ways to protect health under stress and enhance fighting strength.

To our knowledge, this scientific methodology for using real small teams in standardized simulations is unique. The research is directed to occupational-medical hazards specific to the Army and has already provided a vehicle for communication between TSG environmental medical research and Army doctrine-generating and analyzing agencies.

Progress:

Two laboratory tests of FDC teams from an elite airborne unit subjected to an altitude challenge have demonstrated that a number of medical and performance parameters are sensitive to high altitude (with attendant acute mountain sickness), altered sleep-rest cycles, and fluctuating mission demands. In FY 76, findings from these studies were presented at conferences of the American Psychological Association, American Physiological Association, 5th International Congress of Sleep, and NATO/AGARD (published as AGARD Conference Proceedings No. 180). These tests have also aided identification of aspects of the overall FDC system which can best be manipulated to obtain consistent measures of individual and team well-being and operational efficiency while retaining the complex "real world" context needed to assure team involvement and scientific validity.

Preparations are being made for the study of FDC teams scheduled for February and April 1977. This study is integrating the mission responsibilities and research expertise of USARIEM, the Naval Health Research

Center (NHRC), and the Walter Reed Army Institute of Research (WRAIR), and is drawing upon the military expertise of the US Army Field Artillery School (USAFAS).

A test of the scenario-scripts, i.e., a project methodology developed to regulate mission demands and facilitate data collection and analysis, was conducted at Fort Bragg, NC, in June 1976. Two battery FDC teams were tested successively under simulated operational conditions for 8 hours. Field Artillery personnel assisted in the operation but were controlled and directed by USARIEM Scientific team. The test confirmed the acceptability of the scenario-script's content. The scripts were computer-generated printouts of radio messages and other communications with the FDC, but were developed and organized according to rigorous scientific principles to achieve equivalency of events across time. The feasibility of a system by which serious gunnery errors were fed back realistically to the FDC in real time was also verified. Computer programs are currently being developed to manage and print the large volume of materials required for the scenario scripts and for subsequent data reduction and analysis.

Future Plans:

In February, 1977, two FDC teams from an airborne unit will undergo sustained, intensive operations in the USARIEM FDC simulation. Mission demands in each study will fluctuate from brief lulls to "overload" against a background of communication "noise", with the overall pace permitting little, if any, sleep by any team members. One team will be tested with two 38h operations separated by a 34h (two nights, one day) recovery interval; the other team will be tested with a 72 to 84h continuous operation. In April, 1977, schedules permitting testing of two additional FDC teams will provide a replication of each sustained operational condition.

(83048)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OA 6123	76 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. DISP'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	3E762777A845	00	048
b. ~~XXXXXXXXX~~	6.27.58.A	3A762758A827	00	048
c. ~~XXXXXXXXX~~	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: Not Applicable EXPIRATION:
b. NUMBER:*
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 76(7T)	8 (2)	340 (70)
	CURRENT 77	8	378

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST 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 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:
ASSOCIATE INVESTIGATORS
NAME: Goldman, Ralph F., Ph.D.
NAME: DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U) Tolerance Prediction; (U) Protection; (U) Biophysics; (U) Military Clothing; (U) Heat; (U) Cold; (U) Wind

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 the Man-Clothing-Environment system, to provide a 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)75-07 - 76-09 Studies of auxilary heating and cooling for improved protection in extreme environments were continued, including manikin measurements to establish power requirements for an extreme cold casualty bag liner. Planning, guidance and on-site technical support was furnished Combat Developments Command in Grand Plot III, dealing with troop effectiveness in CW clothing in the heat. Currently prescribed women's field clothing was measured to provide guidance for designing systems with improved protection. Characteristics of Air Force and Navy anti-immersion and exposure suits were determined in air and on an immersed manikin. Measurements were made, in support of AMC developments, of fine-fiber mitten liners (heavier but no warmer than polyester), military and commercial footwear, CW-protective ensembles, and current production LINCLOE sleeping items (quality control check). Similar measurements were made on items for NATO nations. Consultation services on protection were provided various Army, Navy, Air Force, and civilian agencies. Resources utilized during FY 7T: Professional Man Years 2 ; Funds $ 70 (in thous).

*Available to contractors upon originator's approval

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Electrically Heated Liner for Casualty Holding Bags for Extreme Cold
Investigators:	George F. Fonseca, M.S., John R. Breckenridge, and Ralph F. Goldman, Ph.D.

Background:

Past studies have shown quite clearly that no insulated bag of practical proportions can, by itself, limit heat loss sufficiently to prevent accumulation of heat debt in an inactive man exposed in environments below -30°C. The situation is especially critical if the man is a casualty, possibly in shock and producing less than his normal metabolic heat. Where such a casualty must be held for prolonged periods in unheated or exposed positions prior to evacuation, auxiliary heating in some form is the only practical means of providing adequate protection, i.e., preventing degradation of his thermal state. Electrical heating with bag liners is one of many solutions; others are hot air heating and circulation of heated liquids through tubing attached to a liner inside the bag. The present program was concerned with specifying the design parameters for an electrically heated liner which could be used inside specially designed casualty holding bags or, as an alternative, inside standard LINCLOE extreme cold sleeping bags. In collaboration with US Army Medical Bioengineering Research and Development Laboratory, Fort Detrick, MD, using bags developed by Natick Research and Development Command, studies have been conducted utilizing a sectional copper manikin to determine the power input and distribution requirements for an electrically heated liner capable of providing protection for a prolonged period.

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Progress:

Manikin measurements of reduction in heat loss with electrical heat were made for combinations employing one standard and two prototype bags and two liner heating circuit configurations. The latter permitted a choice of delivering power to heating panels above or below the waist, or to the two panels under or on top of the manikin. Measurements were made at full and half power with various combinations of panels heated. Insulation values for the various bag/liner combinations were also measured (without auxiliary heat). These measurements showed that, for all systems, the greatest insulation was provided over the torso, and the least over the head, hands and feet. Although none of the bags provided adequate protection for exposure at -40°C without heating, the study indicated that colder environments could be safely handled with total power input of 150 to 200 watt. The recommended power distribution based on manikin temperatures was as follows: head, 15%; torso, 15%; arms, 15%; legs, 25%; hands, 10% and feet, 15%. Subjective trials with all the heating concentrated under the man were recommended as a starting point. If this proved unsatisfactory, USAMBRDL was advised to transfer a fraction of the heating capability to the liner surfaces covering the man. The suggestion was also made to test the feasibility of using the standard LINCLOE sleeping bag, augmented with an electrically heated liner, in lieu of a special casualty bag. Under combat conditions, the former would be more likely to be available in quantity than a special purpose item.

Future Plans:

As design of prototype casualty bags develops, both manikin and human evaluations will be employed to provide guidance to bag designers. Several design stages may be required before a bag/liner system suitable for field trials is evolved.

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Air Force Ventile Anti-Immersion Flight Suits
Investigators:	James E. Bogart, Clement A. Levell, and Ralph F. Goldman, Ph.D.

Background:

In FY 76, an arrangement providing for permanent loan of two electrically heated copper manikins from the Air Force, in exchange for a limited number of uniform evaluations per year by USARIEM, was negotiated. This Agreement was beneficial to both the USAF, which had only a limited requirement for manikin evaluations, and USARIEM, currently experiencing a shortage of operational manikins. The first evaluations being conducted under the Memorandum of Agreement are of ventile (breathable) anti-immersion flight suits. These suits are intended to protect during immersion by swelling of the fibers to provide an essentially water-tight covering. A variety of garment configurations were used under the ventile suit, including the basic nomex underwear plus flight suit, basic system plus spacer, extra nomex underwear, basic system plus Brynje (fish net) underwear, and systems which included an anti-G suit. Measurements are being conducted in air, with the manikin in a life raft, and with the manikin immersed to the neck. In connection with this project, a Navy impermeable suit with an air ventilated cooling system is also being evaluated per request of C. O., Naval Air Test and Evaluation Squadron 4, Point Mugu, California, with Air Force concurrence.

Progress:

Various combinations of items plus the USAF ventile suit have been measured in air on the immersible manikin. The basic USAF ensemble plus ventile suit measured 2.3 clo, compared to 2.4 clo for the Navy suit (unventilated). Add-on values for other components were: spacer, 0.1 clo; Brynje under nomex underwear, 0.3 clo; batting underwear, 0.6 clo; anti-G suit (over flight suit), 0.3 clo; extra nomex jacket, 0.4 clo; flight jacket liner, 0.9 clo. Based on the air results, it was concluded that only four of the combinations required measurement with the manikin immersed. Each of the others had a value in air similar to that for one of these four combinations. It was therefore reasonable to expect that their values in water could be estimated with sufficient accuracy using the four measured results.

Future Plans:

The basic plus ventile suit ensemble will be measured with the manikin in a life raft on water. This ensemble is also one of the four which will be measured in water, along with the Navy suit. During the water measurements, the capabilities of the ventile suit for preventing water infiltration will be assessed. Additional measurements in air are also planned to establish the evaporative cooling characteristics of the USAF ventile suit in its dry, i.e., air exposure, state. The cooling characteristics of the Navy suit with ventilating air being supplied will also be studied.

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Auxiliary Body Cooling Employing Wettable Ensemble Covers
Investigators:	John R. Breckenridge and Clement A. Levell

Background:

A variety of methods have been employed to reduce the heat stress experienced by men wearing impermeable clothing as protection against toxic environments. The latest approach has been to equip the man with a battery powered backpack which forces filtered, ambient air through the suit. This enhances evaporative heat loss from the skin and extends tolerance time during activity in hot environments from less than one hour, to several hours or more depending on the work level and environment; such an approach has been followed in the Explosive Ordnance Disposal (EOD) Suit, as reported last year. Another approach is the use of a water cooled undergarment to directly cool the body; results of this approach were also reported last year; heat removal was clearly demonstrated as proportional to the difference between skin and inlet temperatures. A head cooling cap for cooling men exposed to high temperatures in Army aircraft has also been investigated; in a severe hot dry environment (47^{o}C, 37% RH) heat removal by the cap was 30 kcal/hr, enough to improve comfort and extend tolerance at low work levels, but of marginal benefit during heavier work. Jackets containing refreezable pouches of water, or simply designed to accommodate slabs of ice have also been used; while the extension of tolerance is directly relatable to the mass cooling available, improvement in subjective comfort was marked probably because, with the skin kept cool, the increased deep body to skin temperature difference helped heart rate stay at

comfortable levels. A final method for obtaining increased body cooling, where sweat evaporation is blocked by an impermeable layer, involves the use of a wettable cover on the outside of the clothing. This method was used, with some success a number of years ago, on the Toxicological Agent Protective (TAP) suit and is currently the approach adopted by some nations; as water evaporates from a terry cloth cover, the cover temperature is lowered and heat transfer from the skin to the cover increases. This, "remote", evaporation is, at best, only 20 to 30% efficient for heat removal from the skin. Although the concept has merit, despite the low efficiency, since the only auxiliary equipment required is a supply of water, the approach was used ad hoc, with no definition of the environments in which it would work, and now appears to have been discarded by the US, the wettable terry cloth cover for the TAP ensemble is no longer listed in the pamphlet on Protective Clothing and Equipment (DA PAM 385-3, Rev - 1975).

Progress:

A mathematical model based on the physical laws of heat exchange has been developed which accurately describes the cooling benefit from a wetted cover worn over a system with an outer impermeable layer at any ambient temperature/humidity environment. The mathematical relations for this model were derived by writing a complete heat balance involving all the heat exchanges at the cover surface. The model has been validated for an ensemble consisting of fatigues, an impermeable garment and a wettable cover. Input parameters, i.e., total and local insulation values, and coefficients describing internal vapor transfer processes were obtained with an electrically heated copper manikin. Validation was accomplished using power input data for the manikin combined with rate of water loss from the cover, which was continuously recorded using an electronic balance. Predicted values of cooling benefit agreed well with changes in manikin input power, usually within 3 to 5 watts, over a range of air temperatures and humidities. The cover evaporative loss, which was calculated, also

agreed well with the loss indicated by weight changes.

Future Plans:

The prediction model will be validated further by checking results against manikin data at different wind speeds and with other clothing systems. Human studies to better define the effects of body motion on the insulating properties of such clothing will also be conducted to improve the accuracy of the model when dealing with active man. These alterations in insulating properties have an important effect on the cooling rates calculated by the model and must be accurately determined to avoid underestimating the efficiency of such cooling when ambient air motion is low.

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Insulating Characteristics of Women's Field Clothing
Investigators:	Clement A. Levell, John R. Breckenridge and Ralph F. Goldman, Ph.D.

Background:

Increasing integration of women into the Armed Forces has made it necessary to investigate, among other factors, differences is male and female physiological responses to heat and cold, and the adjustments in thermal protection of men's clothing which are needed to make it suitable for women. Information is gradually being accumulated on female physiological responses to environmental stress, which will ultimately indicate how the insulating and evaporative heat transfer characteristics of current military clothing should be modified for females. In the interim, AMC clothing designers, anticipating a program for development of new field clothing for women, have requested evaluation of the protection characteristics of currently-prescribed uniforms for guidance purposes. At present, garments are simply added over the normal female attire in an effort to provide adequate insulation for cold-wet and Arctic environments, in contrast to the protection system for men, which employs layer systems appropriate for each environment. The present study was performed using a copper manikin with a male form which was anatomically slender enough to be fitted with the larger sizes of women's clothing.

Progress:

Insulating values for a variety of women's ensembles were measured with a dry manikin; the evaporative heat transfer characteristics of each

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system were also measured by operating the manikin with a wet "skin." In general, ensembles with skirts provided inadequate protection, based on a man's requirements, for moderately cold environments. An ensemble with knee-length wool skirt and wool jacket provided only 1.7 clo of insulation. Compared to 3 clo protection for the men's cold-wet uniform, which protects down to about 15°F, the current women's cold-wet uniform, which employs long underwear, wool shirt and trousers, lined field jacket and pile cap, had a clo value of 2.03, almost 1 clo less than the men's uniform, corresponding to protection down to only about 35°F. The difference was attributed to the fact that the men's uniform had lined trousers, with good wind-resistant properties, instead of wool trousers. Based on the add-on for men's parka and Arctic trousers, it was estimated that women's Arctic uniform would have an insulating value of 3.8 clo vs 4.7 clo for the men's.

With regard to comfort in hot environments, the evaporative heat transfer properties of women's ensembles with trousers were comparable to those for similar men's uniforms. Ensembles with skirts, as might be expected, had noticeably better evaporative potentials than those with trousers. This increased potential for evaporative cooling would be beneficial in terms of comfort, and probably would increase tolerance in extremely hot environments.

Future Plans:

In collaboration with AMC developers, prototype clothing designs will be evaluated and recommendations made for modifications which will provide improved protection, reduce clothing weight, and be better matched to requirements imposed by peculiarities in the female physiological response to heat cold stress. As funding permits, a manikin with female form will be designed and procured. In addition, physiological differences between men and women that may require provisions of different amounts of insulation in hot or cold climates are currently being evaluated (SEE WORK UNIT NO. 053).

