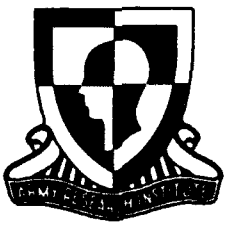


U.S. Army Research Institute
for the Behavioral and Social Sciences

Research Report 1651

Stinger Team Performance During Engagement Operations in a Chemical Environment: The Effects of Heat and Exercise

Joan D. Silver and John M. Lockhart
U.S. Army Research Institute

Daniel P. Redmond
Walter Reed Army Institute of Research

Preston A. Brawner
New Mexico State University

November 1993

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	1993, November	Final Mar 91 - Jun 93

4. TITLE AND SUBTITLE
Stinger Team Performance During Engagement Operations in a Chemical Environment: The Effects of Heat and Exercise

5. FUNDING NUMBERS
DAAL02-90-C-0071
63007A
793
0001BL
1217

6. AUTHOR(S)
Silver, Joan D.; Lockhart, John M. (ARI); Redmond, Daniel P. (WRAIR); Brawner, Preston A. (New Mexico State University)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
New Mexico State University
Las Cruces, NM 88003-0001

8. PERFORMING ORGANIZATION REPORT NUMBER
--

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Institute for the Behavioral and Social Sciences
ATTN: PERI-IB
P.O. Box 6057
Fort Bliss, TX 79906-0057

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
ARI Research Report 1651

11. SUPPLEMENTARY NOTES
Contracting Officer's Representative, John M. Lockhart. Prepared in cooperation with Walter Reed Army Institute of Research (WRAIR) and Army Research Laboratory (ARL), formerly Human Engineering Laboratory (HEL).

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE
--

13. ABSTRACT *(Maximum 200 words)*

Research with Stinger teams (baseline) conducted under benign environmental conditions established that engagement performance of both the team chief and gunner was significantly impaired by the Mission Oriented Protective Posture (MOPP) clothing. This study replicated the experimental design used in the baseline research and included exposure to heat and exercise (HEX).

Workload and stress levels, casualty rates, and physiological measures were significantly affected by the combination of MOPP gear, heat, and exercise. However, the expected Stinger engagement performance decrement did not occur.

Explanations for the lack of a MOPP4, heat, and exercise decrement focus on the arousing effects of high heat on performance and motivational differences between the baseline and HEX groups.

14. SUBJECT TERMS		15. NUMBER OF PAGES
Stinger Engagement simulation Subscale aircraft	Range Target System (RTS) Chemical Protective (CP) clothing Mission Oriented Protective Posture (MOPP)	42 16. PRICE CODE --

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

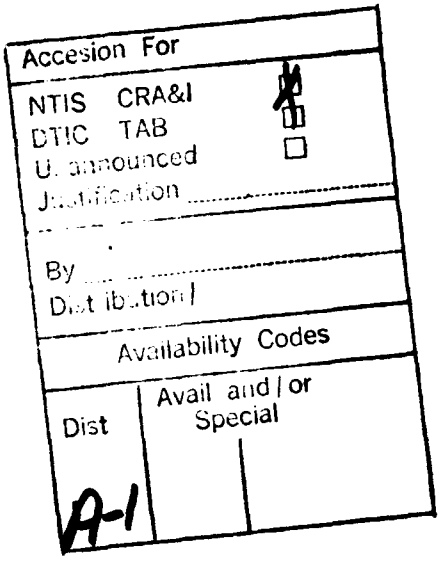
U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency Under the Jurisdiction of the Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Director

Research accomplished under contract
for the Department of the Army

New Mexico State University



Technical review by

Kurtz F. Griffin, Directorate of Combat Development, U.S. Army Air Defense Artillery School
Gerald Hudgens, U.S. Army Research Laboratory

NOTICES

DISTRIBUTION: Primary distribution of this report has been made by ARI. Please address correspondence concerning distribution of reports to: U.S. Army Research Institute for the Behavioral and Social Sciences, ATTN: PERI-POX, 5001 Eisenhower Ave., Alexandria, Virginia 22333-5600.

FINAL DISPOSITION: This report may be destroyed when it is no longer needed. Please do not return it to the U.S. Army Research Institute for the Behavioral and Social Sciences.

NOTE: The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

Research Report 1651

Stinger Team Performance During Engagement Operations in a Chemical Environment: The Effects of Heat and Exercise

Joan D. Silver and John M. Lockhart
U.S. Army Research Institute

Daniel P. Redmond
Walter Reed Army Institute of Research

Preston A. Brawner
New Mexico State University

Field Unit at Fort Bliss, Texas
Michael H. Strub, Chief

Training Systems Research Division
Jack H. Hiller, Director

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

Office, Deputy Chief of Staff for Personnel
Department of the Army

November 1993

Army Project Number
2Q263007A793

Human Factors in Training
Operational Effectiveness

FOREWORD

The Crew Weapons Performance Team of the Fort Bliss Field Unit of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) investigated the effect of Mission Oriented Protective Posture (MOPP) clothing on the performance of air defenders as part of an ongoing program of research sponsored by the Physiological and Psychological Effects of the Nuclear, Biological, and Chemical Environment and Sustained Operations on Systems in Combat (P^2NBC^2) program, U.S. Army Chemical School, Fort McClellan, Alabama. The results of the investigations established that both Stinger and Avenger team chief performance is impaired by the MOPP gear. Stinger gunner performance is also degraded by the protective clothing, but Avenger gunner performance is not impaired. This study, the last to be conducted in this program of research, examined additional contributions of heat and exercise to Stinger engagement performance decrement beyond that created by the MOPP gear alone.

The proponent for the Stinger research, the Directorate of Combat Developments, Fort Bliss, Texas, reviewed the results and submitted an Abbreviated Operational Assessment to the P^2NBC^2 program. The results of this research were briefed to the P^2NBC^2 joint working group 21 January 1993. The findings suggest that the engagement performance of strongly motivated Stinger teams may not be impaired by the MOPP gear, even though the detrimental effects of the protective clothing, extreme heat, and exercise may be reflected in physiological and in other psychological measures.

EDGAR M. JOHNSON
Director

STINGER TEAM PERFORMANCE DURING ENGAGEMENT OPERATIONS IN A CHEMICAL ENVIRONMENT: THE EFFECTS OF HEAT AND EXERCISE

EXECUTIVE SUMMARY

Requirement:

This research examined the engagement performance of Stinger teams (team chief and gunner) under conditions of Mission Oriented Protective Posture (MOPP), heat, and exercise. Previous research (baseline) conducted under benign environmental conditions revealed that the MOPP gear significantly degraded the performance of both the Stinger team chief and gunner. The baseline experimental design was replicated in this research, and heat and exercise (HEX) were added to allow their relative contributions to any additional performance decrement to be examined.

Procedure:

The effects of MOPP gear, heat, and exercise on Stinger teams engaging subscale aircraft in a simulation facility were investigated. Stinger teams received 13 engagement trials in MOPP0 and 13 in MOPP4. After engagement trial 6 in both MOPP clothing conditions, each team member carried a Field Handling Trainer (FHT) a total of 200 meters on a dirt road. Workload ratings were given by each team member after every engagement trial, and stress ratings were given pretest, midtest, and posttest in both MOPP clothing conditions. Physiological data in the form of heart rate, core temperature, and left and right skin temperatures were recorded for every participant.

Findings:

As predicted, all physiological measures, casualty rates, and stress and workload ratings reflected the degrading effects of the MOPP gear, heat, and exercise. Only the casualty rates and stress levels, however, revealed the additional contributions of heat and exercise beyond those of the MOPP gear alone. The combination of MOPP gear, heat, and exercise did not produce the expected Stinger engagement performance decrement. Post hoc explanations focusing on the arousing effects of high heat on performance and motivational differences between the baseline and HEX Stinger teams were invoked to account for the lack of a MOPP4, heat, and exercise decrement.

Utilization of Findings:

These results should serve as the impetus for subsequent research that specifically investigates the effects of high heat on Stinger performance and further examines motivational differences between those who volunteer for hazardous research versus nonhazardous research.

STINGER TEAM PERFORMANCE DURING ENGAGEMENT OPERATIONS IN A CHEMICAL ENVIRONMENT: THE EFFECTS OF HEAT AND EXERCISE

CONTENTS

LIST OF TABLES

CONTENTS (Continued)

LIST OF FIGURES

CONTENTS (Continued)

STINGER TEAM PERFORMANCE DURING ENGAGEMENT OPERATIONS IN A CHEMICAL ENVIRONMENT: THE EFFECTS OF HEAT AND EXERCISE

Introduction

The Fort Bliss Field Unit of the U.S. Army Research Institute (ARI) has conducted a series of investigations examining the effects of Mission Oriented Protective Posture (MOPP) on the performance of Air Defenders (Johnson & Silver, 1992; 1993; Silver & Lockhart, 1993). Stinger and Avenger teams participating in these investigations engaged subscale aircraft in an engagement simulation facility under conditions of MOPP0 and MOPP4. A soldier in MOPP4 is completely encapsulated by the components of the chemical protective (CP) clothing (boots, gloves, overgarment, and mask). In MOPP0, a soldier is attired in battle dress uniform, carries the CP mask, and has the other components of the clothing readily available.

A consistent pattern of results emerged from these investigations. The team chief's ability to identify aircraft was significantly impaired by the MOPP gear regardless of aircraft type (fixed-wing or rotary-wing) or weapon system (Stinger or Avenger). Stinger gunner performance was impaired by the CP clothing when engaging rotary-wing aircraft, but there was no effect of the MOPP gear when engaging fixed-wing aircraft. By way of comparison, there were no adverse effects of the MOPP gear on Avenger gunner performance regardless of mode of operation of the weapon system (see Tables 1 and 2).

Other psychological effects of the MOPP gear on air defender performance were assessed using the National Aeronautics and Space Administration (NASA) Task Load Index (TLX) (NASA-Ames, 1986) and the Self-Evaluation Questionnaire (SEQ) (Spielberger, 1983). The TLX is a multidimensional rating procedure that derives an overall workload score from six subscales: mental demand, physical demand, temporal demand, effort, performance, and frustration. The workload rating scale was administered after each engagement trial and was used to ascertain the differences, if any, in perceived workload between MOPP0 and MOPP4 trials. The SEQ assesses state anxiety that is a reaction or process taking place at a given time and level of intensity. The questionnaire consists of 20 statements intended to evaluate how respondents feel at a particular moment in time. The ratings given by the participants were used to quantify stress levels before and after each sequence of engagement trials in MOPP0 and MOPP4. Stress was assumed to vary in direct relationship with reported SEQ anxiety levels.

In each of the studies involving Stinger teams (Johnson & Silver, 1992; 1993), workload was reported as being significantly higher when the CP clothing was worn. Avenger teams (Silver & Lockhart, 1993), however, reported equivalent workload in both clothing conditions (see Table 3).

Table 1

FAAD Engagement Performance in a Chemical Environment: Fixed-Wing Task Performance Measures

Task Performance Measures	Stinger Low Exp	Stinger Cue	Stinger Baseline	Avenger Turret	Avenger Remote
DETECT		*		*	*
IFF		*			
ACQUIRE				---	---
UNCAGE VERIFY	---	---	---		
IDENTIFICATION	*	*	*	*	*
LOCK-ON				---	---
FIRE					

* Performance significantly impaired by MOPP gear
--- Data not available for this measure

Table 2

FAAD Engagement Performance in a Chemical Environment: Rotary-Wing Task Performance Measures

TPM	Stinger Low Exp	Stinger Cue	Stinger Baseline	Avenger Turret	Avenger Remote
AVL-DET	*		*		
DET-ID	*	*	*	*	*
DET-IFF	*		*		
DET-ACQ	*			---	---
ID-UNC	---	---	---		
ACQ-LO		*		---	---
LO-FIRE	*	*	*	---	---
ID-FIRE	*	*	*		
DET-FIRE	*	*	*		*

* Performance significantly impaired by MOPP gear
--- Data not available for this measure

Table 3

FAAD Engagement Performance in a Chemical Environment: Workload Rating Results

Prior Research	MOPP0 vs MOPP4
Stinger Low Exp	*
Stinger Cue	*
Stinger Baseline	*
Avenger Turret	
Avenger Remote	

* Workload ratings significantly higher in MOPP gear

Stress ratings follow the same pattern. Stinger teams report higher levels of stress in MOPP gear but Avenger teams report stress as being equivalent in both clothing conditions (see Table 4). Neither group of Air Defenders reported a significant increase or decrease in perceived stress over the course of engagement trials in either clothing condition.

The investigations of air defender engagement performance by Johnson and Silver (1992; 1993) and Silver and Lockhart (1993) were conducted under benign environmental conditions (i.e., took place during the cooler months of the year) to establish the effects of the MOPP gear alone on performance. The present study was a test of Stinger teams (team chief and gunner) within an experimental design that replicated the previous work of Johnson and Silver and further included exposure to heat and exercise. The addition of heat and exercise (HEX) to the experimental design allows the relative contributions of these variables to any additional performance decrement to be examined. The research was carried out jointly by ARI, Walter Reed Army Institute of Research (WRAIR), and the Army Research Laboratory (ARL), [formerly the Human Engineering Laboratory (HEL)].