(83105)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA 0A 6146	76 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. DISP'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	H. Terminated	U	U	N/A	N/L	XX YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.58.A	3A762758A827	00	049
b. CONTRIBUTING				
XXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U) Prevention and Treatment of Disabilities Associated with Military Operations in the Cold (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology; 005900 Environmental Biology; 003500 Clinical Medicine

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

17. CONTRACT/GRANT NOT APPLICABLE

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:*

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 76 (7T)	5 (1)	200 (50)
	CURRENT		

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:* Evans, Wayne O., LTC, MSC

TELEPHONE: 955-2822

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

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

NAME: 955-2865 DA

21. GENERAL USE

Foreign Intelligence Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U) Cold Injury; (U) Frostbite; (U) Thermoregulation; (U) Microcirculation; (U) Acclimatization; (U) Performance Decrement; (U) Psychomotor Skills

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

23. (U) Measure and describe: the effects of cold on military performance, the effect of local and/or general cold exposure in inducing damage or reducing man's efficiency; the biological defenses which minimize, delay or repair the damage, from cellular to the intact organism level (soldier, animal, or model).

24. (U) A multi-faceted approach will emphasize: (1) actual or potential biochemical histological, and/or physiological changes associated with the site of cold injury; (2) techniques for initiating and strengthening natural defenses against the effects of cold (conditioning, acclimatization, indoctrination) and study of their practical limitations; (3) types and extent of military performance adversely affected by cold (manual dexterity, target detection, vigilance, problem solving) and (4) utilize infra-red scanning equipment to evaluate clinical cold injury and personal equipment. Studies will use animal or human subjects, as appropriate.

25. (U) 75 07 - 76 09 Patients with severe alterations in their peripheral vascular response (scleroderma and Raynauds) have shown a unique pattern of heat loss from the affected area and an abnormal rewarming response. Data suggests the ability of thermography to separate centrally mediated vasoconstrictor response from the locally mediated constriction. Auto regulation studies demonstrate the ability of certain individuals to rewarm their extremities from mild cold exposure by "thinking warm." Individual variability is great however. Terminating: Scleroderma manuscript is in preparation. Other peripheral vascular studies will continue under different work unit. Auto regulatory studies have terminated and manuscripts have been submitted for publication. Resources utilized during FY 7T: 1 Professional Man Years; Funds (in thous) $50.

*Available to contractors upon originator's approval.

Program Element: 6.27.58.A MILITARY MEDICAL INVESTIGATIONS

Project: 3A762758A827 Military Environmental Medicine

Work Unit: 049 Prevention and Treatment of Disabilities Associated with Military Operations in the Cold

Study Title: Anxiety and the Temperature Response of the Hand in Cold

Investigator: James B. Sampson, Ph.D.

Background:

The impact of anxiety on the incidence of cold injury in the extremities has long been speculated but has been difficult to document. Prior study has shown weak correlations between subjective state anxiety and reduced heat output of the hand in acute cold exposures. The present study attempted to actively manipulate anxiety during hand immersion in cold water.

Progress:

Twenty-six subjects were given a fifteen minute cold water hand immersion test on three consecutive days. On the second day each man was presented a stress producing movie in conjunction with hand immersion. Measurements taken during the study included subjective state anxiety; heart rate and skin temperature of cold exposed and non-exposed hands. The hypothesis was that anxiety provocation would enhance vasoconstriction and inhibit vasodilation in the cold exposed hand. Contrary to expectation the results show anxiety increased vasodilation as indicated by time to and incidence of warming in cold.

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AD-A042 652 ARMY RESEARCH INST OF ENVIRONMENTAL MEDICINE NATICK MASS F/G 6/5
US ARMY MEDICAL RESEARCH AND DEVELOPMENT ANNUAL PROGRESS REPORT--ETC(U)
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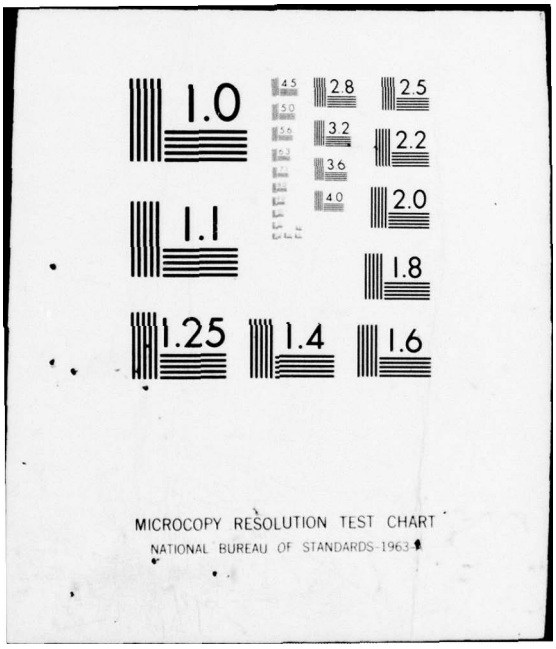
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Recommendations:

The conflicting data suggests that the vasomotor response to anxiety arousal situations is dependent on initial vasomotor state. Given the initial state of vasoconstriction anxiety arousal will lead to vasodilation.

Program Element: 6.27.58.A MILITARY MEDICAL INVESTIGATIONS

Project: 3A762758A827 Military Environmental Medicine

Work Unit: 049 Prevention and Treatment of Disabilities Associated with Military Operations in the Cold

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

Investigators: Joel J. Berberich, CPT, MSC, Ph.D.; David A. DuBose; Jerry M. Brown, MAJ, MSC

Background:

Previous work by Bader & Macht with 2 subjects (1948) established that warming the face in mild ambient temperature environments elicited peripheral vasodilation. Peripheral vasodilation due to facial warming logically may be postulated either as a reflex phenomenon, since facial neurothermosensitivity is well documented, or as a central phenomenon, since facial warming may warm the blood perfusing hypothalamic thermoregulatory centers. It was proposed to evaluate this observation in greater detail to determine whether or not facial warming would induce vasodilation in the hands or feet of cold exposed subjects. Such facial warming-induced peripheral vasodilation might improve performance in the cold and reduce the likelihood of cold injury.

Progress:

A protocol for human experimentation was submitted and approved with final MRDC approval on 17 March 1976. In conjunction with other studies, a procedure was developed for a bare hand in cold air model plus a second

gloved hand in severe cold air model. Procedures for temperature measurement using a Leeds and Northrup Numatron and scanner with magnetic tape recorder and interfacing devices were also accomplished in conjunction with other studies. A helmet device for warming the forehead was constructed and additional experimental techniques were perfected. To date, preliminary test subject familiarization has been completed and actual data collection is ongoing with ten test subjects. This data collection should be completed by 15 October 1976.

Recommendations:

Data from the facial warming study be evaluated; recommendations for future studies and for the utility of this technique as a prophylactic measure for cold exposure can then be made.

Program Element: 6.27.58.A MILITARY MEDICAL INVESTIGATIONS

Project: 3A762758A827 Military Environmental Medicine

Work Unit: 049 Prevention and Treatment of Disabilities Associated with Military Operations in the Cold

Study Title: Hand Rewarming by Means of Arm Exercise

Investigators: James E. McCarroll, MAJ, MSC, Ph.D., Marcos U. Ramos, M.D., MAJ, MC, James J. Jaeger, CPT, MSC, Donald E. Roberts, Ph.D., James B. Sampson, Ph.D.

Background:

It is difficult for a soldier who is immobile in periods of long exposure, such as in combat, to rewarm his extremities. Epidemiologic data from wartime indicates a very high incidence of cold injury cases during defensive combat. An effective technique is needed for extremity rewarming which can be easily used in the field by the individual soldier during periods of sustained operations.

Cold environmental temperatures produce peripheral vasoconstriction which tends to prevent heat loss from the extremities and protects the core from cooling for a longer period of time. In the short run, peripheral cooling is harmful to man by producing discomfort, pain, decreased manual dexterity and non-freezing cold injury and in the long run by producing frostbite. In the hands, skin temperature primarily reflects blood flow to the skin. Heat is produced by the process of metabolism and work and is transferred by blood flow and peripheral vascular changes. Exercise is known to increase local blood flow. The vascular bed is known to be affected by peripheral factors (temperature, metabolites, chemical and physical changes) and central nervous system factors. Theoretically, many of these parameters can be influenced to effect changes in blood flow, skin temperature and thereby, maintain warm skin temperature.

Progress:

Experimental procedures have been developed to evaluate the task proposed. Equipment has been ordered and is in the process of being interfaced.

Future Plans:

Will depend on progress of the research

Program Element:	**6.27.58.A MILITARY MEDICAL INVESTIGATIONS**
Project:	**3A762758A827 Military Environmental Medicine**
Work Unit:	**049 Prevention and Treatment of Disabilities Associated with Military Operations in the Cold**
Study Title:	**Evaluation by Infrared Thermography of Susceptibility to Peripheral Local Cold Injury**
Investigators:	**Murray P. Hamlet, D.V.M., Ph.D.; Joel J. Berberich, CPT, MSC, Ph.D.**

Background:

Analysis of previous wars has indicated that there may be persons who are more susceptible to cold injury. The fundamental objective of this study is to determine whether or not such individuals can be identified prior to cold exposure as a preventive measure.

A screening procedure to identify soldiers who are more susceptible to cold injury must be practical and thus must entail three elements: it must be rapid, limited to the minimal population size, and noninvasive.

As part of the first phase of this study, we would propose to compare hand cooling and rewarming rates to the cold pressor test (one minute in ice water), cold water immersion test (twenty minutes in cold water) and cold hand in air test (90 minutes). We would hope to identify whether or not a short time exposure test, like the cold pressor test, can clearly delineate differences between cold sensitive and cold hardy individuals.

In conjunction with this testing goal, as a secondary objective we would seek to evaluate whether or not infrared thermography can be used as part of such a predictive system. Infrared thermography offers the advantages of being rapid and non-invasive, requiring no physical contact with the subject and requiring little operator training.

Progress:

A protocol for human experimentation has been submitted and approved with final MRDC approval on 6 Oct 75. Initial efforts have been devoted to achieving a system for useful analysis of infrared thermographic images. Infrared thermograms have been recorded routinely as color or black and white photographic mosaic images. These images are limited in their capability for research analysis, for they greatly reduce the ability to examine dynamic events. This is limiting since hand cooling and warming show marked temporal changes. In addition, spatial analysis is also limited since these images have too much information for visual and mechanical reduction. Thus efforts to computerize the massive amount of information have been underway. A system for digitization of thermographic data, data storage on a video memory disc, and interfacing the data to a minicomputer has been identified. Details of this system have been coordinated with contracting agencies and the required equipment is presently being procured. Personnel from the ADP Branch of USARIEM have been receiving training in the thermography camera-computer interfacing and in the needed software for data analysis. The system should be received and operational by mid FY 1977. This system will accomplish spatial and temporal analysis of surface temperatures rapidly and over large body surfaces.

Future Plans:

Development of AGA thermography camera-computer interface continue. Following initial set up of the system, data collection should be initiated to compare responses to cold pressor, cold water immersion, and cold hand in air tests.

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	049 Prevention and Treatment of Disabilities Associated with Military Operations in the Cold
Study Title:	The Effect of Physical Fitness on Extremity Temperature
Investigator:	Donald E. Roberts, Ph.D.

Background:

It has been reported that one result of physical fitness training is an enchanced ability to maintain a higher than normal skin temperature when exposed to a cold environment. If this finding is true, and it is questioned by some investigators, then the physically fit subject should be able to maintain warmer extremities and therefore function better in the cold than can non-physically fit subjects. Finding new methods of increasing extremity temperature and thereby improving troop performance in cold environments is of major military importance.

It is the purpose of this study to test this hypothesis by using a hand in cold air model to determine if there is any improvement in hand temperature with improved physical fitness.

Progress:

Five control subjects and six trained subjects (Ave. 11% increase in max VO_2) were tested in the cold before and after training. The trained subjects were followed for two weeks after completion of training to study detraining effects on hand rewarming.

Data analysis is underway.

Recommendations:

Since the number of test subjects tested was smaller than originally requested, this study will be given more validity by doing another group of training subjects. Arrangements for personnel and equipment have been completed in order to permit the initiation of data collection on 1 November 1976 of a second group of subjects.

Program Element:	**6.27.58.A MILITARY MEDICAL INVESTIGATIONS**
Project:	**3A762758A827 Military Environmental Medicine**
Work Unit:	**049 Prevention and Treatment of Disabilities Associated with Military Operations in the Cold**
Study Title:	**Determination of Rate of Heat Loss from the Hands of Males before and after Blood Donation**
Investigators:	**Richard L. Burse, Sc.D. and Ralph F. Goldman, Ph.D. (with the collaboration of Russell W. Newman, Ph.D., retired)**

Background:

Heat loss rates from the hand under prolonged cold stress are proportional to the circulatory heat input to the hand via arterial blood flow. Blood flow to the hand is controlled by the degree of vasoconstrictor tone. Both cold stress itself and reduced blood volume (hypovolemia) after blood loss are vasoconstrictive stimuli. To determine if the circulatory heat input to the hand under cold stress is even less after a mild degree of blood loss, heat loss rates from the hand were determined before and after a one-unit donation of blood to the American Red Cross. Such a donation represents a blood loss of 450 ml, or about 6-8% of the typical blood volume in males. A decrease in heat loss from the cold-soaked hand after blood donation would denote reduced circulatory heat input to the hand and, by inference, to the other extremities as well. If the reduction in heat input were severe enough, hypovolemic individuals (e.g. battle casualties) would be at greater risk of cold injury under conditions of prolonged cold stress.

Progress:

In March, heat loss rates from hands immersed in 16°C water for 25 min were determined in 11 men before and after a 450 ml blood donation. Baseline heat loss rates were determined both with and without antecubital venipuncture (as a "sham donation" control) on successive days, in counterbalanced order. On the following day, heat loss rates were determined within 1 hour after blood donation. There were no significant differences between any of the conditions in the heat lost during the first 15 min of hand cooling ($\bar{X} \pm 1$ S.E. = 21.59 $\pm$ 1.14 kJ), indicating no change in tissue heat content prior to immersion. Heat lost ($\bar{X} \pm 1$ S.E.) during min 16 to 25 was 6.42 $\pm$ 1.25 kJ for the control condition, 7.55 $\pm$ 1.39 after venipuncture alone and 5.69 $\pm$ 0.89 after donation, representing rates of 10.7 $\pm$ 2.1, 12.6 $\pm$ 2.3 and 9.5 $\pm$ 1.5 W, respectively. Only the latter two values were significantly different ($P<.05$), suggesting that venipuncture by itself may be followed by a reactive vasodilatation, but venipuncture with 450ml phlebotomy significantly enhances arterial vasoconstriction under moderate cold stress. To investigate the possibility that blood pressures were elevated after venipuncture but depressed after donation, and thus caused the results observed, four of the original men were restudied before and after the next blood donation in June. In general, the mean arterial pressures for the group were elevated nearly 10% after venipuncture and were unchanged or somewhat depressed after donation, as suspected; however, the hand heat flows during the last 10 minutes of cold immersion were elevated after donation, rather than depressed. This finding was the reverse of responses obtained from the same individuals 3 months previously. Comparisons of the control and post-donation heat flows by analysis of variance showed that the interaction between treatments and months was significant at the $p<.05$ level, indicating a seasonal difference in the heat loss responses before and after donation. However, no main effects were found to be significant.

Conclusion:

There is a marginally significant decrease in circulatory heat input to the hand after a 1-unit blood donation in March, which was not observed in June. Since the effect is not very pronounced, even in March, there is probably no added risk of cold injury when hypovolemia of this magnitude accompanies cold exposure. Nontheless, a more marked reduction in heat input to the extremities after more severe blood loss is quite likely.

Future Plans:

None, as this laboratory does not have the capability to investigate more severe degrees of blood loss in humans.

Program Element: 6.27.58.A MILITARY MEDICAL INVESTIGATIONS

Project: 3A762758A827 Military Environmental Medicine

Work Unit: 049 Prevention and Treatment of Disabilities Associated with Military Operations in the Cold

Study Title: Reactive Hyperemia as a Method of Rewarming Extremities

Investigator: James Jaeger, CPT, MSC

Background:

The hyperemia following release of arterial occlusion may be a useful means of maintaining hand warmth or rewarming hands previously chilled. This experiment is designed to evaluate the magnitude of rewarming which can be achieved once the optimum time to produce the hyperemia, the site for occlusion and the length of occlusion have been determined.

Progress:

This protocol received MRDC approval on 28 June 1976. Preliminary work on this protocol has been in developing an interface between a multipoint temperature scanner and the USARIEM PDP-11 computer. This arrangement allows real-time calculation of mean weighted skin temperature and monitoring of up to 35 separate skin temperatures for both data collection and safety purposes. In addition, two methods of estimating finger blood flow are being evaluated for use on hands exposed to low ambient temperatures. Indications so far are that impedance plethysmography will be more suitable than the mercury strain gauge method.

Future Plans:

Evaluation of methods to estimate finger blood flow should continue through December 1976. Actual execution of this protocol should occur in January 1977.

Program Element: 6.27.58.A MILITARY MEDICAL INVESTIGATIONS

Project: 3A762758A827 Military Environmental Medicine

Work Unit: 049 Prevention and Treatment of Disabilities Associated with Military Operations in the Cold

Study Title: Cold Environment Evacuation Exercise

Investigators: Michael B. Young, MAJ, MC; Ronald E. Jackson, MAJ, MC: Gaither D. Bynum, MAJ, MC; Danney L. Wolfe, CPT, VC; Lee M. Philo, CPT, VS; Cornelius R. Fay, CPT, MSC; Donald O. White, SFC

Background:

U.S. military forces lost a staggering 9 million man days due to cold injury during the combined campaigns of World War II and Korea. In Korea alone 6000 men were evacuated due to cold injury. The incidence of cold injuries in Korea accounted for 10 percent of all casualties sustained, a casualty figure similar to that caused by malaria during the conflict in Vietnam. The USSR has reported that 15-25 percent of all injuries in wartime have been due to frostbite.

Considerable evidence exists that medical treatment and evacuation in the cold environment are less than desirable. Training in the problem of the cold environment represents a negligible portion of AMMED training. The paucity of training is further complicated by: (1) the lack of wheeled field ambulances capable of transversing more than 12 inches of snow cover; (2) lack of a tracked vehicle that can negotiate more than 29 inches of snow cover; (3) the inability to utilize air evacuation due to adverse weather conditions; (4) threat of surface to air missles; (5) absence of specialized medical equipment for cold weather use; and (6) the absence of force structure modifications for cold weather in face of the 4-5 man requirement to evacuate one casualty by achkio.

Approach:

A scenario was designed to test present medical doctrine, training, force structure and equipment for initial treatment and evacuation of wounded personnel in cold weather regions.

A platoon size unit experienced in cold weather operations was deployed on a combat mission in Alaska without prior knowledge of the scenario. An observation team from USARIEM intercepted this unit and tasked it with treatment and evacuation of five simulated casualties. It was assumed that adverse weather conditions and enemy hand-held SAMS precluded air evacuation. Thirty-six inches of snow cover prevented mechanized transportation until an access road was reached three kilometers away.

Conclusions:

Observations from this exercise lead to the conclusion that present medical doctrine, training, force structure and equipment are totally inadequate for initial treatment and evacuation of wounded in cold weather regions. It was apparent that walking wounded rapidly progress to litter patients. In addition to inadequate first aid, litter patients are susceptible to frostbite and death from hypothermia. Therefore, the evacuation procedures used would have resulted in increased injury under true combat conditions.

Recommendations:

Appropriate agencies should reconsider all aspects of medical treatment, evacuation and support of military operations in cold weather regions.

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
DA OA 6147	76 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. DISP'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	6.27.58.A	3A762758A827	00	050
b. CONTRIBUTING				
c. CONTRIBUTING	CARDS 114f			

11. TITLE (Precede with Security Classification Code): (U) Prevention and Treatment of Disabilities Associated with Military Operations in the Heat (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
70 07		DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: Not Applicable EXPIRATION:
b. NUMBER:
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	76(7T)	9 (2)	340 (70)
FISCAL YEAR — CURRENT			

19. RESPONSIBLE DOD ORGANIZATION
NAME: USA RSCH INST ENV MED
ADDRESS: Natick, MA 01760

RESPONSIBLE INDIVIDUAL
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TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION
NAME: USA RSCH INST ENV MED
ADDRESS: Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
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TELEPHONE: 955-2871
SOCIAL SECURITY ACCOUNT NUMBER

ASSOCIATE INVESTIGATORS
NAME: Hubbard, Roger W., Dr.
NAME: 955-2873 DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)
(U) Heat Stress; (U) Heat Tolerance; (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) (1) Identification, prediction, and prevention of heat-induced disabilities which decrement military performance. (2) Development of prophylactic and treatment for conditions as dehydration, heat exhaustion, and heat stroke.

24. (U) Approaches will be interdisciplinary and include: (a) determining effects of heat on biophysical, biochemical, physiological and psychological function; (b) defining the interaction of factors as solar load, clothing and equipment, and work requirements on tolerance limits; (c) studying methods of prevention and treatment of heat casualties to improve their efficacy.

25. (U) 75-07 - 76-09 Blood and urine samples were collected while test volunteers were undergoing heat acclimatization; quantitation of various constituents produced a number of interesting observations. Thus, plasma protein increased significantly on the first day of exercise in the heat yet after acclimatization this increase was attenuated; this observation supports the hypothesis that the ability to work successfully in the heat may be dependent upon increased vascular volume and protein. Of the plasma enzymes tested creatine phosphokinase was the most sensitive; however, acclimatization did not repress the anticipated increments. Of all the parameters measured plasma potassium levels increased most consistently with exercise in the heat, and after acclimatization muscle potassium efflux was attenuated, an important observation in view of the hypothesis relating hypokalemia to heat injury. Cortisol, growth hormone, thyroxin, and insulin indicated no significant changes with acclimatization. This study demonstrated that the most important biochemical indices of acclimatization may be related to vascular and ionic responses rather than metabolic or neuroendocrinological alterations. This work unit has been terminated and work will be continued under a new work unit. Resources utilized during FY 7T: Professional Man Years 2; Funds $70 (in thous).

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	050 Prevention and Treatment of Disabilities Associated with Military Operations in the Heat
Study Title:	Biochemical Correlates of Hemodynamic and Thermoregulatory Responses During Acclimatization to Heat in Man
Investigators:	Ralph Francesconi, Ph.D., John Maher, Ph.D. John W. Mason, M.D., and Gaither Bynum, M.D., MAJ, MC

Background:

The process of heat acclimatization allows man to perform mild or moderate work in hot environments with a minimum of the usual distressing symptoms accompanying such activity. For example, physiologically the acclimatization process has been shown to permit a given amount of work under specified conditions with a reduced final rectal temperature, reduced heart rate, and increased output of a more dilute sweat. While these physiological adaptations are clearly beneficial to man, the neuroendocrinological and biochemical mechanisms whereby acclimatization is achieved remain speculative. While many comprehensive surveys are available regarding the physiological responses to heat, only a few appraisals have been made of the neuroendocrine and biochemical involvement to high temperature exposure, and, to the best of our knowledge, none has been made serially during the process of heat acclimatization. Thus, it was our purpose in this study to: 1) examine the response of plasma hormones, enzymes, and cations to acute exposure to work in the heat, and modification of that response by repeated heat work exposures, 2) correlate the neuroendocrinological and biochemical adjustments with concomitant alterations in cardiovascular and thermoregulatory parameters, 3) separate the effects of heat and exercise on

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the physiological and biochemical adaptations resulting in heat acclimatization, and 4) to determine whether predictive correlations can be deduced retrospectively between degree of acclimatization and biochemical responses observed during the acclimatization process.

Two groups of test subjects were exposed to 49°C/27°C dry/wet bulb temperatures after an 8-day stabilization period for 90 min/day. One of the groups, designated as exercising, walked at 5.6 Km/hr to become heat acclimatized while the second, called sedentary, remained inactive under the same conditions, and thus developed no measure of heat acclimatization. On the final control day (21°C/10°C, dry/wet bulb) and the first and seventh days of recurrent heat exposure, brachiovenous catheters were introduced for serial blood sampling at 0, 20, 45, and 90 minutes. Thus, this experimental design allowed serial blood samples prior to, at the start of, and after the acclimatization process in the exercising and sedentary group as well. Under the carefully controlled conditions of these experiments, we could then evaluate the enzymatic, neurohormonal, and cationic responses to recurrent exercise in the heat and hopefully relate these alterations to the process of heat acclimatization.

Progress:

We have completed numerous quantitative analyses on the blood plasma and 24 h urine samples taken from these test subjects with a number of interesting results. Hematocrit ratios, although not significantly affected by the acute heat or mild exercise regiment described in this study, changed subtly and all plasma analyses were corrected for these alterations in order to insure accuracy. On the first day of exercise in the heat, total plasma protein increased significantly; yet after acclimatization this response had been attenuated. However acclimatization was unable to repress increments in levels of creatine phosphokinase as a result of mild exercise in the heat. Lactate dehydrogenase, although displaying trends toward increasing levels of

activity in the exercising group on both the first and final days of heat exposure, was less sensitive as an indicator of mild exercise coupled with acute heat. Both plasma enzymes, glutamate-oxaloacetate transaminase and glutamate-pyruvate transaminase, seemed to be more sensitive to the heat as evidenced in several significant increments among the sedentary men on both days 1 and 7 of heat exposure.

Although hypokalemia, or reduced potassium concentration, has been identified as a factor predisposing to heat injury, relatively few studies have addressed the effects of heat acclimatization on plasma potassium responses, and to the best of our knowledge, none has investigated whether the acclimatization process can reduce potassium efflux from muscle tissue as a result of intermittent exercise in the heat. As anticipated, the mild exercise program described herein effected a moderate increase in plasma potassium levels probably reflective of potassium efflux from muscle. Interestingly, after acclimatization this potassium efflux was attenuated with significant reductions attained 45 minutes on the final day of exercise in the heat. While plasma levels of sodium displayed no significant inter-or intra-group differences, urinary sodium loss was significantly reduced in the exercising men.

Plasma cortisol, long considered to be a primary endocrinological manifestation of generalized stress response, demonstrated extremely high levels even prior to exposure to heat or exercise. During the serial sampling times these levels were reduced, particularly in the sedentary men, while the mild exercise program seemed to preclude attentuation in the exercising group. Patterns of alteration of growth hormone indicated a significant response even to the mild exercise program described here, while heat stress alone, pre- or post-acclimatization, seemed to have no effect upon plasma levels. Plasma total thyroxin levels demonstrated several randomized changes which did not, however, reflect decreased output under the acute conditions described here for either the walking or sedentary group. The mild exercise program effected significantly reduced

levels of plasma insulin which were not affected by the recurrent heat exposure.

Conclusions:

We concluded from these studies that the process of heat acclimatization cannot attenuate the anticipated muscle enzyme response to exercise in the heat. Alternatively, the data indicated that acclimatization might be adaptive to tissue retention of potassium as manifested in reduced plasma levels in exercising men after acclimatization. Adrenocortical activity was significantly reduced by continued heat exposure despite the fact that thyroid activity, as reflected in levels of total T_4, was unaffected by recurrent exposure. Growth hormone secretion was stimulated by even the mild exercise described herein while insulin levels were reduced. Generally, however, the process of acclimatization failed to affect biochemical and neuroendocrinological responses to recurrent exercise in the heat. Also, we concluded from these experiments that it is difficult to relate degree of either heat acclimatization or level of physical fitness to plasma biochemical responses, although it should be noted that we are considering here a limited number of test subjects and very specific environmental and work conditions.

Future Plans:

Studies of this nature approach a problem of recurrent interest to the US Army - namely, the attempt to identify quantifiable biochemical correlates which can be associated and identified with the ability (or inability) of an individual to be minimally affected by adverse environmental conditions. As such, it is anticipated that similar experiments will be continued at this Institute as resources permit.

(83051)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA 0A 6148	76 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. DISP'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	3E762777A845	00	051
b. CONTRIBUTING	6.27.58.A	3A762758A827	00	051
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: NOT APPLICABLE

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:*

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 76 (7T)	14 (6)	460 (154)
FISCAL YEAR CURRENT 77	9.5	305.7

19. RESPONSIBLE DOD ORGANIZATION

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20. PERFORMING ORGANIZATION

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

NAME:* Maher, John T., Ph.D.

TELEPHONE: 955-2851

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) Hypoxia; (U) Disabilities; (U) Sensory Processes; (U) Combat Effectiveness; (U) Pharmacology.

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) (1) Carbon dioxide supplementation accentuates the hypoxemia of altitude via impaired oxygen diffusion. (2) Myocaridal catechol-o-methyltransferase levels were elevated in chronically hypoxic goats. This suggests the possibility that increased enzymatic catabolism is causally related to the attenuated cardiac responsiveness to adrenergic stimulation observed under hypoxic conditions. (3) A significant alteration of blood coagulation in normal men, suggestive of a hypercoagulable state, occurs during acute exposure to hypobaric hypoxia. (4) The effects of increased arterial oxygen content during sojourn at high altitude exceed those of reduced maximal cardiac output, resulting in increased systemmic oxygen transport and maximal oxygen uptake. (5) Altitude induced polycythemia is of value in increasing work capacity at high altitude. Resources utilized during FY 7T: Professional Man Years 6 ; Funds (in thous) $ 154 .

*Available to contractors upon originator's approval.