Table 4

FAAD Engagement Performance in a Chemical Environment: Stress Rating Results

Prior Research	Pretest 0 vs 4	Posttest 0 vs 4	MOPP0 Pre vs Post	MOPP4 Pre vs Post
Stinger Low Exp	*	*		
Stinger Cue	*	*		
Stinger Baseline	*	*		
Avenger Turret				
Avenger Remote				

* Significant effect of MOPP gear

ARI collected data on human performance measures associated with operation of the Stinger missile system. Workload and stress levels as a function of MOPP level (0 or 4), heat, and exercise were also assessed. The results of previous Stinger research (Johnson & Silver, 1992; 1993) conducted by ARI led to several predictions (see Tables 1, 2, 3, and 4). The Stinger team chief's ability to identify aircraft was expected to be significantly degraded by the MOPP gear, regardless of aircraft type. Stinger gunner engagement performance was expected to be impaired for rotary-wing targets. The engagement performance MOPP4 degradation was expected to be greater for these teams than for a baseline group because of the addition of these teams of heat and exercise to the experimental design. Workload and stress levels were also expected to be greater when the MOPP gear was worn and the levels reported for each were predicted to be higher than those reported by Stinger teams in the baseline research (Johnson & Silver, 1993). The data collected by Johnson and Silver and referred to therein as the "high experience group" served as baseline data against which comparisons from the present study were made.

Physiological data were collected by WRAIR using the Biomedical Field Monitoring System (BFMS) which was developed "to

provide a practical means of monitoring the physiological and clinical status of soldiers during field tests with minimal disruption and discomfort" (Redmond, Leu, Popp, Hall, Galinski, & Gutierrez, 1992, p. 31). Measures of heart rate, core temperature, and left and right skin temperature taken in MOPP4 were expected to be significantly different from those obtained in MOPP0. Measures of activity level were not expected to differ as a function of the CP clothing.

ARL assembled a comprehensive battery of psychological measures designed to determine the effects of stress on performance. These tests were administered at Fort Bliss by ARI personnel once prior to the field test to determine baseline and to familiarize participants with the instruments. At the field test site, participants completed the ARL questionnaires six times during the course of the day -- prior to engagement trials (pretest), after the 200 meter walk (midtest), and at the completion of trials (posttest) -- both in the morning and in the afternoon. Participants were expected to report greater levels of stress under conditions of MOPP4. The results will appear under separate cover, with the exception of the SEQ results which are reported in this document.

Method

Participants

Participants consisted of nine Stinger teams (team chief and gunner) from U.S. Army Forces Command (2-1 ADA BN, 5-62 ADA BN, and 3rd Armored Cavalry Regiment) located at Fort Bliss. Ages ranged from 19 to 27 years ($\underline{M}$ = 22.5). In accordance with AR 70-25, which governs the use of volunteers as participants in research, potential volunteers were informed of conditions of participation, possible risks posed by participation, and the measures taken to minimize such risks. Benefits accruing to participants were also explained. Participants understood that they could withdraw from the research at any time.

Apparatus

Testing took place at the ARI Range Target System (RTS) engagement simulation facility located at White Sands Missile Range, New Mexico. Participants employed the Stinger Tracking Head Trainer (THT) in simulated engagement of subscale fixed-wing and rotary-wing aircraft in the RTS facility. The THT is a Stinger weapon system training device used to develop and maintain gunner proficiency in tracking aircraft and firing the Stinger weapon. The missile seeker on the THT works the same as that on the weapon and the audiovisual indications when acquiring and tracking a target are also the same as the weapon (FM 44-18-1, 1984).

All targets were one-fifth scale, three dimensional, molded fiberglass replicas of US or Soviet aircraft. Fixed-wing aircraft were flown remotely according to prescribed flight paths

and maneuvers. Rotary-wing aircraft appeared from designated positions via pneumatic stand-lift mechanisms.

Each of four Stinger THTs was cabled to a Data Acquisition Station (DAS). Signal taps were installed on key weapon pins. Gunner actions were collected automatically by the DAS and time coded with a resolution of 250 msec. Team chief actions were recorded by four data collectors who entered keystrokes on DAS computer keyboards located at each weapon position.

Procedure

Each test day, participants were met at their respective batteries by personnel from ARI, WRAIR, the Chemical School of Fort McClellan, Alabama, and a civilian medical doctor. WRAIR personnel monitored ingestion of a device designed to register deep body ("core") temperature; this device is a component of the BFMS. After ingesting the temperature device, Stinger teams were transported from Fort Bliss to the RTS test site at White Sands Missile Range.

Upon arrival at the RTS site, test participants completed a battery of paper and pencil questionnaires administered by WRAIR personnel. Each soldier then went through a series of procedures, also administered by WRAIR, which included being outfitted with a "body-worn multichannel system for logging, display, and/or local telemetry of data" (Redmond et al., 1992, p. 31). This system, like the deep body temperature device, is a component of the BFMS (see Redmond et al. for a complete description of the medical monitoring system). The BFMS enabled WRAIR personnel to collect data on heart rate, activity level, core temperature, and left and right skin temperature for each participant in each clothing condition.

Next, teams were assigned to data collectors and weapon stations. The data collectors reviewed test procedures and answered any remaining questions. Teams were then seated in shaded areas where they remained when not engaging targets. Prior to the start of the morning trials, each team member completed the battery of questionnaires provided by ARL. When the questionnaires were completed, engagement trials began.

The start of an engagement trial was signalled by the verbal alert "Red Tight" given by each data collector. The end of a trial was signalled by the verbal cue "Condition Yellow," also given by the data collector.

The teams received 13 engagement trials in each of two clothing conditions, MOPP0 and MOPP4. Clothing conditions were counterbalanced over DASs. One set of engagement trials occurred during the morning, the other in the afternoon. Each set was preceded by one practice trial. After each engagement trial participants rated workload for that trial using the NASA TLX rating scale (NASA-Ames, 1986).

Engagement scenarios were comprised of single rotary-wing aircraft, single fixed-wing aircraft, a mix of one fixed-wing and one rotary-wing aircraft, or three rotary-wing aircraft; aircraft could be friendly (US) or hostile (Soviet).

After trial six in both clothing conditions, each team member marched (self-paced) 100 meters out and back (for a total of 200 meters) on a dirt road carrying a Field Handling Trainer (FHT). The FHT has the same size, weight, and external appearance as the Stinger weapon-round. This activity simulated movement of the Stinger team to an alternate location and constituted the exercise portion of the experimental design.

Testing occurred over a period of four days (7-10 July 1992), with different teams being tested each day. Ambient temperatures in the shade during exposure in MOPP4 ranged from 91.0°F to 95.3°F in the morning and from 96.7°F to 105.0°F in the afternoon under clear skies or high scattered clouds. At the end of a test day each data collector provided his team with feedback on their performance over the 26 engagement trials.

ARI personnel ensured that each team member was continually supplied with water throughout the test day. Each data collector observed his team for outward signs of undue psychological or physiological stress. Participants were constantly supervised by the medical monitoring team which was comprised of the civilian medical doctor, WRAIR personnel, and personnel from McAfee Health Center, White Sands Missile Range, New Mexico. The BFMS aided the team in determining whether a participant could safely remain in the test. An ambulance was present throughout each test day and William Beaumont Army Medical Center, Fort Bliss, Texas, was on alert to provide an emergency medical helicopter, should it be required.

Results

Engagement Performance

Data were collected on task performance measures (TPM) and summary performance measures (SPM) for both fixed-wing and rotary-wing aircraft. TPM are expressed as ranges for the fixed-wing aircraft and as elapsed time for the rotary-wing aircraft. SPM are collected by summing over scenarios and are expressed as percentages.

HEX fixed-wing TPM. Data were collected on six fixed-wing TPM. DET is the range of the aircraft at the detection response given by the team chief. IFF is the range of the aircraft at identification friend or foe button press made by the gunner. ACQ is the aircraft range at weapon acquisition signal, a gunner response. ID is the aircraft range when a "friendly" or "hostile" identification is made by the team chief. LOCK-ON is the range of the aircraft at the press of the uncage bar which locks the missile onto the target and FIRE is the aircraft range at fire trigger pull, both gunner responses.

An equipment malfunction limited our fixed-wing TPM data collection effort to three teams. Because the sample size was so small, only descriptive statistics are presented (see Table 5). The HEX TPM means are compared to the baseline TPM means in Figure 1. It is not possible to reach conclusions regarding Stinger fixed-wing engagement performance under conditions of MOPP4, heat, and exercise because of the small HEX sample size.

Table 5

HEX Fixed-Wing TPM Means

Statistic	MOPP0	MOPP4
	Detect	
Mean	7.19	6.19
SD	1.62	1.54
	Identification Friend of Foe	
Mean	6.22	6.24
SD	1.80	2.24
	Acquire	
Mean	4.71	3.24
SD	1.37	2.25
	Identify	
Mean	3.48	2.72
SD	1.79	2.38
	Lock-on	
Mean	1.37	.67
SD	1.55	1.59
	Fire	
Mean	1.05	.005
SD	1.48	1.60

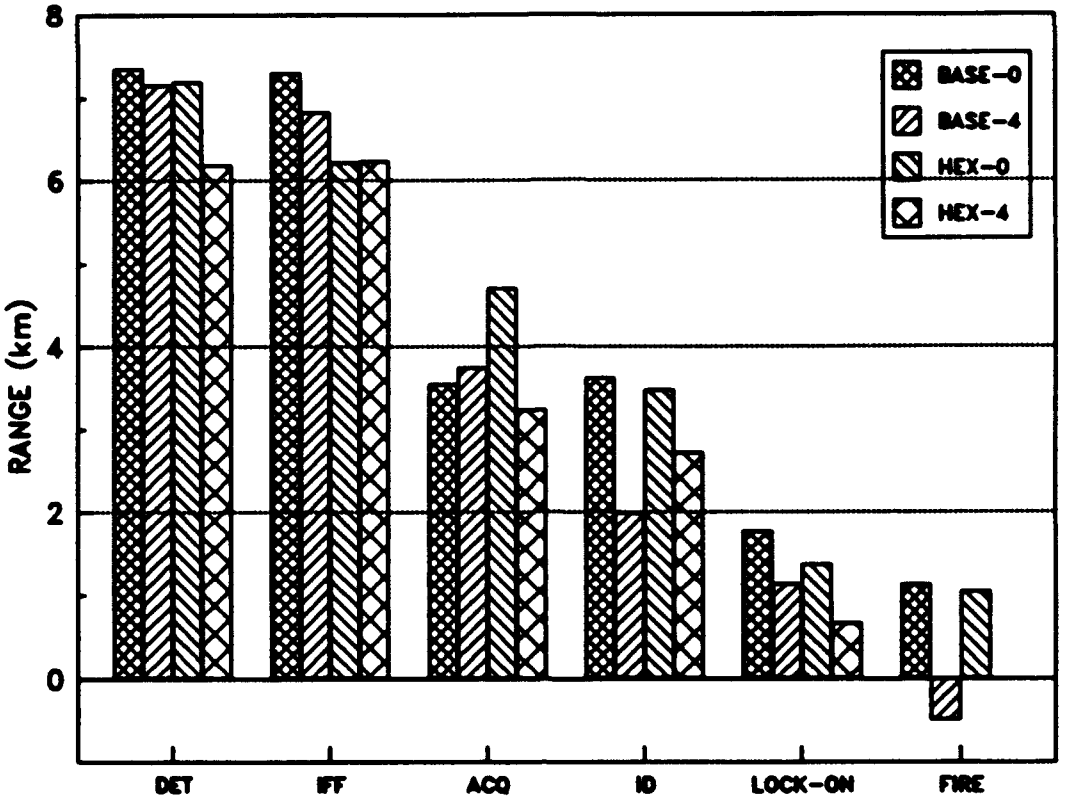


Figure 1. Comparison of baseline and HEX fixed-wing task performance measures.

HEX fixed-wing SPM. The same SPM are calculated for fixed-wing and rotary-wing aircraft. The percent aircraft detected is the number of aircraft for which a detect response is given divided by the total number of aircraft presented. The percent aircraft identified correctly is the number of aircraft for which a correct identification response is given divided by the total number of aircraft detected. The percent friendly aircraft identified correctly is the number of friendly aircraft for which a correct identification response is given divided by the total number of friendly aircraft detected. The percent hostile aircraft identified correctly is the number of hostile aircraft for which a correct identification response is given divided by the total number of hostile aircraft detected.

Attrition is defined as the number of hostile aircraft credited as "killed" divided by the total number of hostile aircraft presented. Fratricide is the number of friendly aircraft credited as "killed" divided by the total number of friendly aircraft presented. The percentage of hostile aircraft "killed" prior to ordnance release is calculated by dividing the number of hostile aircraft "killed" prior to ordnance release by the total number of hostile aircraft presented. Ordnance release is defined as 2 km from the weapon for fixed-wing aircraft and 20 sec after target availability for rotary-wing aircraft. The

probability of kill given fire is the number of aircraft credited as "killed" (hostile plus friendly) divided by the total number of fire events (fire trigger pulls).

The baseline and HEX SPM means are represented graphically in Figure 2. The small size of the HEX sample precludes statistical analyses.