* U.S. GPO: 1974—540-843/8691

Program Element: 6.27.58.A MILITARY MEDICAL INVESTIGATIONS

Project: 3A762758A827 Military Environmental Medicine

Work Unit: 051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations

Study Title: Medical and Operational Problems in a Selected Military Population at High Altitude

Investigators: John T. Maher, Ph.D.; Joseph C. Denniston, MAJ, VC; Jimmie T. Sylvester, MAJ, MC; Allen Cymerman Ph.D.; James J. Jaeger, CPT, MSC; Joel J. Berberich, CPT, MSC and John L. Kobrick, Ph.D.

Background:

More than 10 million people live in various parts of the world where altitudes are above 3600 meters, and which are also areas of particular political instability. Because they are natural geographic boundaries and buffer zones between world nations, they become sites of border disputes and confrontations, one of which was the 1962-63 Chinese invasion of the Indian Himalayas. The extensive medical problems and marked decrements in military performance experienced by the Indian troops, due to their lack of high altitude acclimatization, highlight the importance of altitude research in meeting military requirements. High altitude pulmonary edema (HAPE) reached 15.5%, and the physical exertion, cold exposure, and anxiety involved are thought to have contributed to this high incidence. This figure represents only the clinically obvious cases; subclinical incidence could well have been even more common. In fact, it is quite possible that subclinical HAPE may be even more frequent in occurrence than is commonly

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realized. Visitors to mountainous regions of the United States who contract shortness of breath and cough might well show changes indicative of HAPE in chest roentgenograms and other measures of lung function if they were taken. While this is speculative, there is other suggestive evidence that HAPE should be considered an uncommon disease because of its infrequency of recognition rather than its occurrence, and may be found more often than expected in civilian and military sectors.

Other disabilities commonly encountered at high altitude are acute mountain sickness, characterized by headache, nausea, insomnia, and lassitude (AMS), decreased work capacity, and reduced capability for perceptual and intellectual function. These effects, particularly in the first few days following arrival, can seriously jeopardize military operations, as was the case with the Indian troops in the India-China war. In recognition of the possibility that U.S. forces may be required to operate at high altitude in peace-keeping or disaster-response roles, the present study was conducted to investigate the nature, incidence, and severity of subclinical and clinical pulmonary edema in unacclimatized soldiers abruptly committed to a combat military training exercise at high altitude. Empirical data on the nature and magnitude of military performance decrements, indices of visual perceptual capability, and personality and personal history information were also obtained.

Progress:

Two "A" teams of 12 men each, of the 10th Special Forces Group, Fort Devens, MA, were used as subjects. Thorough historical, physical and roentgenographic examinations were first performed on all men to insure normality. Following a 2-day period of baseline measurements on the tests to be described, the troops were transported to a low elevation site (300-1040 meters) in the White Mountain National Forest, NH. Thereafter, they completed an abbreviated scenario which was judged for military effectiveness by Special Forces umpires using their own standard performance scales.

The subjects were also rated by self-administered quesionnaires, post-maneuver interviews, and records of illnesses and symptoms treated by Special Forces medical corpsmen.

One week after the low altitude phase, the subjects were air transported into Peterson Field, CO, and were then taken overland to Pike National Forest, where they completed a 3-day tactical maneuver at elevations of 3600-4300 meters.

The following measurements were made during sea level pre-testing:

1. physical examination
2. 12-lead electrocardiogram,
3. test of ability to perceive geometric shapes embedded in concealing background material, to determine basic perceptual capability,
4. paper and pencil personality test, to determine basic personal traits for later comparison with possible stress responses,
5. questionnaire of personal history and experience which could relate to stress tolerance.

The following measurements were also obtained during sea-level testing, and again prior to, midway through, and after both the low and high altitude maneuvers:

1. closing volume, a sensitive measure of incipient pulmonary edema reflecting fluid accumulation in the peribronchial and perivascular interstitial spaces,
2. vital capacity, the maximum amount of air which can be forcefully expired from the lungs after maximal inspiration, expected to be a sensitive measure of edema,
3. pulmonary compliance, the slope of the static transpulmonary pressure/lung volume curve, which has shown alteration in acute pulmonary vascular congestion or edema, although not necessarily in mild to moderate degrees of pulmonary interstitial edema,
4. thoracic impedance, a measure of electrical resistance to alternating current, which should be expected to show impedance changes due to fluid increases in pulmonary edema,

5. chest X-rays, which should show characteristic changes in pulmonary density during HAPE,

6. alveolar/arterial oxygen gradients, which should show an overall reduced efficiency of oxygen transport across the lung,

7. a test of perceptual efficiency across the entire visual field, consisting of a number matrix flashed repeatedly but briefly on a screen, which the subject must attempt to perceive correctly in detail.

Military performance tests were also obtained periodically throughout all three phases of the test. These included assembly and disassembly of three basic military weapons, radio communication tasks, code encription and decription, overland navigation, and tactical acquisition and mock demolition of selected military targets. Data collection was completed, and analysis is underway.

Program Element: 6.27.58.A MILITARY MEDICAL INVESTIGATIONS

Project: 3A762758A827 Military Environmental Medicine

Work Unit: 051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevation

Study Title: Mechanism of the Attenuated Cardiac Responsiveness to Adrenergic Stimulation in Hypoxia

Investigators: John T. Maher, Ph.D., Joseph C. Denniston, MAJ, VC, Allen Cymerman, Ph.D. and Danney L. Wolfe, CPT, VC

Background:

Recent studies carried out in this Laboratory have demonstrated a significant attenuation of both the chronotropic and inotropic response of the heart to β-adrenergic stimulation following chronic exposure to hypobaric hypoxia. However, the mechanism of the attenuation has not been elucidated. In this connection, three factors warrant consideration. Firstly, the possibility cannot be excluded that chronic hypoxia is associated with a more rapid rate of inactivation of catecholamines, i.e., effectively less of a stimulus. The two enzymes that are of major importance in the metabolic transformation of catecholamines in the mammal are catechol-O-methyltransferase (COMT) and monoamine oxidase (MAO). Secondly, an increased level of parasympathetic activity during chronic hypoxia could also account for the attenuated response. The level of vagal activity in hypoxia can be determined by blockage of this limb of the autonomic nervous system with atropine. A third possible explanation for the diminution in responsiveness is that the elevated level of sympathetic activity accompanying hypoxia may result in a relative refractoriness of the cardiac β-receptors - somewhat analogous to a tachyphylaxis.

The present study was designed to identify the causal factor(s) in the abnormal cardiac response to chronic hypoxia. Understanding of the mechanisms responsible for the altered function appears to be a valuable basis for management of the performance decrements of high altitude.

Progress:

Observations were made in six intact, conscious goats at sea level and in another six goats maintained in a chronically hypoxic state (4,300 meters) for 10 days. No differences in cardiac frequency and several indices of myocardial contractility were demonstrable between the normoxic and chronically hypoxic groups either before or after cholinergic blockage with 1.0 mg/kg iv of atropine methyl bromide. Following hemodynamic studies, the animals were stunned, thoracotomies were performed and biopsies were obtained from each of the cardiac chambers. Myocardial MAO concentrations were unaltered by chronic hypoxia. However, mean COMT levels were significantly elevated above sea level values in both atria and ventricles of the hypoxic animals. Analyses of tissue catecholamines are on-going.

Conclusions:

The preliminary finding that myocardial catechol-O-methyltransferase activity in chronically hypoxic goats was elevated suggests the possibility that increased enzymatic catabolism is causally related to the attenuated cardiac responsiveness to adrenergic stimulation in this condition.

Future Plans:

Additional work in this area must await completion of biochemical and data analyses.

Program Element: 6.27.58.A MILITARY MEDICAL INVESTIGATIONS

Project: 3A762758A827 Military Environmental Medicine

Work Unit: 051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations

Study Title: Human Coagulation Abnormalities during Acute Exposure to Hypobaric Hypoxia

Investigators: John T. Maher, Ph.D., Peter H. Levine, M.D. and Allen Cymerman, Ph.D.

Background and Rationale:

Sudden exposure of lowlanders to elevations above 3,000 meters causes a high incidence of acute mountain sickness (AMS). Various theories have been advanced in an attempt to explain the etiology of the disorder; however, we still do not understand clearly the immediate pathogenic mechanisms. On the basis of evidence drawn from human and animal studies, it has been recently suggested that the symptoms of AMS result from brain cell edema and distortion of intracranial structures secondary to increased cerebral pressure. It is of interest in this connection that platelet and fibrin agglutination and microthrombi have been found in the brain and lung capillaries of monkeys exposed to hypobaric hypoxia, as well as in the lungs of humans succumbing to a more serious, though less frequent, medical disorder incident to acute hypoxic exposure; namely, high altitude pulmonary edema. If several of a cluster of capillaries are occluded, then those remaining patent are subjected to greatly increased pressure and flow. Thus, cerebral vascular occlusion by microthrombi may be expected to increase pressure and conceivably result in brain cell edema and compression with attending headache, nausea and dizziness - prominent symptoms of the acute mountain sickness syndrome.

The purpose of the present study was to preliminarily examine this hypothesis by determining whether or not coagulopathies are demonstrable at altitude concurrent with the development of AMS.

Progress:

Multiple coagulation studies were carried out in eight healthy young men at sea level (SL) and after 1, 24 and 48 hours at a simulated altitude of 4,400 meters. Platelet aggregation, as induced by ADP, epinephrine and collagen, was not significantly altered by high altitude (HA) exposure. Mean, 2,3-diphosphoglycerate, a physiological inhibitor of platelet aggregation, rose ($P<.001$) after 24 hours at HA and remained elevated while no changes in circulating catecholamines were observed. Platelet count, factor 3 availability and membrane lipid peroxide formation were likewise unaltered at HA, as were prothrombin and thrombin times and protamine paracoagulation test. However, mean partial thromboplastin time was significantly shortened ($P<.01$) after 1 and 24 hours at HA, recovering to SL control by 48 hours. Fibrinogen and Factor VIII levels also fell ($P<.01$ and $P<.02$) after 1 hour at HA but returned to the preexposure values by 24 hours. Fibrin degradation products were transiently detectable in 3 subjects at HA. Headache, nausea and dizziness were maximally present after 24 hours at HA and tended to remit thereafter.

Conclusions:

Although normal platelet function did not appear to be modified by short-term exposure to simulated high altitude, evidence for a coagulopathy was obtained. Inasmuch as the multiple coagulation abnormalities were observed concurrent with the development of acute mountain sickness, a causal relationship cannot be discounted.

Future Plans:

Studies will be carried out at high altitude to assess symptomatology in subjects pre-treated with an anticoagulant in an effort to shed further light on the nature of the relationship between coagulation defects and acute mountain sickness.

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrail Elevation
Study Title:	$\dot{V}O_2$ Max, Endurance Performance, Oxygen Delivery as Functions of Prolonged Stay at High Altitude
Investigators:	Donald Horstman, Ph.D., Richard Weiskopf, M.D. and Ronald Jackson, M.D.

Background:

The abrupt exposure of man to terrestrial altitudes in excess of 3000m is accompanied by a decrement in maximal oxygen consumption ($\dot{V}O_2$ max) and in the ability to perform prolonged physical work (endurance performance). With residence at high altitude for 2 to 3 weeks some recovery of endurance performance occurs, although alterations in physiological factors involved in prolonged work, such as $\dot{V}O_2$ max, have not been clearly established. $\dot{V}O_2$ max is a function of maximal systemic O_2 transport (TO_2 max), the product of maximal cardiac output ($\dot{Q}$ max) and arterial O_2 content (C_aO_2). When C_aO_2 is reduced with acute hypoxia, $\dot{V}O_2$ max is reduced in exact proportion. With prolonged hypoxic exposure, C_aO_2 increases as a result of both increased arterial O_2 capacity (O_2 cap) and increased arterial O_2 saturation (S_aO_2). With increased C_aO_2 one would expect an increase in $\dot{V}O_2$ max, however, chronic exposure to hypoxia has also been shown to result in reduced $\dot{Q}$ max. The question remains as to what extent increased C_aO_2 and reduced $\dot{Q}$ max balance each other and the resultant effects of this balance on $\dot{V}O_2$ max. This information is significant relative to the relationship of endurance performance to $\dot{V}O_2$ max. Although many factors affect endurance performance, if $\dot{V}O_2$ max increases, one would expect a concommitant increase in endurance performance. The purpose of this study

was to determine the effects of extended sojourn at 4300 m, and the relative value of altitude induced polycythemia, on $\dot{V}O_2$ max, endurance performance, and related factors.

Progress:

$\dot{V}O_2$ max, TO_2 max, the components of TO_2 max, i.e., Q max and C_aO_2, and endurance performance were determined in 9 male volunteers within 36 hours of arrival and again after two weeks at 4300 m. After two weeks, VO_2 max and TO_2 max increased 10% as compared to values obtained at 36 hours. Increased TO_2 max was the result of an 18% increase in C_aO_2 and an 8% decrease in Q max. A 12% increase of O_2 cap and a 6% increase of S_aO_2 produced the increased C_aO_2. Endurance time to exhaustion at a constant work intensity (5.5 mph, 1% grade) increased 60% after two weeks.

The effects of polycythemia were evaluated after three weeks at 4300 m as measurements were repeated following the removal of 450 ml of whole blood (volume replaced with IL Ringer's solution) from 5 of the subjects (BLED), with the remaining 4 subjects acting as controls (SHAM). For this procedure a double blind design was utilized; all subjects underwent identical procedures (including anticubital venipuncture) with the exception of actual blood removal. Knowledge of which subjects were BLED and which SHAM was withheld from the subjects and all members of the research team except the medical monitor. Hematocrit (hct) decreased to levels similar to those observed at 36 hours for BLED and remained unchanged for SHAM. $\dot{V}O_2$ max and TO_2 max for BLED were reduced 7% and 6%, respectively. C_aO_2 fell 12% as a result ofan 11% fall in O_2 cap; Q max increased 6%. All physiological parameters for SHAM remained unchanged. A 50% reduction in endurance time to exhaustion at 5.5 mph, 1% grade occurred for BLED, while no change occurred for SHAM.

Conclusions:

We concluded that the effects of increased C_aO_2 during three weeks sojourn at 4300 m exceed those of reduced $\dot{Q}$ max, resulting in increased TO_2 max and $\dot{V}O_2$ max. Further, altitude induced polycythemia is a major contributor to increased TO_2 max and is of value in increasing work capacity at high altitude.

Future Plans:

Manuscripts are in preparation. We are considering testing the efficacy of altering the potential for increased C_aO_2 prior to high altitude sojourn, and the effects on work capacity. This would take the specific forms of increasing hct, increasing ventilatory drive, and/or shifting the oxygen-dissociation curve.

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	Hypoxemia during CO_2 Supplementation at High Altitude
Investigators:	F. G. Heineken, Ph.D.; G. F. Filley, M.D.; J. T. Reeves, M.D.; R. F. Grover, M.D., Ph.D.; John T. Maher, Ph.D.; Julio C. Cruz, M.D.; Joseph C. Denniston, MAJ, VC; and Allen Cymerman, Ph.D.