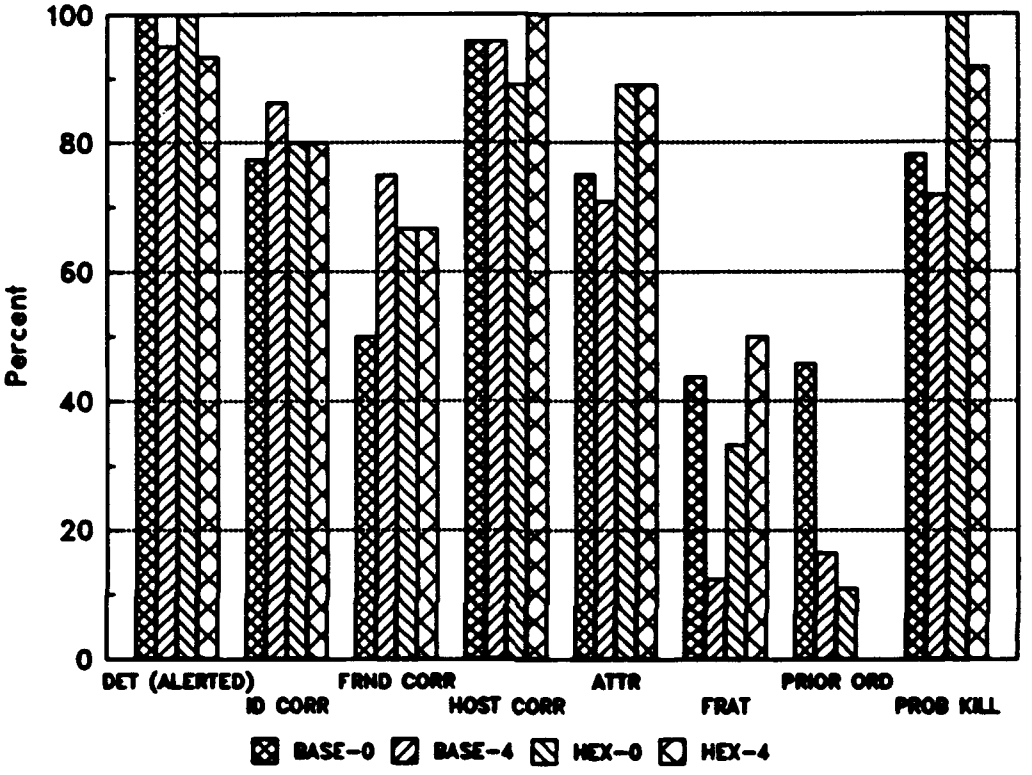


Figure 2. Comparison of baseline and HEX fixed-wing summary performance measures.

HEX rotary-wing TPM. Data were collected on eight rotary-wing TPM. AVL-DET is the time from availability of the target to the detection response, and DET-ID is the elapsed time from the detection response to identification of the aircraft; both are team chief responses. The next five rotary-wing TPMs are gunner actions and are collected automatically by the DAS. DET-IFF is the elapsed time from target detection to identification friend or foe button press. DET-ACQ is the time from detection to weapon acquisition signal. ACQ-LO is the elapsed time from weapon acquire signal to the press of the uncage bar which locks the missile onto the target. LO-FIR is the time from the press of the uncage bar to fire trigger pull. ID-FIR is the time from identification response to fire trigger pull. DET-FIR, a combined team chief and gunner action, is the elapsed time from the detection response to the fire trigger pull.

The HEX rotary-wing TPM means and results of the within-subjects repeated measures analysis of variance (ANOVA) using the SPSS/PC+ Advanced Statistics software package (Norusis, 1986, pps. B153-B181) performed on each pair of MOPP0 and MOPP4 means are listed in Table 6. The means appear in graphic form in Figure 3. The MOPP4 performance decrements, seen consistently in prior Stinger research (Johnson & Silver, 1992; 1993), were absent in the present study. There were no significant differences between the clothing conditions for any of the TPM.

Table 6

HEX Rotary-Wing TPM Means and ANOVA Results

Statistic	MOPP0 (sec)	MOPP4 (sec)	Results
	AVAILABLE TO DETECTION		
Mean	7.89	8.33	F(1,8) = .38
SD	2.28	1.77	
	DETECTION-IDENTIFICATION		
Mean	8.82	8.78	F(1,8) = .00
SD	2.35	3.68	
	DETECTION-IFF		
Mean	3.37	3.27	F(1,6) = .01
SD	2.28	3.18	
	DETECTION-ACQUISITION		
Mean	8.65	7.93	F(1,7) = 1.95
SD	4.18	4.57	
	ACQUISITION-LOCK-ON		
Mean	3.86	3.68	F(1,8) = .09
SD	3.11	3.01	
	LOCK-ON-FIRE		
Mean	2.17	2.23	F(1,8) = .11
SD	.46	.59	
	IDENTIFICATION-FIRE		
Mean	7.23	6.33	F(1,7) = 1.49
SD	3.81	3.50	
	DETECTION-FIRE		
Mean	14.21	13.75	F(1,7) = 1.32
SD	4.94	5.55	

All comparisons are non-significant

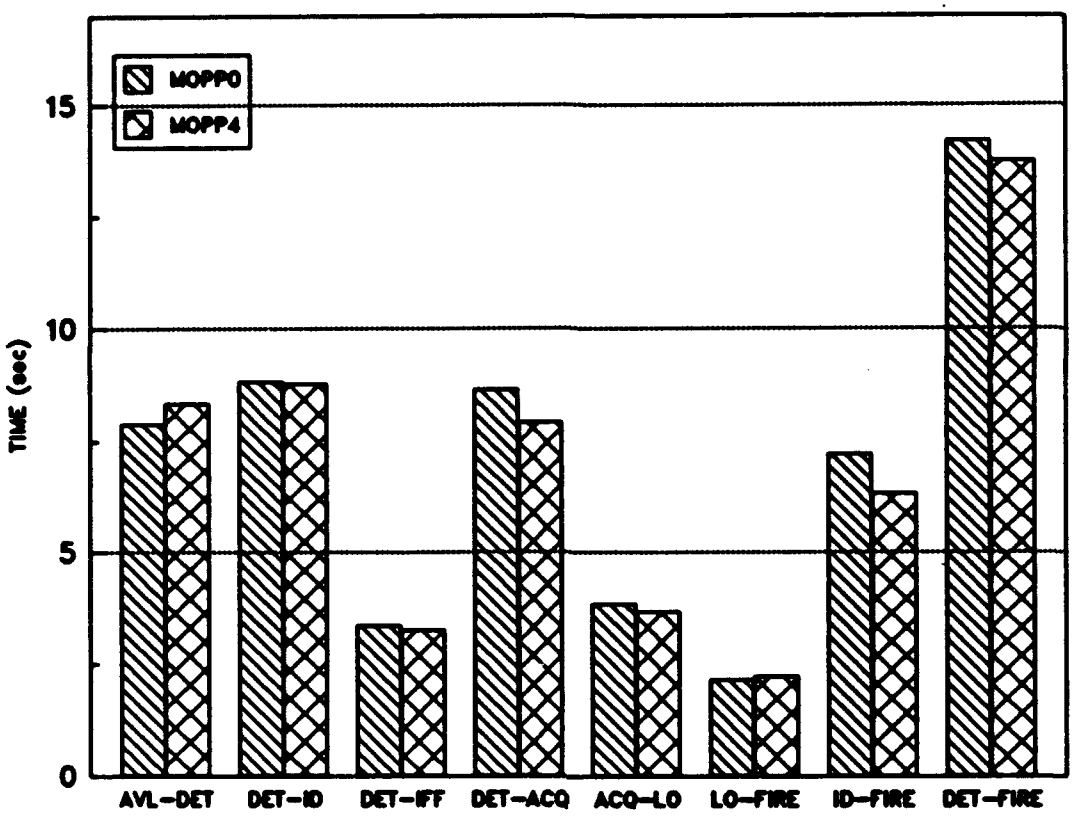


Figure 3. HEX rotary-wing task performance measures.

Comparison of baseline and HEX rotary-wing TPM. A mixed-model ANOVA (Norusis, 1986, pps. B153-B181) was performed on the baseline and HEX rotary-wing TPM means. Treatment (baseline vs HEX) formed the between-subjects comparison and MOPP level (0 or 4) comprised the within-subjects comparison. TPM means are listed in Table 7 and represented graphically in Figure 4.

There was a main effect of treatment (baseline vs HEX) for only one measure, LO-FIRE [$F(1,19) = 3.51$, $p<.08$]. There was a main effect of the MOPP gear [$F(1,19) = 5.65$, $p<.03$] and a significant interaction of treatment and MOPP [$F(1,19) = 3.66$, $p<.07$] also for this TPM. Soldiers in the baseline study took significantly longer to fire after locking on to the target in MOPP4.

There was a main effect of MOPP [$F(1,19) = 3.09$, $p<.10$] and a significant interaction of treatment and MOPP [$F(1,19) = 3.37$, $p<.08$] for the DET-ID TPM. Soldiers in the baseline study took significantly longer to identify aircraft in MOPP 4.

The ACQ-LO TPM yielded a significant interaction of treatment and MOPP [$F(1,19) = 3.11$, $p<.10$]. MOPP4 times were significantly longer for the baseline group.

Table 7

Baseline and HEX Rotary-Wing TPM Means

Statistic	Baseline MOPP0	Baseline MOPP4	(sec)	HEX MOPP0	HEX MOPP4
		AVAILABLE-DETECTION			
Mean	7.28	7.83		7.89	8.33
SD	1.01	1.92		2.28	1.77
		DETECTION-IDENTIFICATION			
Mean	8.54	10.59		8.82	8.78
SD	1.98	3.30		2.35	3.68
		DETECTION-IFF			
Mean	2.20	3.19		3.37	3.27
SD	1.42	3.07		2.28	3.18
		DETECTION-ACQUISITION			
Mean	7.48	8.00		8.65	7.93
SD	3.56	5.30		4.18	4.57
		ACQUISITION-LOCK-ON			
Mean	3.07	5.28		3.86	3.68
SD	2.85	4.66		3.11	3.01
		LOCK-ON-FIRE			
Mean	2.33	2.95		2.17	2.23
SD	.67	.71		.46	.59
		IDENTIFICATION-FIRE			
Mean	5.21	6.23		7.23	6.33
SD	2.92	3.79		3.81	3.50
		DETECTION-FIRE			
Mean	13.03	15.75		14.21	13.75
SD	4.09	6.12		4.94	5.55

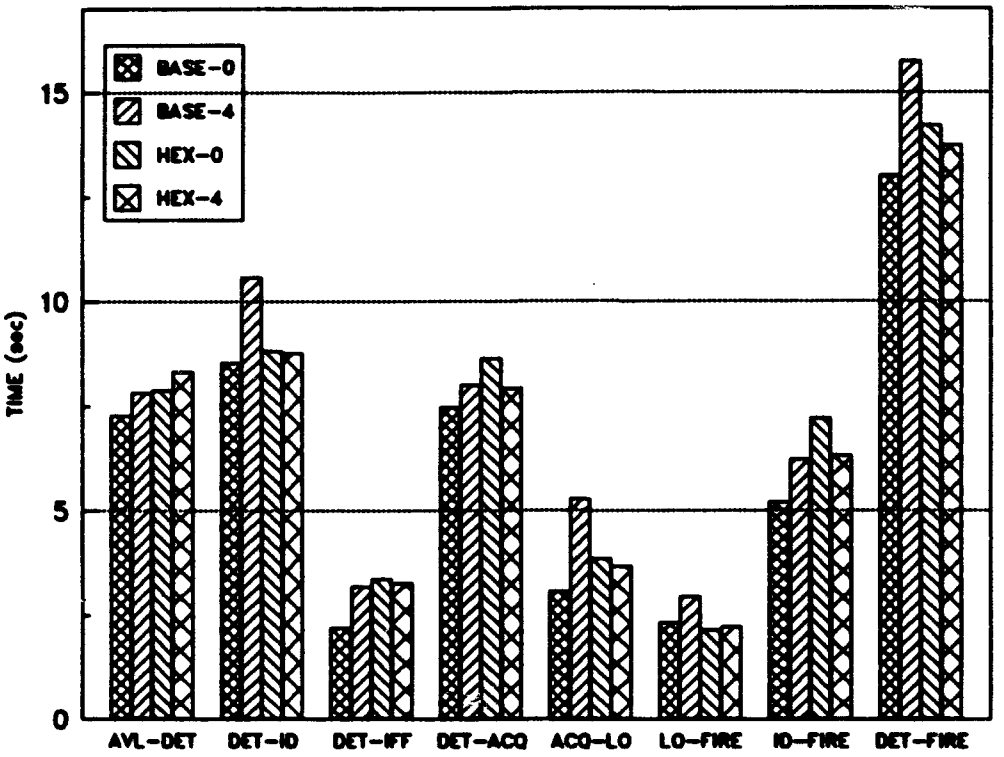


Figure 4. Comparison of baseline and HEX rotary-wing task performance measures.

Finally, there was a treatment by MOPP interaction for the DET-FIRE TPM [$F(1,18) = 5.10$, $p<.04$]. As in each of the above cases, soldiers in the baseline study took significantly longer to perform this task in MOPP4.

HEX rotary-wing SPM. The HEX rotary-wing SPM means and standard deviations are listed in Table 8. The means are depicted in graphic form in Figure 5. There were no significant differences between the MOPP0 and MOPP4 SPM comparisons. The CP clothing had no adverse effect on performance for any of these measures.

Table 8

HEX Rotary-Wing SPM Means

Statistic	MOPP0	MOPP4
	Percent	
	Aircraft Detected (Alerted Trials)	
Mean	100.00	100.00
SD	0	0
	Aircraft Identified Correctly	
Mean	64.00	65.67
SD	22.91	18.00
	Friendly Aircraft Identified Correctly	
Mean	41.67	36.11
SD	33.07	28.26
	Hostile Aircraft Identified Correctly	
Mean	86.11	91.67
SD	18.16	12.50
	Hostile Attrition	
Mean	88.89	90.78
SD	13.18	14.03
	Fratricide	
Mean	55.56	61.11
SD	32.54	28.26
	Hostile Kills Prior to Ordnance Release	
Mean	19.44	25.00
SD	30.45	43.30
	Probability of Kill Given Fire	
Mean	98.67	100.00
SD	4.00	0

All comparisons are non-significant

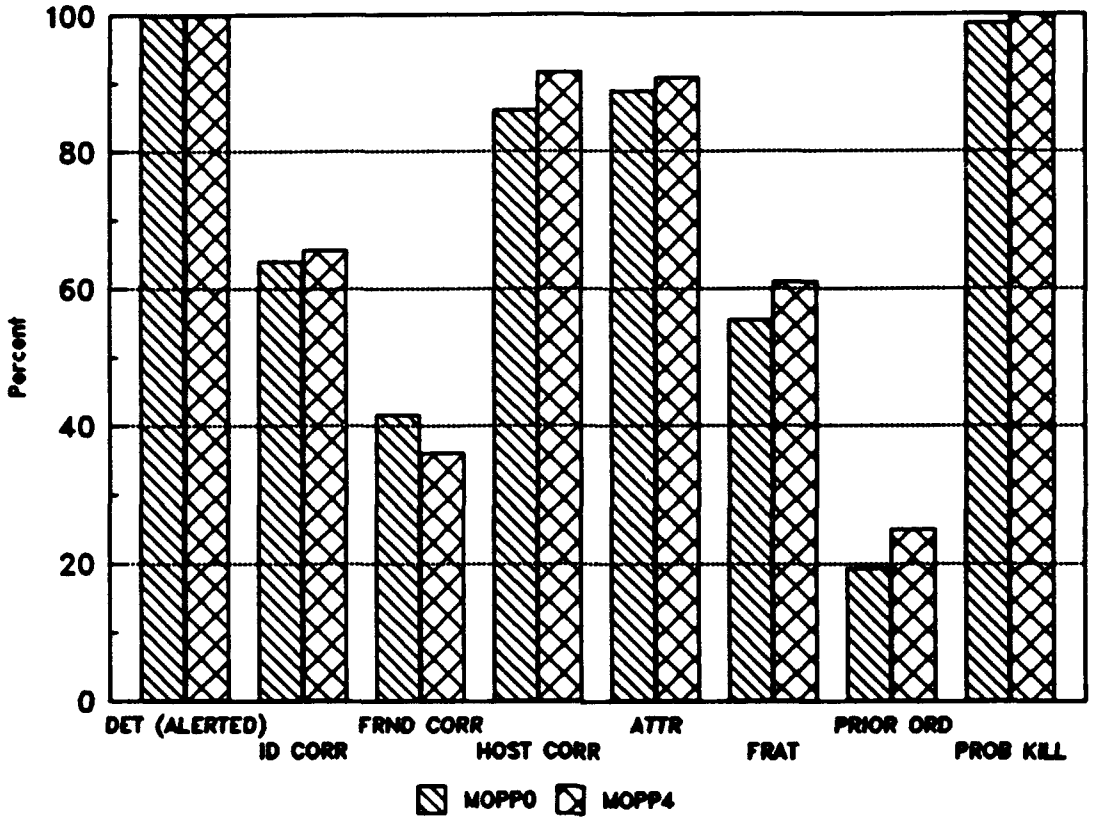


Figure 5. HEX rotary-wing summary performance measures.

Comparison of baseline and HEX rotary-wing SPM. The means and standards deviations for baseline and HEX SPM are listed in Table 8. The means appear in graphic form in Figure 6.

There was a main effect of treatment for two SPM--Hostile Attrition [$F(1,19) = 4.74$, $p<.04$] and Fratricide [$F(1,19) = 3.66$, $p<.07$]. Although Hostile Attrition was significantly better for the HEX Stinger teams, their incidence of Fratricide was significantly greater. There was also a treatment by MOPP interaction for the Hostile Kills Prior to Ordnance Release SPM, $F(1,19) = 3.49$, $p<.08$. HEX teams "killed" significantly fewer aircraft in MOPP0 prior to ordnance release than the baseline teams.

Table 9

Comparison of Baseline and HEX Rotary-Wing SPM Means

Statistic	Baseline MOPP0	Baseline MOPP4	HEX MOPP0	HEX MOPP4
		Percent		
		Aircraft Detect (Alerted Trials)		
Mean	100.00	98.08	100.00	100.00
SD	0	4.48	0	0
		Aircraft Identified Correctly		
Mean	74.75	67.08	64.00	65.67
SD	16.99	16.95	22.91	18.00
		Friendly Aircraft Identified Correctly		
Mean	58.33	52.08	41.67	36.11
SD	30.77	32.78	33.07	28.26
		Hostile Aircraft Identified Correctly		
Mean	90.42	79.58	86.11	91.67
SD	14.69	17.89	18.16	12.50
		Hostile Attrition		
Mean	88.33	75.42	88.89	90.78
SD	14.96	15.15	13.18	14.03
		Fratricide		
Mean	35.42	41.67	55.56	61.11
SD	24.91	24.62	32.54	28.26
		Hostile Kills Prior to Ordnance Release		
Mean	49.58	35.00	19.44	25.00
SD	30.56	27.47	30.46	43.30
		Probability of Kill Given Fire		
Mean	98.83	97.92	98.67	100.00
SD	4.04	7.22	4.0	0

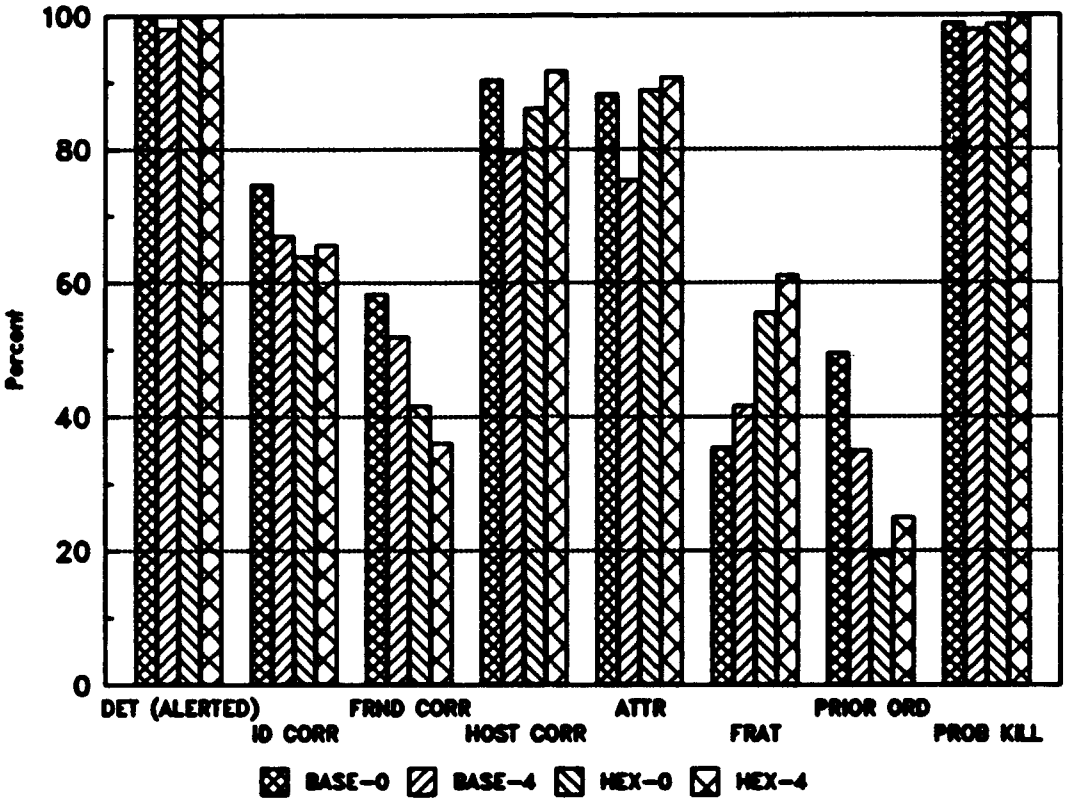


Figure 6. Comparison of baseline and HEX rotary-wing summary performance measures.

Workload Analyses

Participants rated workload on the NASA TLX rating scale after each engagement trial in each clothing condition. It was predicted that the workload ratings given in the MOPP4 clothing condition would be significantly higher than those given in the MOPP0 condition. It was also predicted that the workload ratings given by the Stinger teams in the HEX study would be significantly greater than those given by the Stinger teams in the baseline research. The latter results were expected because of the addition of heat and exercise to the HEX experimental design.

Hex results. A mixed model repeated measures ANOVA was performed on the workload data using the SPSS/PC+ Advanced Statistics software package (Norusis, 1986, pp. B153-B181). Duty position (team chief or gunner) was the between-subjects factor and MOPP level (0 or 4) was the within-subjects factor. The means, standard deviations, and number of observations for the workload ratings are listed in Table 10. The means are depicted graphically in Figure 7.

There were no significant difference between the ratings given by the team chiefs and the gunners, nor was there an

interaction between duty position and MOPP gear. As expected, however, there was a significant difference between the ratings given in MOPP0 and MOPP4 [$F(1,16) = 27.29$, $p<.05$].

Table 10

HEX Workload Ratings

	MOPP0	MOPP4
	Team Chief	
Mean	22.80	47.98
SD	13.76	13.31
N	9.00	9.00
	Gunner	
Mean	30.01	44.94
SD	16.72	18.26
N	9.00	9.00
	Team Chief and Gunner Combined	
Mean	26.45	46.46
SD	15.32	15.58
N	18.00	18.00

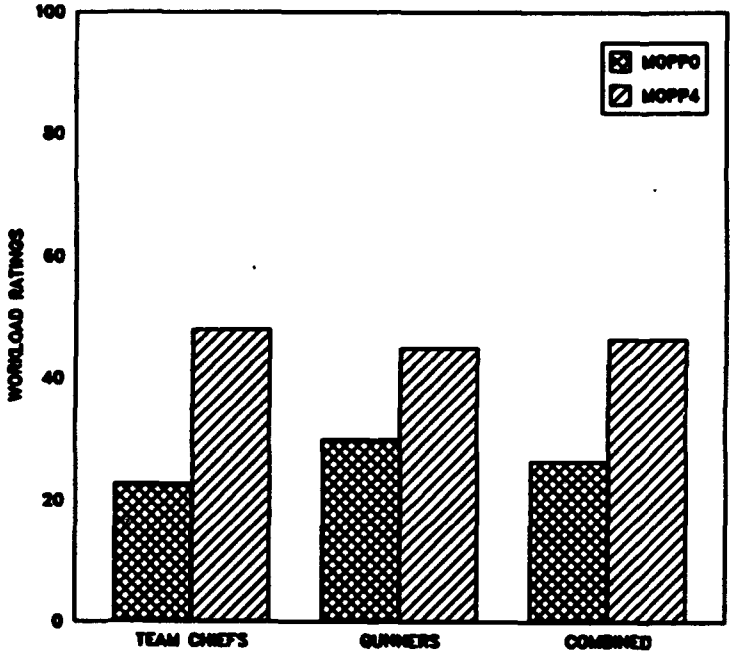


Figure 7. HEX workload ratings.

Baseline versus HEX results. A mixed-model repeated measures ANOVA (Norusis, 1986, pp. B153-B181) was used to compare the workload ratings given by the Stinger teams in the baseline and HEX studies. The between-subjects variables were treatment (baseline or HEX) and duty position (team chief or gunner). MOPP level (0 or 4) was the within-subjects variable. The mean workload ratings for both groups are represented graphically in Figure 8.

Despite the addition of heat and exercise to the HEX study, there was no significant difference between ratings given by the baseline and the HEX teams. Workload ratings given by the team chiefs and gunners in both studies were also equivalent. There were no significant interactions of Treatment X Position, Position X MOPP, Treatment X MOPP, or Treatment X Position X MOPP. There was, however, the expected effect of the CP gear on workload [$F(1,38) = 52.77$, $p<.05$], with ratings being significantly greater in MOPP4. It may be that it is not possible to isolate from workload ratings the additional contributions of heat and exercise beyond those of the MOPP gear because workload ratings are given in the relative sense. That is, each individual is rating workload in the MOPP4 condition relative to that experienced in the MOPP0 condition. Individuals in the HEX study were not rating workload relative to the baseline condition which, of course, they never experienced.