Background:

In a recent study, the addition of carbon dioxide (CO_2) to the inspired air of normal subjects during five days at high altitude was accompanied by unexpected hypoxemia, particularly during maximum exercise, when compared to a control group. The alveolar oxygen tensions as calculated from the alveolar gas equation were similar in the two groups indicating an excessively wide alveolar-arterial oxygen difference ($A\text{-}aDO_2$) in the group breathing supplemental CO_2. There are no experiments reported previously of long-term CO_2 supplementation at high altitude. Thus, we wished to examine the apparent widening of the $A\text{-}aDO_2$ because it represents a novel finding of unknown mechanism.

Progress and Conclusions:

Using hypobaric chambers, two groups of healthy young men were exposed to reduced atmospheric pressure for a period of 5 days. One group (CO_2 group) had supplemental CO_2 (3.77%) added to the room air mixture for the

entire 5-day period with an atmospheric pressure of 455 mm Hg. The other group (control group) breathed a normal (21% O_2, 79% N_2) air mixture at an atmospheric pressure of 440 mm Hg. The chamber pressures were adjusted to give similar P_AO_2 values for each group based on calculations from the alveolar gas equation with the assumption that $P_ACO_2 = P_aCO_2$. During maximal exercise, P_aO_2 fell to 39 mm Hg for the CO_2 group whereas the P_aO_2 for the control group fell to 48 mm Hg. This gave an unexpectedly high alveolar-arterial oxygen difference for the CO_2 group of 23 mm Hg when compared to the control group value of 15 mm Hg. Another unexpected finding during maximal exercise in the CO_2 group was the observation that the mixed expired P_{CO_2} equalled the arterial P_{CO_2} measurement. This implies that $P_ACO_2 > P_aCO_2$ if one assumes a finite dead space for the CO_2 group. Assuming equivalent dead spaces for both groups, a corrected P_ACO_2 value for the CO_2 group can be estimated. Such an estimate lowers the calculated P_AO_2 value for this group by 3 mm Hg. Calculated A-aDO_2 values for each group based on estimates for $\dot{V}_A/Q$ mismatching showed no significant difference between the two groups. Thus, the remaining 5 mm Hg of 8 mm Hg A-aDO_2 between the two groups was attributed to impaired O_2 diffusion in the group breathing supplemental CO_2.

Future Plans:

Studies have been designed to explore the mechanism of the impaired pulmonary oxygen diffusion in subjects given supplemental carbon dioxide at high altitude.

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6127	76 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. DISP'N INSTR'N	8B. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	6.27.58.A	3A762758A827	00	052
b. CONTRIBUTING				
c. ~~XXXXXXXX~~	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U)The Relationship between Physical Exercise and the Health, Efficiency and Morale of the Soldier (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
73 07		DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: Not Applicable EXPIRATION:
b. NUMBER:*
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 76(7T)	15 (5)	350 (70)
FISCAL YEAR CURRENT		

19. RESPONSIBLE DOD ORGANIZATION
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ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL
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20. PERFORMING ORGANIZATION
NAME:* USA RSCH INST ENV MED
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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* VOGEL, James A. Dr.
TELEPHONE: 955-2878
SOCIAL SECURITY ACCOUNT NUMBER:

21. GENERAL USE
Foreign Intelligence Not Considered

ASSOCIATE INVESTIGATORS
NAME: HORSTMAN, Donald H. Dr.
NAME: 955-2879 DA

22. KEYWORDS (Precede EACH with Security Classification Code)
(U)Facilitation of Work; (U)Physical Exercise; (U)Physical Fitness; (U)Endurance Performance

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

23. (U)In order to make physical training in the Army more efficient and effective, the following questions require resolving: (1) What benefits are accrued from physical training; (2) what is the most efficient means of training in terms of intensity, duration, frequency and mode; and (3) how do levels and objectives for training and/or fitness vary for different military populations?

24. (U)Research will include studies to determine optimum levels of fitness and training methods in respect to baseline requirements, MOS, unit assignment, age and sex.

25. (U)75-07 - 76-09 (1) Studies of physical fitness of basic trainees indicate that male soldiers have 25% more aerobic fitness and 30-50% more muscle strength than female soldiers at the start of basic training. While men showed improvement in both aerobic fitness and muscle strength during the seven weeks of basic training, women showed none. (2) Women undergoing the Military Academy men's basic training program exhibited excellent responses in aerobic fitness. A specific muscle strength program in these women produced equivocal results. (3) The isokinetic mode of muscle strength training appears to produce more rapid gains in the strength of some muscle strength compared to the isotonic and isometric modes. (4) A very low incidence of coronary risk factors was found in a 35-50 year old officer population where physical fitness was emphasized. This work unit is being terminated and work reported under several new work units. Resources utilized during FY 7T: Professional Man Years 5 ; Funds $ 70 (in thous).

*Available to contractors upon originator's approval.

Program Element: 6.27.58.A MILITARY MEDICAL INVESTIGATIONS

Project: 3A762758A827 Military Environmental Medicine

Work Unit: 052 The Relation Between Physical Exercise and the Health, Efficiency and Morale of the Soldier

Study Title: Efficacy of Performance Capacity Tests for the Armed Forces Examination Station

Investigators: Dennis Kowal, CPT, MSC, Ph.D. and James A. Vogel, Ph.D.

Background:

The Armed Forces Epidemiological Board recently made the following recommendations: a) "that consideration be given to supplementing the (body) weight standards with standards for physical fitness ..." and b) "that studies be undertaken to determine whether physical fitness testing at Armed Forces Entrance Examination Stations is feasible, and if so, to define standards in relation to performance during basic combat training." In response to these recommendations, this study has been designed to evaluate the efficacy of tests of performance which have been suggested by this Institute for the AFEES application.

Specifically, this study is designed to:

a. Evaluate the feasibility of implementing work, strength and fatness measures at an AFEES, taking into consideration such problems as timing, scheduling, operator training, and reliability.

b. Collect demographic data and establish norms for inductees regarding predicted $\dot{V}O_2$ max, muscle strength and body fatness.

c. Relate above data to assessment of previous physical activity history and attitude toward exercise.

d. Provide data for later follow-up on the relation between these fitness scores and actual PT test scores and attrition in BT and AIT.

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Design: A study has been carried out at the Boston area AFEES. A minimum of 15 subjects were briefed and participated in the study per day. Only those individuals who had satisfactorily completed a physical examination and had been sworn into the Armed Forces were utilized.

Progress:

The preliminary results for muscular strength in men and women entering service are presented in the following Table.

Table 1. Comparison of male and female strengths in 5 major muscle groups (Mean ± SD) in ft/lbs.

	Male	Female	% Diff
n	184	25	
Arm flexors	49 ± 12	26 ± 7	-53
Leg extensors	411 ± 107	255 ± 54	-60
Back flexors	167 ± 41	98 ± 23	-59
Stomach flexors	133 ± 43	69 ± 25	-51
Upper torso strength	229 ± 35	114 ± 15	-50

As can be seen, the average differences between men and women for the major muscle groups is about 50%. This value is somewhat higher compared to that found previously by this laboratory at a basic training center. However, the men's strength levels were comparable to those reported by other investigators. The predicted oxygen uptake values ($\dot{V}O_2$ max) for women were 10% lower than men.

Future Plans:

A new protocol will be written to expand on this pilot study. Additional fitness tests will be evaluated and samples from several AFEE Stations will be obtained.

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	052 The Relationship between Physical Exercise and the Health, Efficiency and Morale of the Soldier
Study Title:	A Comparison of the Effects of Two Types of Physical Training Programs on the Performance of 16-18 Year Old Women
Investigators:	Dennis Kowal, CPT, MSC, Ph.D.; James Vogel, Ph.D.; James Peterson, Ph.D.[1] and Louis Tomasi, A.T.C.[2]

Background:

Every year the United States Military Academy (USMA) selects approximately 1400 individuals for admission. Beginning with FY 1976-77, the entering class will include women candidates. A review of the literature indicates substantive physiological differences between men and women (Peterson, 1975).

The lack of research on the consequences of different training programs for women leaves many unanswered questions relating to what type of training program is best suited for women and what results can be obtained from different types of programs. This study attempted to provide answers to these questions.

Progress:

Sixty women high school athletes, 16-18 years of age participated in the study lasting 8 weeks. Participants were randomly assigned to one of three exercise groups after the pretest measures had been accomplished.

1. Associate Professor, OPE, USMA, West Point, NY
2. Athletic Trainer, OPE, USMA, West Point, NY

a. An experimental group (N=20) participated in a strength training program. This program consisted of 3 days a week prescribed weight exercises utilizing free weights, Universal gym and Nautilus equipment.

b. An experimental group (N=20) engaged in a program of Reveille calesthenics and exercises comparable to that given to the cadets during the first two months of new cadet basic training. This program was conducted on a 4 day a week basis, including endurance runs and grass drills.

c. A control group (N=20) maintained their normal physical activity schedule and did not participate in a formal training program. The following measurements were made during the week before and the week following the training period. Anthropometric measurements; determination of maximal aerobic power; muscular strength, both isometrically and isokinetic, of selected muscle groups; a psychological profile, performance measures including score on the PAE (physical aptitude examination) required for entry into the Academy and 1½ mile run time.

Body weight remained constant in both training groups while the control group had a mean increase of 2.6 kg (5.7 lbs). Only the Reveille training group showed a small decrease in per cent body fat (−4%).

$\dot{V}O_2$ max increased by 10.4% and 10.2%, l/min and ml/kg . min, respectively, in the Reveille group as compared to no change in the control group. The strength group exhibited a 6.4 and 6.9% increase in these same parameters respectively. Significant increases in $\dot{V}_E$ were also noted for both the Reveille and Strength Groups while the Reveille group also had a decrease in maximal heart rate.

The observed increase in $\dot{V}O_2$ max with these training programs is even more significant when one considers their initial relatively high levels of aerobic fitness. Although normative data is scarce for young females, a level of 43 ml/kg . min at the beginning of the study appears to clearly place them into the athletic category.

There was a shift in the measures of psychological health and well being following seven weeks of training. However, while significant changes did occur post-training on several of the mood measures, there were no reliable differences between the three groups either pre- or post-training as indicated by the lack of significant interaction term. These findings suggest that the improvement in psychological states occurred in all groups regardless of whether they were involved in training or not. This finding documents the prevasiveness of the Hawthorne phenomena that so often plays havoc with behavioral research.

In respect to muscle strength assessment, static leg strength did not improve in the strength training group but dynamic strength improved 12% after training. The other two groups displayed no reliable improvement, but dynamic endurance for the strength group improved 14%, but the Reveille group improved a substantial 28%. This latter improvement in arm strength endurance may be attributed to the extensive use of push-ups during their training.

Both training groups also showed a significant ($P < .05$) improvement in the flexed arm hang times, the times for the 300 yard shuttle run and the total overall score when compared to the control groups past performance on the physical aptitude examination (PAE).

A comparison of times for the 1½ mile run showed an improvement for the Reveille Group of 15% and an improvement in the strength training group's performance of 10%. The latter was not expected since they did not participate in any CV endurance training. It suggests the possibility that the strength training was done at a sufficient intensity (i.e., enough to sustain a HR above 150 for 30 min) to be an adequate stimulus to produce a CV training effect. However, this finding still remains to be unequivocally demonstrated.

Conclusions:

The physiological response of the young women in the Reveille Group can be classified as both quantitatively and qualitatively similar to the better documented responses of men to training. The decrease in percent body fat, decrease in submaximal heart rate and ventilation, decrease in maximal heart rate and the 10% increase in $\dot{V}O_2$ max are all typical of responses to a good aerobic training program in young untrained males. More valid comparisons of male and female responses to training will await studies in which both sexes are subjected to identical training programs.

Future Plans:

A series of studies is tentatively planned for next summer in collaboration with the OPE Staff. These studies would concern both male and female responses to training of both selected muscle groups and CV endurance.

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	052 The Relationship between Physical Exercise and the Health, Efficiency and Morale of the Soldier
Study Title:	An Evaluation of Physical Fitness in Men and Women Before and After Basic Training
Investigators:	James A. Vogel, Ph.D.; John F. Patton, CPT, MSC; Marcos U. Ramos, MAJ, MC and Dennis M. Kowal, CPT, MSC

Background:

This study was designed to meet two objectives: 1) to determine the initial level of physical fitness of both male and female personnel upon entry on active duty, and 2) to assess the amount of improvement in fitness gained through six weeks of basic training.

The study was carried out in October 1975, using a cross-sectional approach. Approximately 100 males and 100 females were evaluated during the first and also during the final (sixth) week of training. Evaluation included weight and estimated body fat from skin folds, maximal aerobic power measured directly on the treadmill, muscle strength and endurance of arm and leg flexor and extensors, a submaximal bicycle predictive test of aerobic power and psychological inventories.

Selected results are shown below:

	MALES		FEMALES	
	1st Week	6th Week	1st Week	6th Week
Body fat (kg)	11.8	8.9	16.6	17.8
$\dot{V}O_2$ max (ml/kg . min)	50.8	55.1	38.1	39.5
Knee flexor strength (ft. lbs)	87.0	94.0	59.0	59.0
Arm extensor strength (ft. lbs)	43.0	55.0	29.0	29.0

Principle findings can be summarized as follows:

a. Women tend to gain body fat and total body weight during training. Woman have twice the percent body fat as men.

b. Overall fitness or maximal aerobic power as measured by maximal oxygen uptake ($\dot{V}O_2$ max) and expressed in units of ml per kg of body weight, increased significantly in men with basic training but not in women. Women's aerobic power is approximately 25% less, based on body weight and 12% less based on lean body mass.

c. The bicycle predictive tests showed a definite sex difference: it over predicted for women and under predicted for men. In addition, the difference due to training in men was not reflected with the predictive test.

d. Absolute arm strength of women trainees was 60-70% of males while leg strength was 50-60% of males. Males exhibited a greater training response on the average than females.

e. Women exhibited no meaningful psychological or attitudinal changes during basic training, possibly related to the less demanding nature of their program. For men, on the other hand, the profile of emotional states was significantly improved. Men also showed favorable changes in both attitude toward exercise and one's physical self concept.

Future Plans:

Additional studies will be designed to further evaluate women's response to physical training and to explore the behavioral aspects - perception of effort and self concept.

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	052 The Relationship between Physical Exercise and the Health, Efficiency and Morale of the Soldier
Study Title:	Cardiovascular Fitness and Health in a Selected Army Officer Population 35-50
Investigators:	Dennis Kowal, CPT, MSC, Ph.D.; James A. Vogel, Ph.D. and Joseph Paris, M.D., MAJ, MC*

Background:

The need for physical fitness standards in personnel over 39 years of age has been identified by TRADOC as a pertinent problem area confronting the Army. AR 600-9 "Army Physical Fitness Training", does not now provide training guidelines or standards for personnel over the age of 39. A revision of this AR is anticipated which will include requirements beyond this age. Therefore, it will be necessary to develop modified programs and standards based on the increased risk of cardiovascular accidents that has been documented in the civilian populations over the age of 35. The objective formulation of training guidelines, testing standards, and risk factors involved require that the Army develop a data base on which to make recommendation for the development and implementation of such a fitness training program.