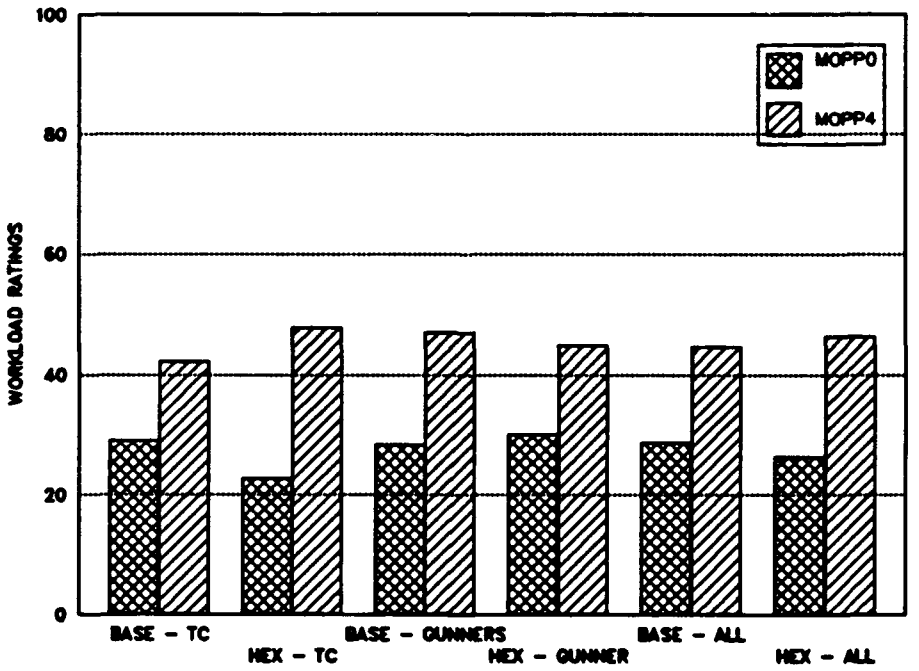


Figure 8. Baseline versus HEX workload ratings.

Stress Analyses

The SEQ (Spielberger, 1983) was administered three times during each clothing condition; pretest, midtest, and posttest. Stress ratings were analyzed using the Mann-Whitney U test for between-group comparisons and the Wilcoxon T test for within-group comparisons (Bruning & Kintz, 1977).

Hex results. Table 11 contains the stress means, standard deviations and number of observations. The mean MOPP0 - MOPP4 comparisons are presented in graphic form in Figure 9 and the pretest - posttest comparisons are presented in Figure 10. As predicted, MOPP4 stress ratings were significantly greater than MOPP0 ratings; Pretest [$T(12) = 7.5$, $p<.01$], Midtest [$T(13) = 0$, $p<.005$], and Posttest [$T(12) = 16$, $p<.05$]. Also as predicted, stress levels neither increased nor decreased significantly over MOPP0 trials or MOPP4 trials.

Table 11

HEX Stress Ratings

Statistic	MOPP0	MOPP4
	Pretest	
Mean	41.13	48.67
SD	6.67	7.15
N	16	15
	Midtest	
Mean	41.83	50.92
SD	6.32	5.60
N	18	13
	Posttest	
Mean	40.50	46.42
SD	6.29	7.48
N	16	12

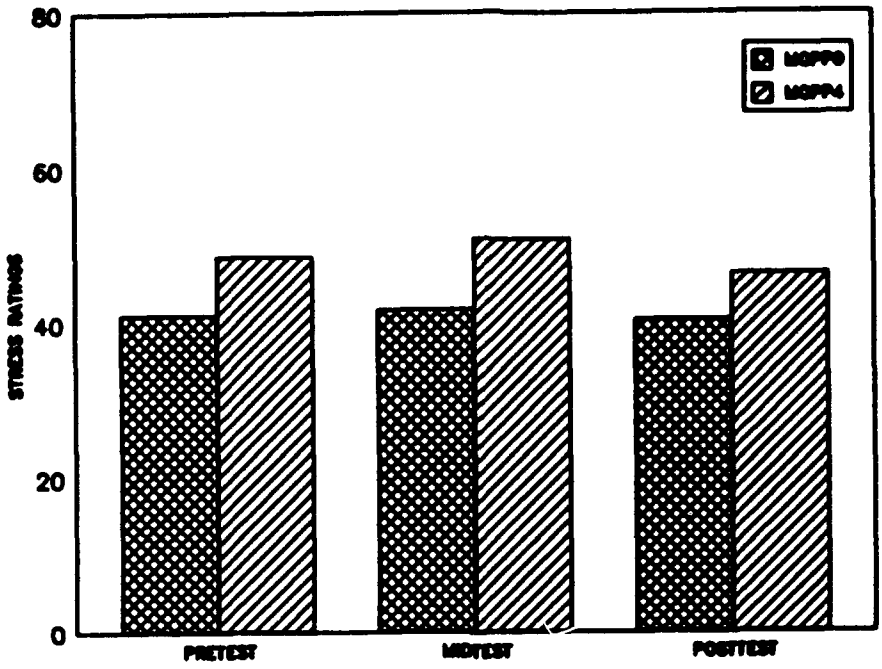


Figure 9. HEX MOPP0 – MOPP4 stress ratings.

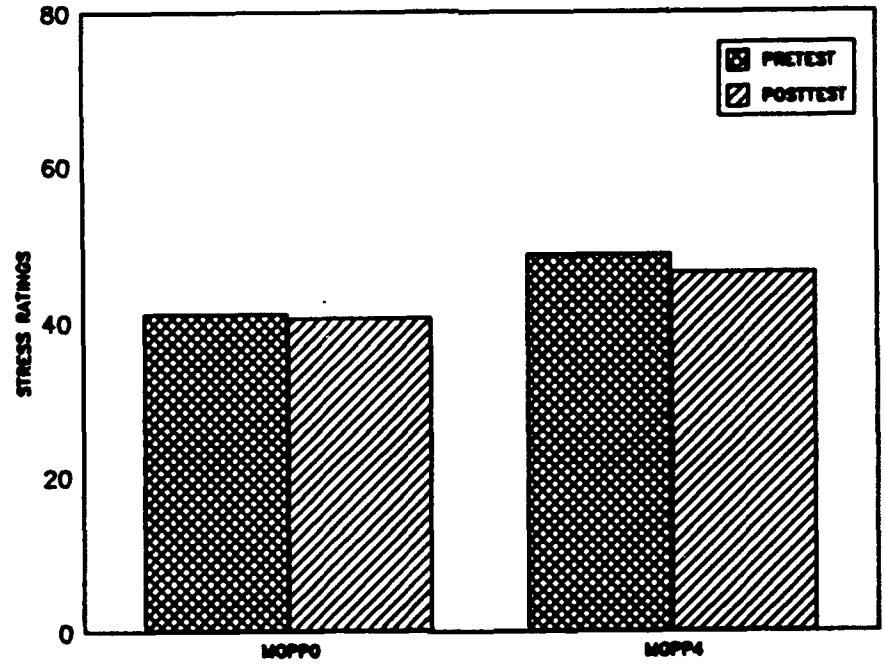


Figure 10. HEX pretest and posttest stress ratings.

Baseline versus HEX results. Baseline and HEX mean stress ratings are listed in Table 12 and appear in graphic form in Figure 11. As expected, HEX stress ratings were significantly greater than those given by Stinger teams in the baseline study MOPP0 Pretest [$z(16,24) = -4.71$, $p < .00003$], MOPP0 Posttest [$z(16,24) = -3.99$, $p < .00005$], and MOPP4 Pretest [$z(15,24) = -3.54$, $p < .0002$]. The baseline and HEX stress levels reported for MOPP4 Posttest, however, were not significantly different from each other [$z(12,24) = -1.31$, $p > .05$].

Table 12

Baseline and HEX Stress Ratings

	Baseline	HEX
Pretest MOPP0	28.08	41.13
Posttest MOPP0	29.63	40.50
Pretest MOPP4	37.08	48.67
Posttest MOPP4	41.17	46.42

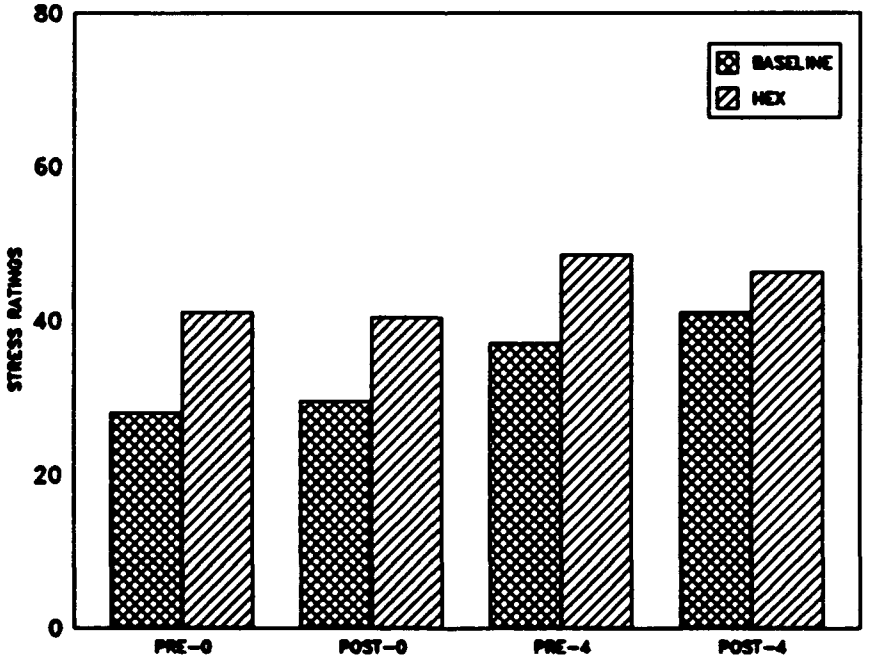


Figure 11. Baseline and HEX stress ratings.

Physiological Measures

The physiological measures collected by WRAIR were expected to be significantly higher in MOPP4. Activity levels, however, were not expected to differ as a function of CP clothing. These predictions were confirmed. Heart rate, core temperature, and left and right skin temperature clearly showed the combined effects of the MOPP gear, heat, and exercise.

Heart rate. Mean heart rate (see Figure 12) was significantly higher when the CP clothing was worn [$F(1,11) = 76.22$, $p<.0001$]. Although the differences in heart rate as a function of duty position are fairly substantial, they are not statistically significant. There was no interaction of duty position and MOPP gear.

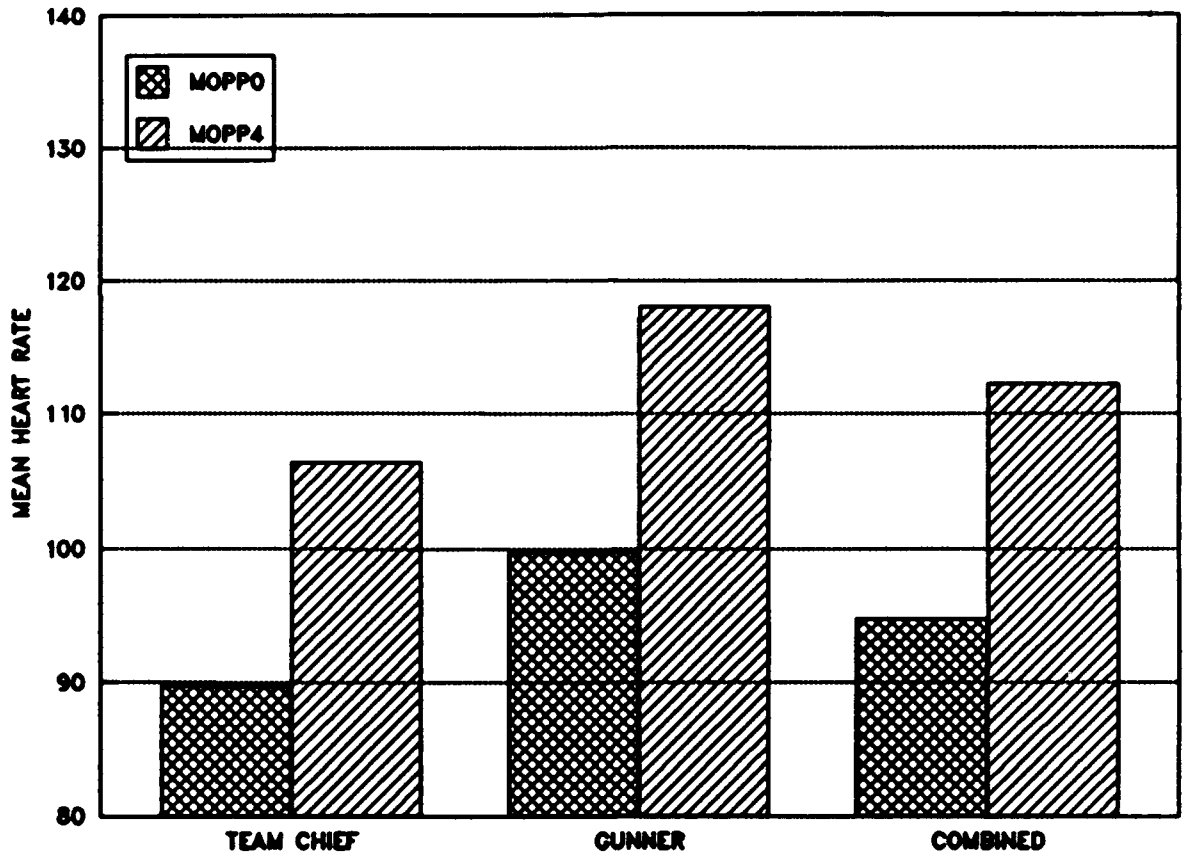


Figure 12. Mean heart rate.

Mean heart rate over trials is seen in Figure 13. The physiological stress created by carrying a THT 200 meters in the desert heat is clearly illustrated by the dramatic increase in heart rate.