While the decline in fitness and the increased risk for CHD with age has been clearly documented, lack of fitness alone is not the singularly most important risk factor for this age group. In a military subpopulation, psychological stress factors and a personality/emotional complex designated as "Type A" may play a much greater pathogenetic role in the development of CHD. With the considerable investment (both financial and professional) that the Army has in this age group, it is imperative that we gain understanding of the levels of physical fitness, the risk factors

*Dept. of Internal Medicine, West Point Hospital, NY

prevalent in this military subpopulation and the medical advisability of introducing a mandatory exercise training and testing program.

Subjects for this study were 56 officers from the staff of the United States Military Academy (USMA) over the age of 35. This source was selected because of its availability, proximity to this Institute, and the large number in this age category in a single location. Because participation was voluntary, the sample was not random and therefore may not truly represent the total population at the Academy or military at large.

The following evaluations were carried out: (a) Personal History Documentation, activity history, behavioral assessment to develop a psychological profile. Anthropometry; (b) Blood lipid profile; (c) Resting coronary risk factor documentation; (d) Pulmonary function test; (e) Electrocardiographic exercise stress test (Progressive); and (f) Measurement of maximal oxygen uptake ($\dot{V}O_2$ max).

Progress:

The results of the study are as follows:

Pulmonary Function: Fifteen percent of those tested had forced vital capacities below the predicted normal range.

Hypertension: The incidence of hypertension (>160/95 mmHg) was 3%, for borderline hypertension (140/90<BP<160/95) it was 25% of the sample. While the remaining 72% of the group were within normal limits.

ECG Stress Test on Bicycle Ergometer: The incidence of abnormal ECGs suggesting ischemic heart disease occurred in 6% of the officers tested. The test was characterized as positive if the ST segment was depressed 1 mm or more for 80 msec. No other abnormalities were noted. No differences were observed in the incidence of positive stress tests among hypertensives or smokers or individuals with cholesterol levels of greater than 200 mg%.

Cholesterol and Triglycerides: Mean values of cholesterol and triglycerides were 224.44 mg/% and 90.51 mg/%, respectively. Only 28% of the subjects exhibited normal cholesterol levels (<200 mg/%).

Percent Body Fat: The measured body fat averaged 18.56% for the population (35-55 yrs old) was quite good since Brozek and Keys (1953) report that average fat content for men of standard weight and 35 years of age is 18.5%.

Aerobic power and max heart rate values: The distribution of aerobic power is presented by age categories. Though the $\dot{V}O_2$ displayed the expected regression with increasing age it should be noted that all values except one fall within the excellent fitness category.

Age	Max HR	Max $\dot{V}O_2$ l/min	ml/kg/min	*Fitness Category
35-39	182	3.91	49.32	Excellent
40-44	182	3.66	44.79	Excellent
45-49	178	3.53	44.93	Excellent
50-54	180	3.08	41.27	Good

*Based on Astrands (1950) Tables using Max $\dot{V}O_2$ in l/min.

Type A Personality: Any discriminating assessment of the Type A personality syndrome depends on the presence of a sufficient number of subjects who have either had a cardiac accident or experienced angina. Since we were testing only healthy males between 35 and 55 years of age, all that can be said is that for a population of Army officers their mean score on this instrument was 30.5 $\pm$ 5 which can provide us with a baseline for comparison with other military populations.

Personality and Mental Health: A series of psychological instruments were administered to assess this population's mental health and well being. The three tests that we administered were the Eysenck Personality Inventory (EPI); Spielberger State-Trait Anxiety Inventory (STAX); and the Profile of Moods States (POMS). The STAX yields measures of situational and enduring anxiety. The EPI provides measures of introversion-extroversion and neuroticism-stability and the POMS yields measures of tension, depression, vigor, fatigue and confusion.

The profile obtained was one that depicts an emotionally stable, vigorous, healthy population. Anxiety was well under control indicating minimum feelings on inadequacy or self doubts. This profile was what one expects of a successful Army officer who is satisfied with his work.

Conclusions:

In general, this study revealed that the officers evaluated were in excellent physical and emotional condition for their age group. Coronary risk factors were also much lower than expected. However, this may reflect the greater emphasis and participation in vigorous physical exercise in the military than in the average population. The fact that there was a 6% incidence of ischemic heart disease in this sample was important for detection and medical management purposes, but also for indicating that even for asymptomatic, active individuals over the age of 35 years, a rigorous medical exam including an ECG stress test should be required before participating in a rigorous physical activity program.

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	052 The Relationship between Physical Exercise and the Health, Efficiency and Morale of the Soldier
Study Title:	A Psychophysiological Model for the Prediction of Running Performance
Investigator:	Dennis Kowal, CPT, MSC, Ph.D.

Background:

Although maximal aerobic power as measured by maximal oxygen uptake ($\dot{V}O_2$ max) is perhaps the single most valid measure of functional capacity of the cardiorespiratory system, its use is limited to the laboratory because of its technical sophistication. Thus, it is not a suitable procedure for the assessment of $\dot{V}O_2$ max in a field setting. What is necessary is the development of a quick, easy and accurate technique for the estimation of aerobic power (AP). Astrand and Rhyming (1954), Saltin (1964) and Wyndham et al. (1966) using the rectilinear relationship between AP and heart rate (HR) have reported good results using a submaximal HR test for the estimation of AP. Another method used to predict AP has been the distance run test. Cooper, 1968; Balke, 1963; and Doolittle, 1969 have demonstrated that this test can be used to estimate AP. However, since it involves other factors besides max $\dot{V}O_2$, i.e., a combination of this plus other unknown psychological factors, i.e. motivation, prediction may be difficult. This fact would indeed explain the erratic correlation between max $\dot{V}O_2$ and distance run tests. In a summary of much of the research on distance run tests, Disch (1975) reports correlations with max $\dot{V}O_2$ ranging from .34 to .90. From these data it can be concluded that the low values may be a function of the homogeneity of the groups tested, i.e. X-country runners or college athletes; methodological error inherent in the methods measurement of max $\dot{V}O_2$ or other contributing factors not considered.

The purpose of this study was, therefore, to compare the measurement of actual $\dot{V}O_2$ max with the Astrand submaximal HR predictive test and Cooper's 12-minute run test using a multiple regression model which includes psychological measures of personality and motivation. The contention is that this approach may provide a quick and easy predictive model for the field assessment of aerobic power.

Progress:

Means and SD for the predictor and criterion variables are presented in Table I.

The multiple regression analysis presented in Table II yielded a multiple R of .97 for both male and female performance on the 12 minute run test.

This value is significantly greater than that usually found using physiological parameters alone, *i.e. max* $\dot{V}O_2$, *max heart rate.* Thus the use of psychological, as well as, physiological variables may be superior for the prediction of performance in a running performance test.

Conclusions:

The efficacy of a multivariate approach for the prediction of running performance has been demonstrated by showing that physical performance prediction can be improved by considering psychological variables in the prediction equation.

Validation on other endurance tests should be attempted.

TABLE I

	Male	Female
$\dot{V}O_2$ max ml/kg/min	49.67 ±5.21	39.24 ±3.77
Predicted $\dot{V}O_2$ max Astrand-Rhyming	36.32 ±7.76	37.92 ±3.57
Endurance (EPPS)	7.00 ±1.82	6.86 ±1.57
Social Desirability	2.14 ±1.30	3.57 ±1.90
Distance in 12 min run (miles/nearest 55 yd segment)	1.31 ± .24	1.09 ± .09
Extroversion (EPI)	10.5 ± 4.5	13.0 ± 3.6
Emotional Stability (EPI)	6.0 ± 4.7	7.4 ± 3.6

TABLE II

Summary Table of Steps in the Multiple Regression Analysis

Males

Dist. in 12 Minute Run	Coeff of Multiple Correlation	Coeff of Deter.	Change in Coeff	Sign. Level
$\dot{V}O_2$ max	.897	.805	.805	.006*
Endurance	.9743	.949	.144	.028*

Females

Dist. in 12 Minute Run	Coeff of Multiple Correlation	Coeff of Deter.	Change in Coeff.	Sign. Level
Predicted $\dot{V}O_2$ max	.912	.832	.832	.004*
Social Desirability	.9744	.945	.117	.038*

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	052 Relation between Physical Exercise and Health, Efficiency and Morale of the Soldier
Study Title:	Comparison of Three Types of Muscle Strength Training
Investigator:	Marcos U. Ramos, M.D., MAJ, MC

Background:

In traditional Army physical training programs, gain in strength and endurance of key muscle groups comes as a by-product of total body endurance exercises. However, in this area several questions remain unanswered.

1. To what extent is muscle strength important in the total physical fitness of today's soldier.

2. Should basic training include exercise programs guided toward the strengthening of selected muscle groups which are heavily used despite today's highly mechanized Army.

3. What would be the impact of strengthening exercises to the lower extremities in the incidence of stress fractures of the lower extremity skeletal structures.

Several strength training modes are at present advocated by many investigators, athletic coaches and trainers. Despite the large amount of reports on the results of different training programs, identification of the most efficient mode is not possible at present. Comparison of the results from these studies is extremely difficult due to the tremendous differences in methodology, training programs, frequency, intensity and total duration of the training periods.

This study was designed to compare the three most popular strength training programs under strict, standard and controlled conditions. Three training modes were compared: (a) isotonic (iso-same; tonic-muscular tone), using free hanging weights; (b) isometric (iso-same; metric-muscle length) the selected muscles exerted tension against an immovable object; and (c) isokinetic (iso-same, kinetic-speed of movement) where an electronic system controlled the speed at which the resistance was overcome.

Progress:

Between February and May 1976, 42 students at Fort Devens, MA, volunteered as subjects in a 10 week training period. After a complete physical examination, followed by the initial gathering of anthropometric, psychological, general fitness and muscle strength information, they were randomly assigned to one of four groups: Control, Isokinetic, Isometric, and Isotonic groups.

They trained 3 times per week for a total of 10 weeks. In order to avoid the variabilities of other previous comparative studies, the following parameters were standardized.

1. Identical stabilization of the body segments and total body posture.

2. Standard predetermined level of the muscle contraction (80% of maximal).

3. Standardized contraction - rest cycles (3 second contractions, 3 seconds rest).

4. Standard number of contractions (50).

5. Standard duration of each exercise - (5 min.).

After the 10 weeks of training, data similar to the one obtained in the initial, pre-training stage were gathered.

Conclusions:

Preliminary results seem to indicate that the group training in the isokinetic mode showed the greatest improvement in maximal force exerted.

Nevertheless, these data are still being analyzed in order to determine also the amount of work done during the training, the ability to develop strength at an optional rate (rate of force development), and also to study the impact of each of these strength training programs in the general fitness, psychological parameters, blood lipids and in the general attitude toward physical training in general.

Future Plans:

After completion of the aforementioned analysis, there are plans to create a Computer Stored Data Base to allow us to interrelate the muscular strength, general stamina ($\dot{V}O_2$), psychological and biochemical (blood lipids) components which are encompassed in the concept of physical fitness.

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	052 **Relation between Physical Exercise and Health, Efficiency and Morale of the Soldier**
Study Title:	Submaximal O_2 Consumption and O_2 Dept Contraction: The Effects of Breathing 80% O_2 Mixtures
Investigators:	Paul D. Allen, MAJ, MC and Kent B. Pandolf, Ph.D.

Background:

It has been held that O_2 availability is one of the most likely factors in limiting the body's ability to perform heavy muscular work. This has been based on demonstration of an increased "performance" when hyperoxic mixtures are breathed. Welch has demonstrated an increase in $\dot{V}O_2$ at submaximal loads by increasing the O_2 content to the breathing mixture.

The plan of this study was to examine whether or not the mechanism for this apparent increase in O_2 consumption during exercise was in part due to a repayment of the O_2 debt before the end of exercise. Secondly, the effects of PO_2 as a cue in perceived exertion by the subjects performing a submaximal and near maximal run were evaluated.

Progress:

An initial study was performed on 12 subjects and answered in part the question concerning perceived exertion demonstrating a significant effect at near maximal work loads. Physiological responses such as heart rate, minute ventilation, tidal volume and respiratory rate were not significantly altered by breathing the hyperoxic mixtures. However, rated perceived exertion (RPE) was significantly lower ($P < .01$) while breathing the hyperoxic mixture at both submaximal work loads (50 and 80% $\dot{V}O_2$ max).

The RPE correlated highly with post-exercise blood lactate concentration ($r = 0.64$). This may indicate that blood lactate concentration is a major or dominant cue in the perception of exertion during physical work. $\dot{V}O_2$ measurements, however, were hampered by difficulties which were found in accurately measuring V_I and V_E.

Future Plans:

The study will be continued using an improved method of measuring V_I and V_E, and on line gas concentrations measured using a Perkin Elmer mass spectrometer. Since MAJ Allen has left the service, Dr. Donald E. Roberts will assume the role of principal investigator during the completion of the study.

(83053)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6148	76 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. DISP'N INSTR'N	8B. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
76 08 20	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	3E762777A845	00	053
b. [redacted]	6.27.58.A	3A762758A827	00	053
c. [redacted]	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: Not Applicable EXPIRATION:
b. NUMBER:*
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 76(7T)	4 (1)	110 (30)
FISCAL YEAR CURRENT 77	5.5	237

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST ENV MED

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RESPONSIBLE INDIVIDUAL
NAME: DANGERFIELD, HARRY G., M.D., COL, MC
TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* Goldman, Ralph F., Ph.D.
TELEPHONE: 955-2831
SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS
NAME:
NAME:

21. GENERAL USE

Foreign Intelligence Not Considered

DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U) Environmental Tolerance; (U) Performance Limits; (U) Work Stress; (U) Heat Stress; (U) Cold Stress; (U) Military Doctrine

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

23. (U) Develop 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, and guide clothing and equipment design, suggest tactical doctrine, and indicate potential environmental casualties.

25. (U) 75-07 - 76-09 Convergence of skin and rectal temperatures has been shown to be significant in limiting tolerance under extreme heat/clothing stress, and is being included in the prediction model. A new equation for heat production, no longer limited to speeds above 2.5 km/hr and therefore useable with heavy loads or difficult terrain, has also been incorporated. A modifier to cover effects of dehydration on performance limits in the heat has been developed, and others to handle sex and physical fitness differences are being evolved. Plans for inclusion of our solar heat load model as a sub-block have been completed. Potential heat stress within the new MICV has been studied in the desert. Approval has been obtained for over-snow studies to determine terrain coefficients with snowshoes and skiis and self-paced mobility afoot. Resources utilized during FY 7T: Professional Man Years 1 ; Funds $ 30 (in thous).