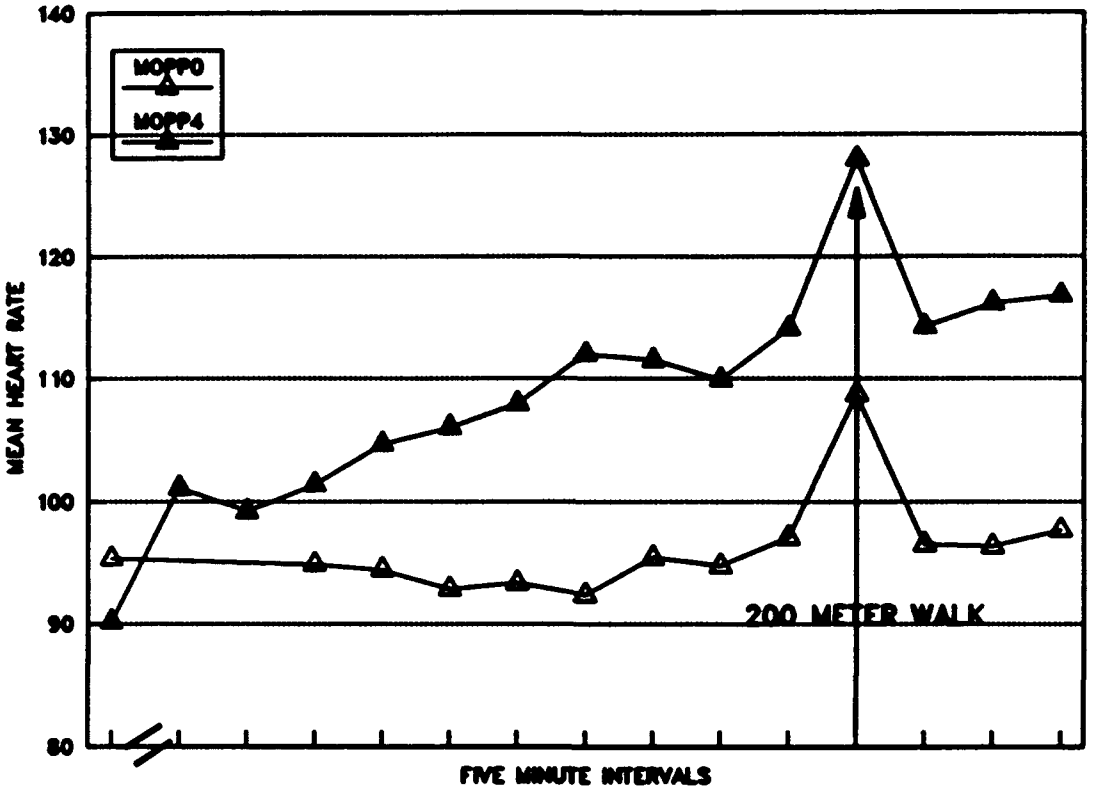


Figure 13. Mean heart rate over trials.

Activity level. As expected, there was no difference between activity levels (see Figure 14) as a function of CP clothing and there was no difference as a function of duty position, nor did duty position interact with MOPP gear. The greater activity associated with the 200 meter walk is seen in Figure 15 in which the mean activity levels over trials are depicted.

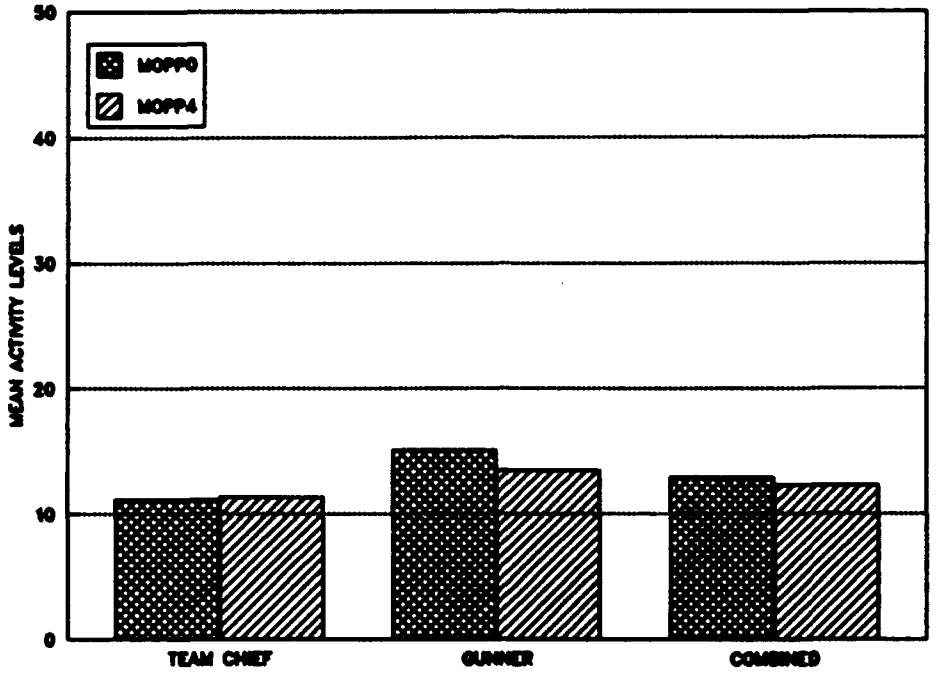


Figure 14. Mean activity levels.

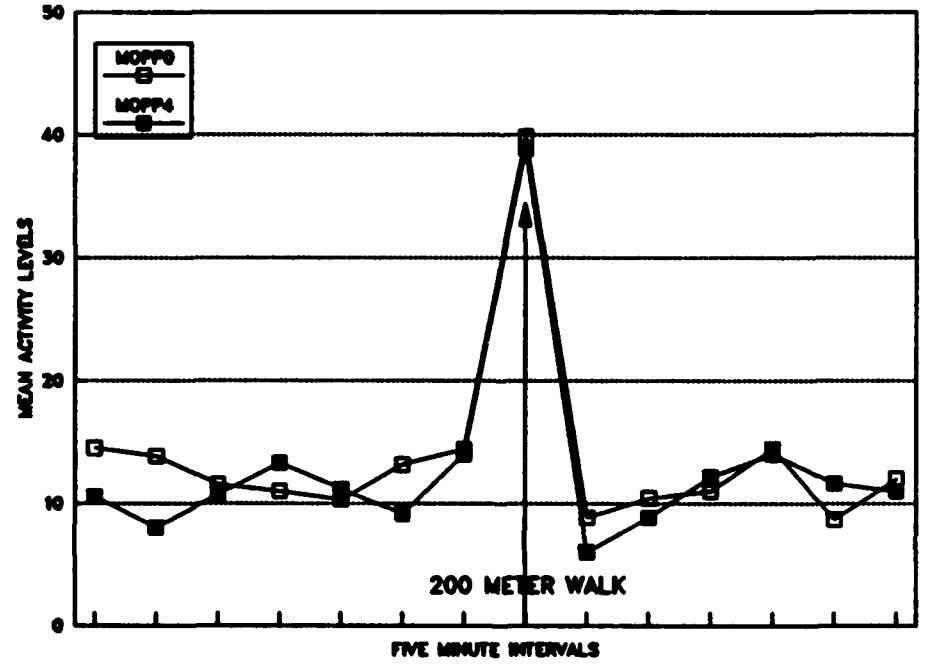


Figure 15. Mean activity levels over trials.

Core temperatures. Deep body, or core temperature, was estimated using an ingestible "temperature pill." A combination of core temperature data and heart rate was used by medical monitors to determine whether a soldier should be withdrawn from test. Skin temperatures provided additional information to aid in making termination decisions (Redmond, et al., 1992). The overall MOPP4 means (see Figure 16) were significantly different from the MOPP0 means [$F(1,16) = 20.78$, $p<.0001$]. The team and gunner mean core temperatures also differed significantly from each other [$F(1,16) = 7.72$, $p<.01$]. However, the interaction of MOPP level and duty position was not significant. Mean core temperatures over trials and team chief and gunner MOPP0 and MOPP4 core temperatures over trials are represented graphically in Figures 17, 18, and 19.

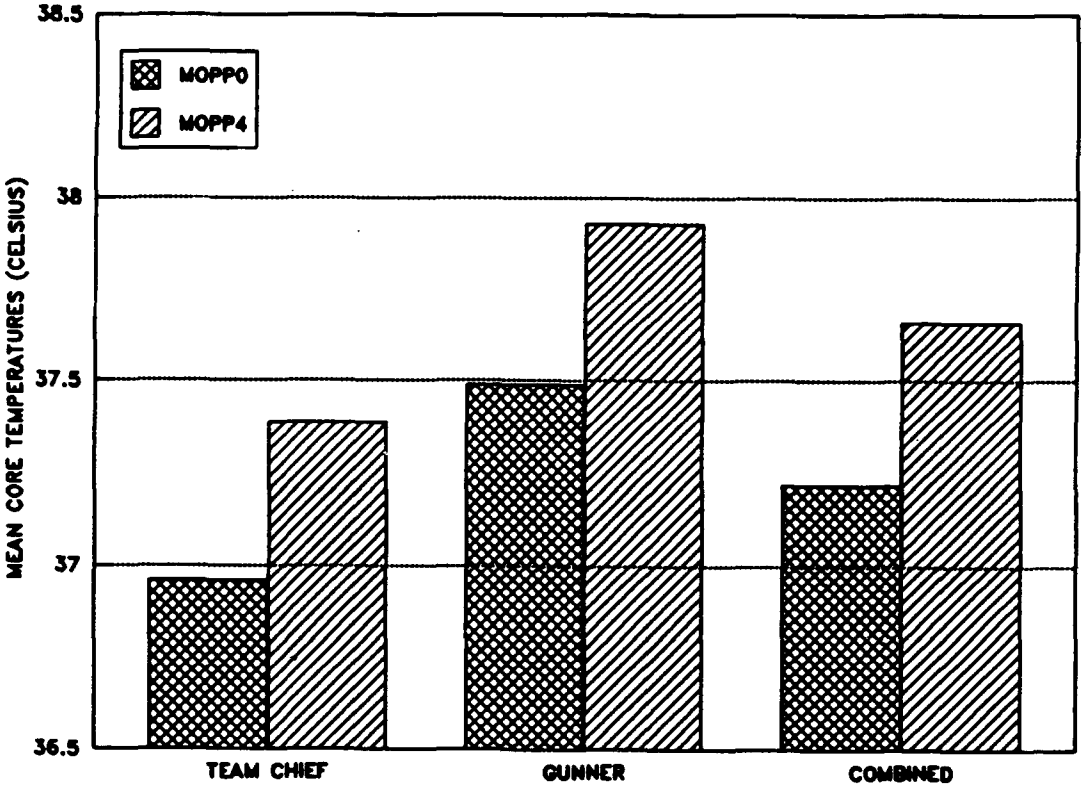


Figure 16. Mean core temperatures.

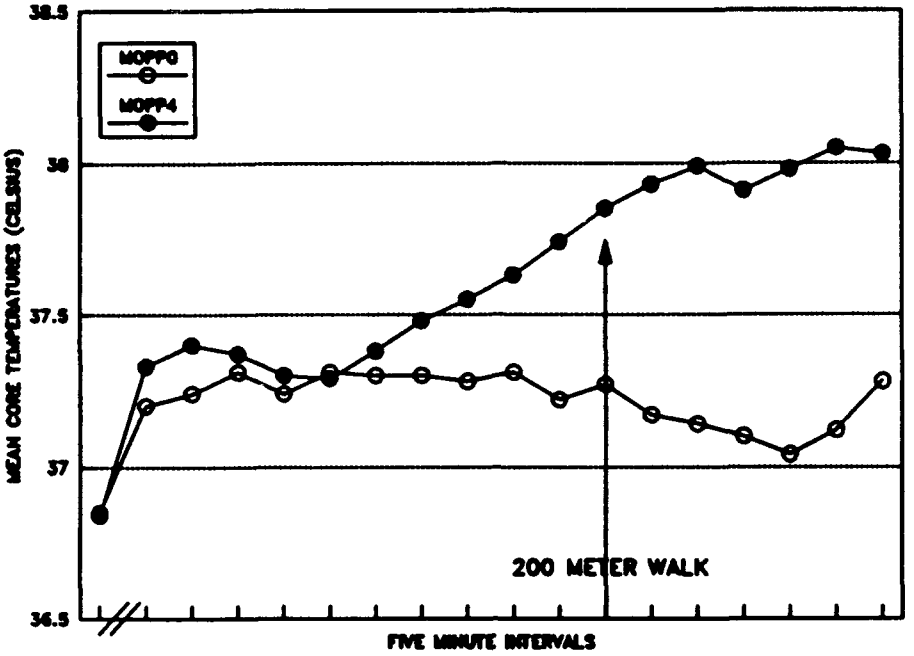


Figure 17. Mean core temperatures over trials.

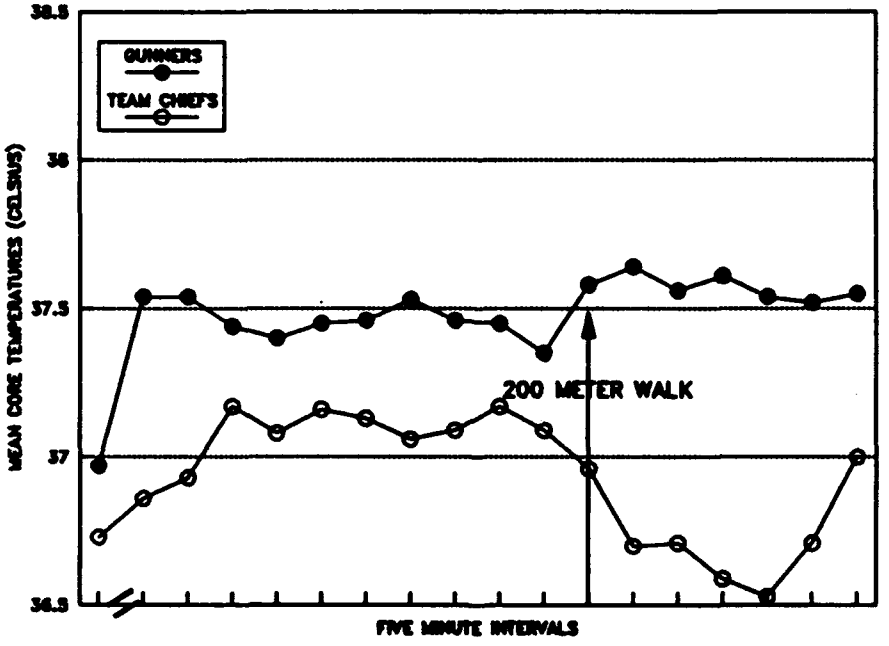


Figure 18. Team chief and gunner MOPP0 mean core temperatures over trials.

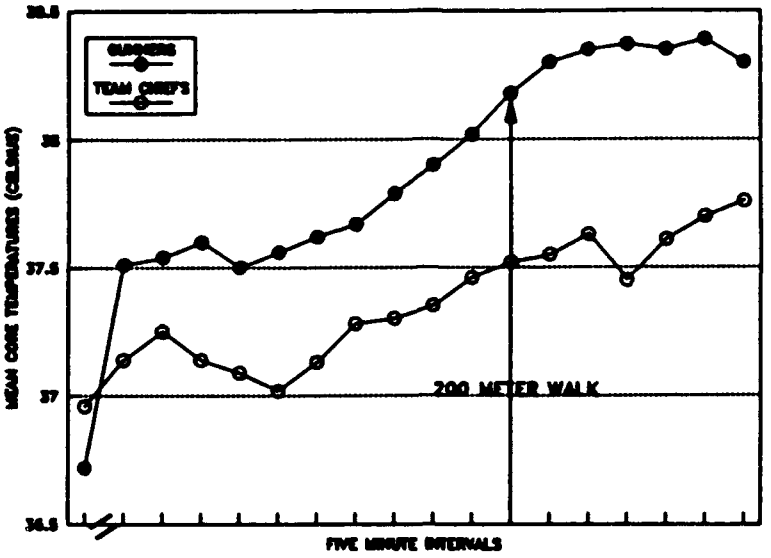


Figure 19. Team chief and gunner MOPP4 mean core temperatures over trials.

Left and right skin temperatures. Mean left and right skin temperatures are represented graphically in Figures 20 and 22 respectively. Mean left and right skin temperatures over trials are depicted in Figures 21 and 23. MOPP4 mean temperatures were significantly higher than MOPP0 [Left - $F(1,16) = 17.78$, $p<.001$; Right - $F(1,16) = 8.38$, $p<.025$], but skin temperature was not affected by duty position, nor was there an interaction of duty position and MOPP gear.

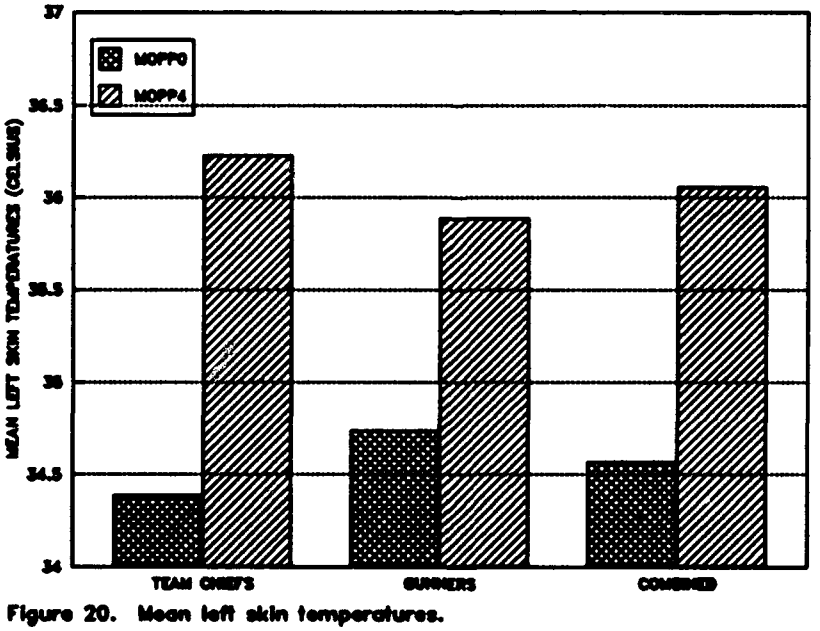


Figure 20. Mean left skin temperatures.

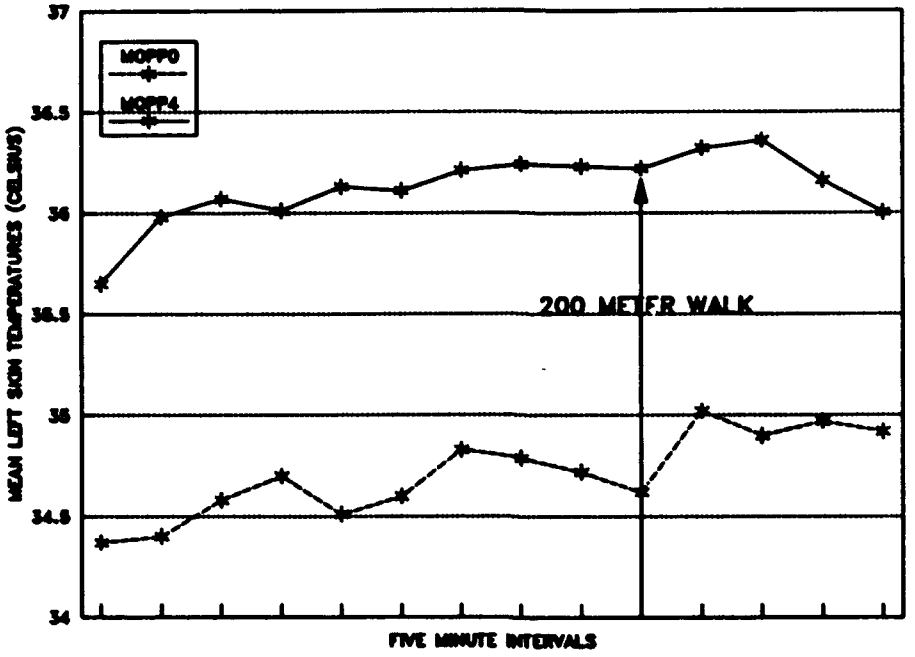


Figure 21. Mean left skin temperatures over trials.

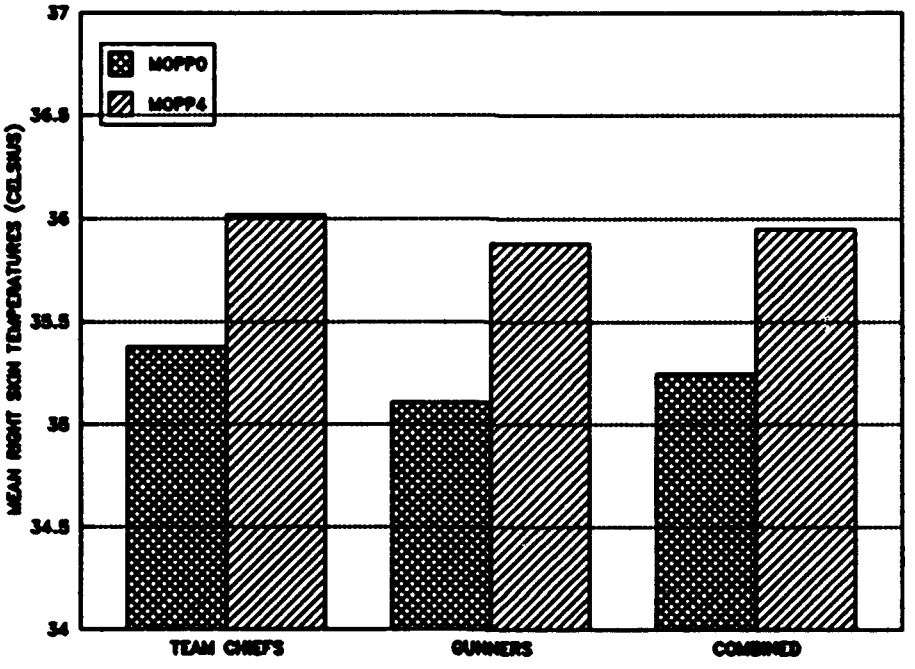


Figure 22. Mean right skin temperatures.

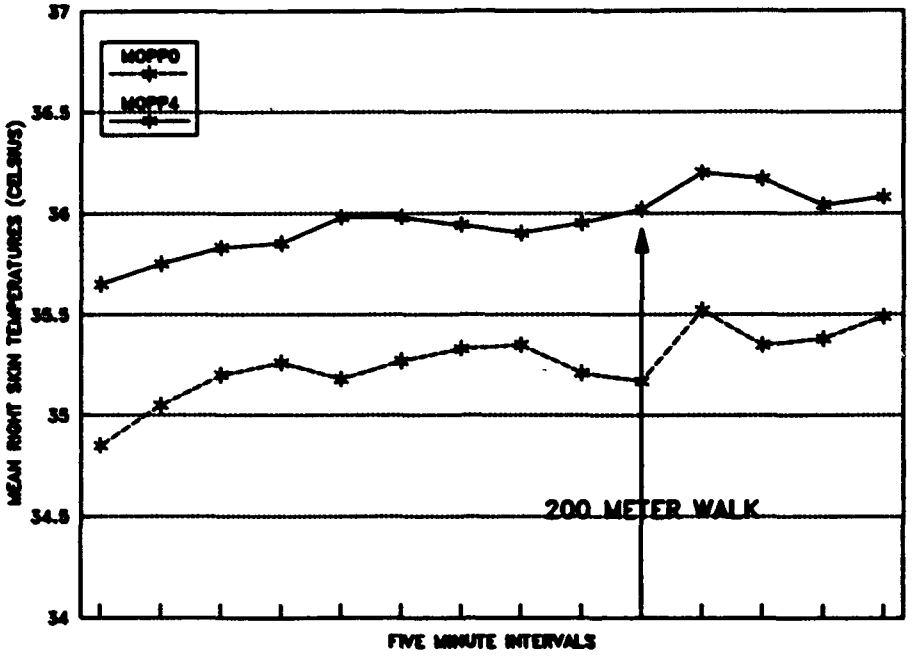


Figure 23. Mean right skin temperatures over trials.

MOPP4 Casualties

Three of our test participants became "casualties" due to the combined effects of the MOPP gear, heat, and exercise. On Day 1 of test, a team chief was judged to be "at risk" by the medical monitor. He was removed from the test and placed under medical observation. Later he was pronounced "fit," returned to test, and successfully completed an afternoon series of MOPP0 trials. On Day 2 of test, two gunners withdrew, complaining of severe nausea and dizziness. They removed their MOPP gear, rested under medical supervision, and suffered no aftereffects as a result of their experience.

It is important to note that each of our three MOPP4 casualties occurred after trial 7, the first trial after the exercise portion of our test during which participants marched a total of 200 meters in the desert heat while carrying a FHT. In the Stinger baseline research, there were no MOPP4 casualties. Not only were there no casualties during that research, there has never been a casualty in any of our previous research investigating the effects of the MOPP gear at the RTS facility. To date, that research has involved 94 individuals. So a casualty rate of 0 percent in all prior RTS MOPP research must be compared to a casualty rate of 17 percent in the present study.

The heart rate, activity level, core temperature, and left and right skin temperature data of the casualties are compared to the group data in Figures 24 through 28.

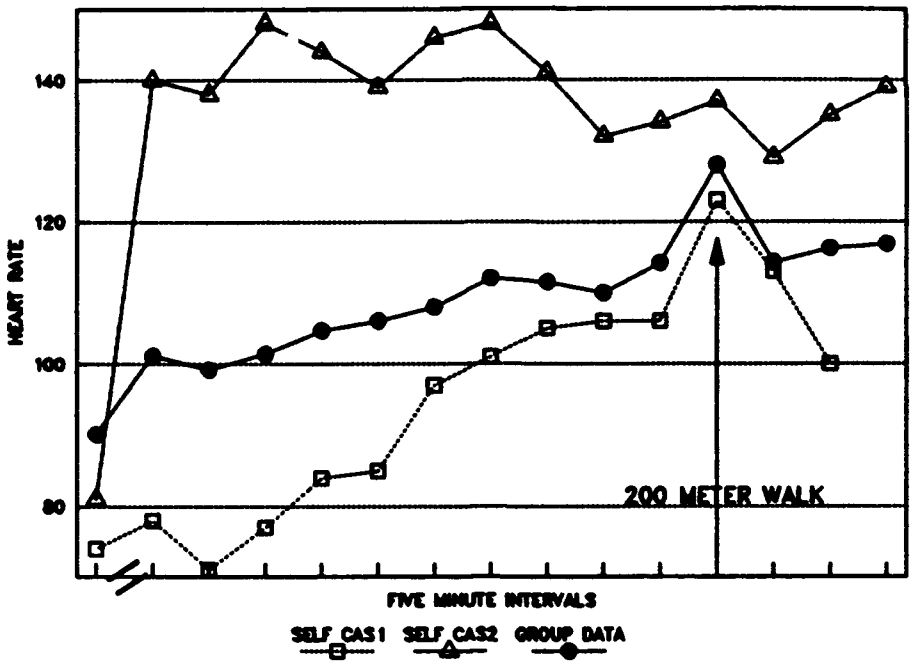


Figure 24. Casualty heart rate over trials.