*Available to contractors upon originator's approval

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	The Convergence of Rectal and Skin Temperature as a Criterion of Heat Tolerance
Investigators:	Kent B. Pandolf, Ph.D. and Ralph F. Goldman, Ph.D.

Background:

Many laboratories, in addition to USARIEM, use criteria of rectal temperature (T_{re}: at USARIEM 39.5° ± 0.5°C) and/or heart rate (HR: 180 beats/min ± 10%) as tolerance limits for men working in the heat. In earlier work from this Institute, we suggested that the mean skin temperature ($\bar{T}_s$) at 10 minutes into the exposure was a prognosticator of the tolerance time for men working in hot environments. More recently, having acquired the ability to simultaneously plot both rectal and skin temperatures of each subject on-line during experimentation, we have been impressed with the extent to which convergence of $\bar{T}_s$ toward T_{re} indicates a decreasing tolerance time. We felt that the convergence might be a better, and certainly more comfortable indicator of approaching intolerance than either T_{re} or HR, alone or in combination.

Progress:

Data from two studies suggest the convergence of $\bar{T}_s$ and T_{re} can indeed be a reliable indicator of decreasing tolerance time, and a voluntary tolerance limit for individuals. Both studies (S_1 and S_2) involved young, fit soldiers who were heat acclimatized for 5 to 7 days. During S_1, involving protective clothing systems, 7 subjects were tested in both a hot-dry (46°C, 10% rh) and hot-wet (35°C, 75% rh) environment with 1.1 m/s wind

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and 360 BTU/sq ft hr radiant heat load. These subjects carried out a variety of physical activities each day for 120 minutes. During S_2, six different rainsuits were evaluated in a hot-dry environment (49°C, 20% rh). In these experiments, 6 subjects attempted a 50 minute walk at 1.34 m/s on the treadmill followed by a 30 minute rest.

In S_1 while wearing a completely impermeable, unventilated protective garment, convergence of $\bar{T}_s$ on T_{re} led to early voluntary experimental termination in both the hot-dry (mean T_{re} = 38.2°C, HR = 142 beats/min, time = 42 min) and hot-wet phases; (mean T_{re} = 38.8°C, HR = 166 beats/min, time = 67 min). During S_2, test exposures in 4 rainsuits were also terminated upon convergence of $\bar{T}_s$ on T_{re} (despite mean T_{re} = 38.3°C, HR = 166 beats/min, time = 33 min). Note that, in all cases, subjective tolerance occurred at T_{re} and HR well below the usual tolerance criteria. Thus, prediction of military performance limits can be improved by using this convergence criteria, in addition to T_{re} and HR.

Preliminary data analysis indicates that linear extrapolation of $\bar{T}_s$ beyond 10 minutes of experimental data acquisition and calculation of predicted T_{re} according to our heat casualty model will provide a more accurate index of projected tolerance time. This modeling is currently being conducted.

Future Plans:

These experimental findings will be formulated into a manuscript and published in the open literature. The improved prediction of the occurance of heat stress and/or heat casualties during military operations that results from inclusion of a $T_{re} - \bar{T}_s$ convergence criterion will be added to our model predicting performance capability.

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environmental, Clothing and Equipment
Study Title:	Studies on the Energy Cost of Load Carriage Considering Slow Walking Speeds and Standing
Investigators:	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 enabled prediction of the metabolic cost of walking and load carrying. The main factors included in the model were: weight of the subject (W), external load carried (L), the speed of walking (V), the grade of the slope (G - in percent), and the nature of the terrain, expressed by a factor (η). This model had a lower limit for speed (0.7 m/s = 2.5 km/hr = 1.5 mph) above which it was applicable. It seemed desirable to extend the range of speed down to zero (standing) and to include the metabolic cost of load carrying while standing. The practical importance of this modification is apparent when the mandatory slow walking speeds ($<$0.7 m/s) for prolonged walking on some terrains, such as soft snow, is considered. Taking into account the above considerations, a new model has been developed which includes the total range of walking speeds, from standing.

Progress:

Two studies have been completed. The first involved external loads of 32, 40 and 50 kg (50 kg = 110 lbs) carried at either 1.0, 0.8, 0.6, 0.4, 0.2

m/s (1.5 mph = 0.7 m/s). The second involved measuring energy cost of standing with 10, 30, and 50 kg loads. A new energy cost prediction equation has been developed for walking which considers load carriage. The new predictive model consists of four components:

a) The metabolic rate (M = watt) related to standing without load, which is assumed proportional to the weight of the body, $M_1 = 1.5\ W$.

b) The metabolic cost of load carrying at a standing position which is assumed to be effected by the total weight (subject + load) as well as a function of the load to weight ratio squared, $M_2 = 2.0\ (W + L)\ (L/W)^2$.

c) The metabolic rate, related to the specified terrain, considering total weight, is a function of the speed squared, $M_3 = \eta\ (W + L)\ (1.5V^2)$.

d) The metabolic rate considering the specific terrain and total weight is a linear function of the speed for a given grade, $M_4 = \eta(W + L)\ (0.35\ VG)$.

Thus, the mathematical form of the new predictive model is:

$$M = 1.5W + 2.0(W + L)(L/W)^2 + \eta(W + L)\ \ 1.5V^2 + 0.35VG$$

The new predictive model has shown good agreement between measured and predicted values. The new model allows prediction for slow walking speeds down to standing, with consideration for load carriage. The new predictive model not only extends the range of application beyond that of the old one, but also is more simplified in its mathematical form and enables hand computation of the metabolic rate. This last factor may greatly facilitate its application.

Future Plans:

The new energy cost prediction equation will be published in the open literature. Prediction of the energy cost of running with and without loads, on laboratory and natural surfaces, will be initiated.

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environmental, Clothing and Equipment
Study Title:	Role of Dehydration in Limiting Human Performance While Working in the Heat
Investigators:	Kent B. Pandolf, Ph.D., Richard L. Burse, Sc.D., Baruch Givoni, Ph.D., and Ralph F. Goldman, Ph.D.

Background:

Our previous studies investigated the effects of dehydration on body temperature and heart rate (HR) responses of men during work at only one hot environmental condition and work level. Results of these earlier studies suggested that the rate of rise of rectal temperature (T_{re}) was increased by roughly 0.1°C per 10 minutes for each percent of dehydration (reduction in initial whole body weight) above the 2% level of dehydration; in consonance with the original reports of Ladell, little reliable effect of dehydration was noted until a 1 or 2% dehydration level was achieved. In addition, the body temperature level at which an equalibrium of deep body temperature could be achieved (if at all), was increased by roughly 0.2°C for each percentage of dehydration above the 2% level. The extent to which these preliminary findings, obtained under a single work level and environmental condition, could be generalized to the entire problem of dehydration for the soldier in the field required further investigation.

Progress:

A major study, challenging the general applicability of the above findings by exposure of 4 to 8 subjects to a wide range of environmental conditions while working or resting has been completed. While some

additional data analysis is required, it appears that a general expression of the effects of dehydration will be able to be used across the range of environments/work conditions in the heat. Dehydration models for heart rate (HR) and rectal temperature have been derived. The proposed formulae are as follows:

Rectal temperature

$$T_{re(Dehyd)_t} = T_{re_{(o)}} + T_{re_{(Hyd)_t}} \exp(0.15)D$$

where D = percent dehydration; $T_{re_{(o)}}$ = initial rectal temperature; $T_{re_{(Dehyd)_t}}$ = rectal temperature at time t of dehydrated subjects; $T_{re_{(Hyd)_t}}$ = elevation of rectal temperature of hydrated subjects at time t, according to the previous Givoni-Goldman heat casualty model.

Heart rate

$$I_{HR_{(Dehyd)}} = 25 + (I_{HR} - 25)(1 + 0.06D)$$

where heart rate (final and at time t) are computed as before, using the I_{HR} for dehydration, and information from the published Givoni-Goldman model.

Future Plans:

This prediction capability is to be added to our model predicting military performance capability and the occurrence of heat stress and/or heat casualties during military operations. Although it is most encouraging that the tentative coefficients developed on the basis of only one work environmental level fit the new data with only minor adjustment, despite an interval of some two years between studies and an entirely different subject group, an additional validation study of the

coefficients derived from the current analyses will be required. The validation study will involve 8 acclimatized subjects, three levels of dehydration (0, 3, 5%), two levels of physical work (300 and 500 Watt) and two environmental conditions (35°, 49°C).

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing, and Equipment
Study Title:	Differences Between Males and Females of Military Age in Their Physiological Responses to Cold and Hot Environments
Investigators:	Richard L. Burse, Sc.D., A. Elizabeth Stubbmann, and Ralph F. Goldman, Ph.D.

Background:

Our prediction model has been developed and validated almost exclusively on *reasonably fit*, *young*, *male* volunteers. One previous attempt to evaluate differences with females, while interesting, proved futile since the female volunteer recruits proved to have work capacities equal to or better than our male subjects, having been recruited from women athletes involved in competitive rowing. In view of the increasing numbers of women in service, and their acceptance into combat support and combat service support units, differences in responses to work and environment clearly must be evaluated.

Pending resolution of the problems of obtaining volunteer subjects in general, and female subjects in particular, a major literature review was undertaken to develop the basis for subsequent laboratory and field studies. Such studies are considered essential to develop and validate the necessary coefficients to modify predicted differences between males and females in their physiological responses to heat and cold stress.

Progress:

The major differences reported in the literature between the physiological responses of males and females to the same environmental temperatures can readily be explained by comparing their relative abilities to produce heat and dissipate it to the environment.

Work: Females in military service have from 19 to 23% less total body mass than do males; 20% is an acceptable approximation. Females from 17 to 29 years old have body fat contents ranging from 13 to 35%, with 29% the average. Males of similar age are quite a bit leaner, from 10-26% fat, with 15% the average. Since fatty tissue in humans is not very active metabolically, the female is at a double disadvantage. Her total mass for producing heat is less than that of the male, and a greater fraction of her mass is the metabolically less active fat. On average, her fat-free mass is calculated to be 33% less than that of the male. Not surprisingly, her maximum capability for performing work is also 33% less than that of the male.

Cold: Because of their smaller body size, females have from 14 to 16% less surface area than men. On average, then, they will therefore lose heat through a 15% smaller surface area, but from a metabolically active lean body mass which is 33% smaller.

The greater layer of subcutaneous fat in the female can also act as increased insulation, reducing heat loss in the cold. However, this advantage exacts its price, which is a skin temperature $1^{\circ}C$ ($1.8^{\circ}F$) lower than that of the male under similar conditions. Since the sensation of cold is perceived at the skin surface, for the same environment and amount of clothing insulation, women feel a bit cooler than men. To maintain similar levels of skin temperature, and therefore comfort, women may require more clothing insulation than men.

The prevention of cold injury among females in severe environments is apt to be a greater problem than it is among males for 3 reasons: (1) because of their lower skin temperatures, women will reach the $40^{\circ}F$ danger

level for cold injury at a less severe ambient temperature than men; (2) because women's extremities are thinner geometric cylinders than are men's, there is a greater surface area-to-mass ratio. Therefore, for the same circulatory heat input, there is a greater heat outflow, which results in women's extremities cooling faster than men's; (3) the advantage of the greater layer of subcutaneous fat in the female, which acts as an insulator over much of the body surface, does not extend to the hands and feet. Therefore, a greater amount of clothing insulation is probably required on the extremities to delay the onset of vasoconstriction and to slow the rate of cooling once vasoconstriction has occurred.

Comfort: Under thermoneutral conditions, women are comfortable under a slightly wider range of ambient temperature than are men. Although it was reported many years ago that female workers engaged in sedentary tasks preferred warmer temperatures than males, these results were established in the period when male office workers typically wore business suit ensembles that averaged 6 pounds and women's clothing outfits averaged 2 ½ pounds. With the current trend towards similar insulation values for men's and women's clothing, these temperature preference differences are disappearing. However, military clothing being developed for women will have to continue to be similar to that for men, if similar temperatures are to be provided for comfort.

Heat: With respect to working under hot conditions, females produce from 15 to 33% less sweat than do men and there is a report of even less. Their smaller requirements for dissipation of metabolic heat makes up for part of this difference, but the lack of sweat to be evaporated results in women having skin temperatures about 0.5°C (0.9°F) higher than men. This results in a reduced ability to move heat from the body core to the skin and thus a greater rate of body heat storage, which reduces their tolerance time. The tolerance time for women, as for men, can be increased by acclimation to work in the heat. However, since their maximum abilities for transporting body heat to the skin and dissipating it by evaporation of

sweat never equal that of men, they always remain at a relative disadvantage. Furthermore, any factor which tends to retard the evaporation of the limited amount of sweat that is produced will place them at a greater disadvantage. For this reason, relatively impermeable rain wear, body armor or chemical-biological protective clothing can be expected to have a greater impact on the tolerance time of females than on that of males.

Conclusions:

It is not unfair to generalize females in their physiological responses to heat and cold as being somewhat similar to a less fit, unacclimatized, and fatter male counterpart. Such a comparison seems useful as a guideline in the development of our initial approach to modifying our model to predict for women.

Future Plans:

Develop tentative modified coefficients for female responses to work, heat and cold and, when female subjects are available, carry out controlled climatic chamber studies to refine our prediction model.

Program Element:	6.27.58.A MILITARY MEDICAL INVESTIGATIONS
Project:	3A762758A827 Military Environmental Medicine
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Evaluation of Thermal Stress in the Mechanized Infantry Combat Vehicle (MICV-XM-723)
Investigators:	Ralph F. Goldman, Ph.D., Fred R. Winsmann and Thomas L. Endrusick

Background:

The Mechanized Infantry Combat Vehicle (MICV-XM-723) has been designed to replace the M-113 Armored Personnel Carrier. This vehicle has a ventilating system which provides filtered air circulation while the squad crew stays in the closed vehicle during hot weather operations. Preliminary studies by the developer indicated that crew compartment ventilation was "adequate", and the noise level for the same test conditions was 92 db which provided "no annoyance from fan noise when seated in the crew compartment." However, further studies at the US Army Yuma Proving Ground indicate that fumes and noise were problems, with occupant hearing protection being necessary, and further evaluation of thermal stress in this vehicle seemed appropriate. USARIEM was contacted to assess the heat stress in the Mechanized Infantry Combat Vehicle during summer operations in the desert. Based on preliminary data on internal temperatures without a full crew, crew compartment humidity build-up with a full complement of men producing sweat was a key question.

Progress:

A study was conducted at the US Army Yuma Proving Ground, Yuma, Arizona (September 1975). Because of the fume and noise problems, no

weapons were fired during the thermal stress evaluation. Measurements included outside and inside (vehicle) dry bulb temperature (T_{db}), wet bulb temperature (T_{wb}), black globe temperature (T_g) and non-psychrometric wet bulb (T_{nwb}) for calculation of the WBGT index, wind velocity (outdoor), air motion (indoor) and solar load (outdoor). These were determined every 15 minutes during a three hour test exposure. Rectal temperatures and heart rates were determined on the subjects in the crew compartment.