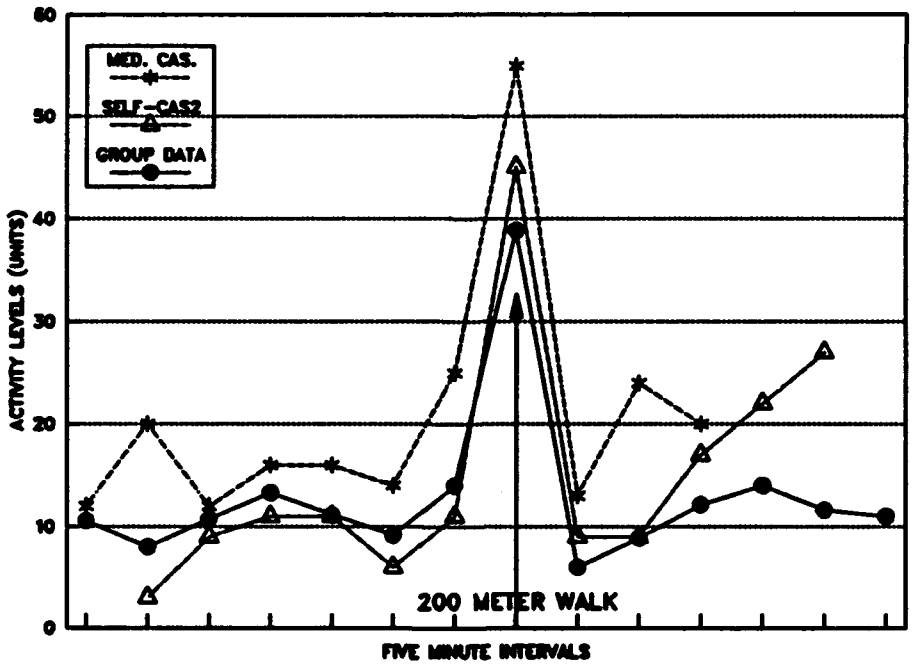


Figure 25. Casualty activity levels over trials.

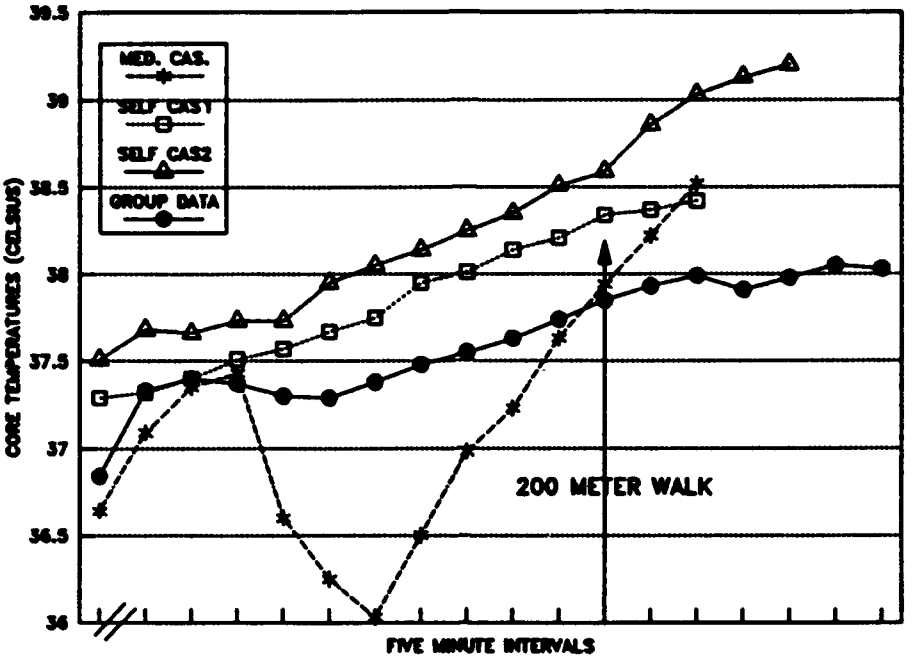


Figure 26. Casualty core temperatures over trials.

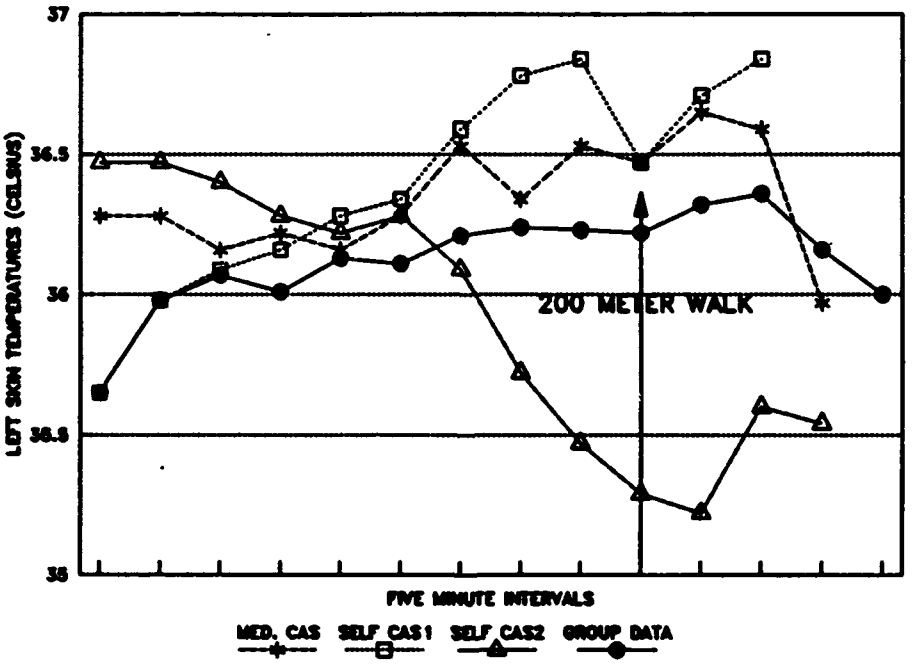


Figure 27. Casualty left skin temperatures over trials.

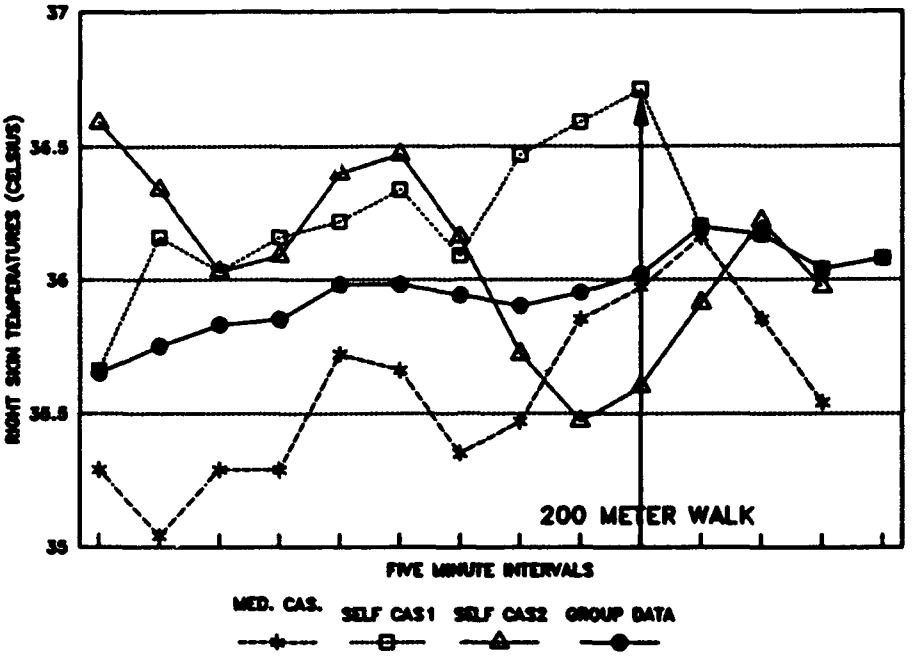


Figure 28. Casualty right skin temperatures over trials.

Discussion

Rotary-wing engagement performance showed neither the expected MOPP4 decrement nor a decrement due to the addition of heat and exercise to the experimental design. The apparent conclusion to be derived from these results, that Stinger engagement performance was not degraded by the MOPP gear, heat, or exercise in the present study, must be tempered by consideration of the other evidence presented in this paper. Measures of workload, stress, heart rate, core temperature, left and right skin temperature, and casualty rates clearly reflected the combined negative effects of MOPP gear, heat, and exercise on Stinger teams. Each of these measures was significantly elevated with respect to their MOPP0 levels. Further, HEX stress levels and casualty rates, without question, reflected the additional contributions of heat and exercise beyond those of the MOPP gear alone. This evidence must additionally be considered in light of results from prior Stinger research, evidence demonstrating the arousing effects of high heat on performance, and finally, examination of the characteristics of our baseline and HEX groups. The combined evidence suggests that fundamental differences in motivation existed between the HEX and baseline groups, and that these differences were further exacerbated by extreme heat.

Recall that in the present study Stinger teams were negatively affected by MOPP gear, heat, and exercise on all measures except engagement performance. This finding is not unusual; the literature contains many instances in which performance on a military task remained unaffected while the

adverse impact of the CP clothing was seen in physiological and/or other psychological measures (Glumm, 1988; Heslegrave, Frim, Bossi, & Popplow, 1990; Posen, Munro, Mitchell, & Satterthwaite, 1986). Although these findings are not unusual, there remains the issue that the results of the present study stand in direct contrast to those from all prior Stinger research, in which the engagement performance of both the team chief and the gunner was impaired by the MOPP gear. Consider, therefore evidence establishing that high heat can have an arousing effect which improves performance for short periods of time under certain conditions (Pepler, 1958; Poulton, 1970; Ramsey & Pei, 1975). Consider further the differences in requirements for participation in the HEX research and the baseline study. Soldiers who volunteer to ingest core temperature devices, wear harnesses and MOPP gear in the desert in July, carry FHT 200 meters in desert heat, and respond to lengthy questionnaires on repeated occasions are by definition "different" from soldiers who volunteer only to wear CP clothing under benign environmental conditions.

Given the aggregated evidence, it seems reasonable to postulate that fundamental differences in motivational levels between the two groups combined with potentially arousing effects of extreme heat enabled HEX teams to overcome the effects of MOPP gear, heat, and exercise on engagement performance.

REFERENCES

Bruning, J. L., & Kintz, B. L. (1977). Computational handbook of statistics. Illinois: Scott, Foresman and Company.

Field Manual No. 44-18-1. (1984). Stinger Team operations. Washington, DC: Headquarters, Department of the Army.

Glumm, M. (1988). Physiological and psychological effects of the NBC environment and sustained operations on systems in combat (P^2NBC^2): Tank systems climate controlled trials (Iron Man) (Technical Memorandum 9-88). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.

Heslegrave, R. J., Frim, J., Bossi, L. L., and Popplow, J. R. (1990). The psychological physiological, and performance impact of sustained NBC operations on CF-18 fighter pilots (DCIEM No. 90-RR-08). Downsview, ONT: Defence and Civil Institute of Environmental Medicine.

Johnson, D. M., & Silver, J. D. (1992). Stinger team performance during engagement operations in a chemical environment: The effect of cuing (ARI Technical Report 957). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A254 524)

Johnson, D. M., & Silver, J. D. (1993). Stinger team performance during engagement operations in a chemical environment: The effect of experience (ARI Research Report 1638). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A268 952)

NASA-Ames Research Center, Human Performance Group (1986). Collecting NASA workload ratings: A paper-and-pencil package (version 2.1). Moffet Field, CA: NASA-Ames Research Center.

Norusis, M. J. (1986). SPSS\PC+ advanced statistics. Illinois: SPSS, Inc.

Pepler, R. D. (1958). Warmth and performance: An investigation in the tropics. Ergonomics, 2, 63-68.

Posen, K. J., Munro, I., Mitchell, G. W., & Satterthwaite, J. S. (1986). Innovative test of physiological and psychological effects of NBC and extended operations on Mechanized Infantry Squads (TRADOC Project No. 0000663). Fort Benning, GA: U.S. Army Infantry Board.

Poulton, E. E. (1970). Environment and human efficiency. Springfield, IL: Charles C. Thomas.

Ramsey, J. D., & Pei, S. B. (1975). Sedentary work by females in hot environments. Proceedings 19th Annual Meeting of the Human Factors Society, pp. 498-500.

Redmond, D. P., Leu, J. R., Popp, K. A., Hall, S. W., Galinski, C., & Gutierrez, P. E. (1992). Proceedings of a symposium--Consequences of wearing the chemical protective ensemble: Illustrative approaches--presented at the meeting of the Military Testing Association (pp. 31-40) (Technical Note No. 9-92). Natick, MA: U.S. Army Research Institute of Environmental Medicine.

Silver, J. D., & Lockhart, J. M. (1993). Avenger team performance during engagement operations in a chemical environment (ARI Research Report 1639). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A269 111)

Spielberger, C. D. (1983). State-trait anxiety inventory: Form Y. Palo Alto, CA: Consulting Psychologists Press.