The ambient air temperatures during the two day experiment averaged about 100°F with relative humidity between 20-25%. Projected build-up of internal humidity, with subjects sweating, during two to three hours did not reach levels which would lead to heat intolerance. It appears that subjects inside the vehicle will be at less thermal risk from heat stress than they would be outside the vehicle, provided the ventilation system is operating and the vehicle is not over-pressurized or tightly sealed against toxic agents. The WBGT measurement inside the vehicle would be quite stressful for active subjects unacclimatized to the heat, but would be reasonably well tolerated by heat acclimatized subjects during the maximum level of confined activity.

Future Plans:

None. A more detailed evaluation of these experimental findings can be found in the recently published technical report (Report No. T 41/76) entitled, "Thermal Stress Evaluation of the Mechanized Infantry Combat Vehicle (MICV-XM-723).

APPENDIX A

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APPENDIX B

PUBLICATIONS*

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APPENDIX C

PRESENTATIONS AND ABSTRACTS

At Scientific Meetings

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Hamlet, M. P. Frostbite, Hypothermia, and Survival at Cold Weather and Isolated Medicine Conference for US Navy and Civilian Physicians, Hospital Corpsmen Paramedics and Physician's Assistant, Washington, DC, 8-11 Aug 76.

Hamlet, M. P. Operation Problems in Alaska and Cold Injury Prevention at 1st Battalion, 25th Marines, 4th Marine Division, Marine Corps Reserve Training Center, Boston, MA, 28 Aug 76.

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Brown, J. M. Medical Lessons Learned - Yom Kippur War. Medical Problems of Winter Warfare. Norwegian Information, 4-5 Sep 75.

Hamlet, M. P. AGA Infrared Thermovision Camera, USARIEM, Natick, MA, 5 Aug 75.

Hamlet, M. P. Cold Weather Problems. Naval Support Force Antarctic Medical Personnel, Washington, DC, 10-11 Aug 75.

Hamlet, M. P.; D. R. Franz; and J. J. Berberich. Arctic Clothing and Equipment (Jack Frost Exercise), Ft. Stuart, GA, 30 Nov 75.

Hamlet, M. P. Cold Injury and Arctic Survival - Predeployment to Alaska. 104th Tac Ftr Gp, Air National Guard, Westfield, MA, 7 Dec 75.

Hamlet, M. P. Cold Weather Problems in Preparation for Exercise Alpine Warrior, 1st Battalion, 8th Marine Regiment, Camp LeJeune, NC, 12-14 Jan 76.

Hamlet, M. P. Cold Weather Briefing for Arctic Environment. Co. A, A, 3rd Battalion, 10th Special Forces Group (Airborne) 1st Special Forces. Ft. Devens, MA, 19 Jan 76.

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Kowal, D. M. Assessment of Physical Fitness and the Selection of Competitive Athletes. Sports and Recreational Directorate, Washington, DC, April 1976.

Wolfe, D. L. Cold Injury Prevention. Ft. Devens, MA, 3 Feb 76.

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Jones, L. G. Lecture on "Recent Advances in Environmental Medicine Research" to Class 6A-F5(1), Health Sciences Academy, Ft. Sam Houston, Texas, 26 Sep 75.

Jones, L. G. Member, Army Panel on "Medical Aspects of Potential Commitments of US Forces and Objectives, Plans and Programs", at Armed Forces Epidemiological Board, WRAIR, Washington, DC, 12 Feb 76.

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Jones, L. G. Lecture on "Recent Advances in Environmental (Climatic) Medicine and Physical Fitness Research", Preventive Medicine Symposium, Walter Reed Army Institute of Research, Washington, DC, 4 May 76.

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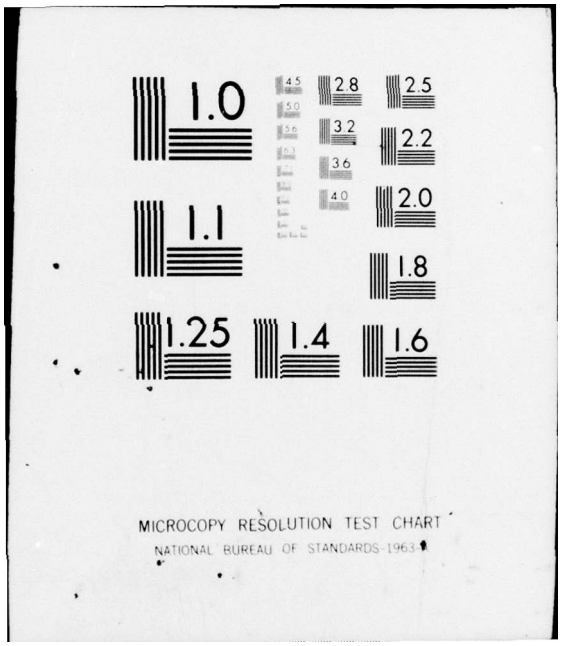
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APPENDIX D

SEMINAR PROGRAM

DATE	LECTURER	SUBJECT
2 July 1975	Dr. Mark Singer Dept. of Physiology & Biophysics Hahnemann Medical College Philadelphia, PA	Adrenergic and Cardiovascular responses of the Anesthetized Dog to Severe Acute Heat Stress
17 July 1975	Dr. William H. Payne, Ph.D. Washington State University Pullman, WA	Computers: Present & Future Trends
29 September 1975	Major Tadataka Yamada Bacteriology Division US Army Medical Research Institute of Infectious Diseases Ft. Detrick, MD	The Role of the Kinin System in Infectious Diseases
29 September 1975	Captain George V. Pettit, MSC Animal Assessment Division US Army Medical Research Institute of Infectious Diseases Ft. Detrick, MD	Myocardial Depressant Factor
4 February 1976	Dr. David B. Dill Laboratory of Environmental Patho-Physiology Desert Research Institute Boulder City, NV	Response of Men and Women to Exercise in Desert Heat
18 February 1976	Dr. David A. Perreault Coordinator of Computer Engineering Boston University, Boston, MA	Analog Versus Digital Instrumentation
9 March 1976	Dr. Charles S. Houston Dept. of Epidemiology & Environmental Health The University of Vermont Burlington, VT	Work and Play at 18,000 Feet
31 March 1976	Dr. J. Alan Herd, M.D. Assoc. Professor of Physiology Harvard Medical School, Boston, MA	Peripheral Circulation in the Cold

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7 April 1976	Dr. R. Henane, Medecin en Chef French Center for Research for the Health of the Army, Lyon, France	Research Program of the Physiology Division-CRSSA
8 June 1976	Dr. Leonard Marcus State Laboratory Institute Boston, MA	Zoonotic Diseases of Laboratory Animals and Housepets
20 August 1976	Dr. Peter Wagner Asst. Prof. of Medicine University of California San Diego, La Jolla, CA	Confidence Limits of Distribution of Blood Flow with Respect to $\dot{V}/\dot{Q}$ in Lungs from Inert Gas Data

SEMINAR PROGRAM (In-House)

DATE	LECTURER	SUBJECT
2 December 1975	Colonel LeeRoy G. Jones, M.D. Commander	What is a USARIEM? Second Version
10 & 17 December 1975	Dr. James A. Vogel, Director Dr. *Donald H. Horstman* Major Marcos U. Ramos, MC Captain John F. Patton, MS Exercise Physiology Division	Physical Fitness in Today's Army or USARIEM and Her Beautiful Exercise Machine
7 & 21 January 1976	Captain John L. Szurek, MS Chief, Automated Data Processing Branch	Computers: Present Capabilities and Future Trends
28 January & 4 February 1976	Dr. Ralph F. Goldman, Director Military Ergonomics Division	What is SGRD-UE-ME?
11 February 1976	Dr. Ralph F. Goldman Mr. John R. Breckenridge Mr. Clement A. Levell Mr. George Fonseca Mr. Leander A. Stroschein Dr. Kent B. Pandolf Dr. Richard L. Burse	Military Ergonomics II
25 February & 3 March 1976	Dr. John T. Maher Major Joseph C. Denniston, VC Major Ronald E. Jackson, MC Major Jimmie T. Sylvester, MC Major Richard C. Weiskopf, MC Dr. John L. Kobrick Dr. Allen Cymerman	USARIEM Altitude Program: Past, Present and Future

17 March 1976	Dr. Ralph F. Goldman, Director Military Ergonomics Division	Environmental Indices for Heat and Cold
5 April 1976	Major Jerry M. Brown, MC Experimental Pathology Division	Whole Body Distribution of Tritiated Ryanodine and Electron Microscope Evidence of Tissue Localizations
5 April 1976	Dr. Richard L. Burse Military Ergonomics Division	Elevated Metabolism in Obese Males after Excess Carbohydrate Intake
5 April 1976	Major Joseph C. Denniston, VC Exercise Physiology Division	Electrical Impedance: A Valid Method of Cardiac Output Measurement at High Altitude
5 April 1976	Dr. Ralph P. Francesconi Heat Research Division	Heat and Hypobaric Hypoxia: Effects on Correlates of Stress and Performance
5 April 1976	Dr. Donald H. Horstman Exercise Physiology Division	Maximal Oxygen Consumption ($\dot{V}O_2$ max) and Systemic Oxygen Transport ($\dot{T}O_2$) During Three Weeks Sojourn at 4300 M(HA)
5 April 1976	Captain James J. Jaeger, MS Cold Research Division	Respiratory Water Loss During Exercise at $+25^{\circ}$ and -20°C
5 April 1976	Dr. Milton Mager, Director Heat Research Division	The Effect of Potassium Depletion on Work Performance and Predisposition to Heatstroke Mortality
5 April 1976	Dr. John T. Maher Altitude Research Division	Coagulation Abnormalities in Man During Acute Exposure to Hypobaric Hypoxia
21 April 1976	Lieutenant Colonel Wayne O. Evans MS Director Captain James J. Jaeger, MS Dr. Donald Roberts Dr. James B. Sampson Cold Research Division	Cold Research Division: Phase I and II
22 April 1976	Captain Frederick M. Bock, MS Chief, Automated Data Processing Branch	Automated Systems in Military Clinical Medicine - The TRIMIS Project

28 April 1976	Captain Murray P. Hamlet, VC Captain Joel J. Berberich, MS Captain David R. Franz, VC Major Jerry M. Brown, MC Dr. Wilbert D. Bowers Experimental Pathology Division	Experimental Pathology Division: Presentation on Active Research Protocols
12 May 1976	Dr. Milton Mager Dr. Bernard J. Fine Dr. Ralph P. Francesconi Heat Research Division	Presentation of film entitled "Prevention of Heat Injury"
26 May 1976	Dr. Ralph P. Francesconi Major Gaither D. Bynum, MC Dr. Roger Hubbard Heat Research Division	Heat Research Division: Part II
4 June 1976	Major Jerry M. Brown, MC Experimental Pathology Division	Information Resource Center
23 June 1976	Lieutenant Colonel James W. Stokes, MC Dr. Louis E. Banderet Mrs. Pamela W. Phair SP4 Rosemary T. Kyte SP5 Rick W. Tanney Cold Research Division	Embedded Assessment of "Well Being" and Performance of an Army Team in the Field Artillery Fire Direction Center (FDC)
21 July 1976	Captain Danney L. Wolfe, VC Experimental Pathology Division	Animal Support of Research at USARIEM

APPENDIX E

AGENDA

CURRENT CONCEPTS IN ENVIRONMENTAL (CLIMATIC) MEDICINE COURSE

17-21 MAY 1976

US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

NATICK, MASSACHUSETTS 01760

PHYSICAL FITNESS AND WORK

Orthopedic Problems of the Seasoned Soldier	MAJ Ernest L. Sutton
Physical Fitness an Training	James A. Vogel, Ph.D. CPT Dennis M. Kowal, MS
Demonstration of Physical Work Capacity Assessment	James A. Vogel, Ph.D.
Work Physiology	Donald H. Horstman, Ph.D.

COLD

Overview of Military Problems in Cold Weather Areas	LTC Wayne O. Evans, MS
Etiology, Pathaphysiology, Diagnosis and Treatment of Frostbite	CPT David R. Franz, VC
Etiology, Pathophysiology, Diagnosis and Treatment of Hypothermia	CPT James Jaeger, MS
Medical Support in Dry Cold and Wet Cold Areas	LTC Michael B. Young, MC
Foreign Army Concepts in Cold Weather Medicine and USARIEM Training Film	Murray P. Hamlet, VC
Panel Discussion on Cold Weather Medicine	LTC Wayne O. Evans, MS LTC Michael B. Young, MC CPT David R. Franz, VC Murray P. Hamlet, VC

HIGH TERRESTRIAL ELEVATIONS

Introductory Remarks - Man at High Elevations: Why are we interested	Sumner M. Robinson, Ph.D.
Ventilatory Adaption: Cause and Effect	MAJ Jimmie T. Sylvester, MC
Cardiocirculatory Response at Rest and Work	MAJ Joseph C. Denniston, VC
The Biochemistry of Hypobaric Hypoxia	Allen Cymerman, Ph.D.
Animal Support of Altitude Research	CPT Danney L. Wolfe, VC
Cognitive and Perceptional Processes	John L. Kobrick, Ph.D.
Clinically Adverse Effects of Altitude	John T. Maher, Ph.D.

HEAT

Assessment of the Environmental (comfort, heat, cold)	Richard L. Burse, Sc.D.
Clothing - the man-environment interface	John R.Breckenridge, BS

Demonstrations

a. Copper Man	Clement A. Levell
b. T_s and T_{re} measurement	Gerard W. Newcomb, BA
c. On-line data computation	Leander A. Stroschein, BA
d. Climatic	Fred R. Winsmann, MS
Responses of Man to Heat	Milton Mager, Ph.D.
Prevention of Heat Illness Film	
Animal Models and Their Use in "Heat" Research	MAJ Gaither D. Bynum, MC Roger W. Hubbard, MC Milton Mager, Ph.D.
Computer Prediction of Heat Stress	Leander A. Stroschein, BA

APPENDIX F

AGENDA

INTRODUCTION TO ENVIRONMENTAL MEDICINE

18-19 September 1976

US Army Research Institute of Environmental Medicine
Natick, Massachusetts 01760

Conducted for the 804th Hospital Center (US Army Reserve) Bedford USAR Center, Hanscom Air Force Base, Massachusetts 01731

18 September 1976, Saturday

Introduction and History	COL Harry G. Dangerfield, MC
Threat Analysis	LTC Wayne O. Evans, MS
Physical Fitness for the Soldier	James A. Vogel, Ph.D.
Prevention and Treatment of Heat Illness	Milton Mager, Ph.D.

19 September 1976, Sunday

Clinical and Operational Problems of Cold Weather Medicine	LTC Wayne O. Evans, MS
Clinical and Operational Problems of Altitude and Mountainous Terrain	MAJ Joseph C. Denniston, VC MAJ Ronald E. Jackson, MC
Matching the Mission to the soldier	Ralph E. Goldman, Ph.D.

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