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EFFECTS OF CHEMICAL PROTECTIVE CLOTHING AND MASKS, AND TWO DRINKING WATER DELIVERY SYSTEMS ON VOLUNTARY DEHYDRATION

U S ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
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BDU: Control group wearing a modified BDU and drinking directly from a canteen,

IC: wearing MOPP IV (Impermeable Clothing) but without the chemical protective mask and drinking directly from canteens,

CS: wearing MOPP IV with the hooded mask and using the current water delivery system,

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FF: wearing MOPP IV with the hooded mask and using a FIST-FLEX type of water delivery system.

Water, iodinated (16 mg I_2/liter) and at ambient temperature (30°C), was provided ad libitum in the appropriate canteen.

The effects of the two water delivery systems on fluid balance and temperature regulation was assessed through measures of fluid intake, body weight changes, heart rate, rectal and skin temperatures, and plasma electrolytes. The experimental design also afforded the additional opportunity to evaluate the impact of MOPP configurations on fluid consumption and body weight loss.

All subjects wearing BDU completed the 300 min of exercise. Consumption of iodinated water (0.25 $\pm$ 0.04 L/hr) partially compensated for sweat losses (0.37 L/hr) that contributed to body weight losses (BWL) of 0.24 $\pm$ 0.02 kg/hr. Although mean BWL in the IC group was not different from BDU, both mean sweat rate (0.53 L/hr) and fluid consumption (0.34 $\pm$ 0.03 L/hr) increased for similar exercise times. Compared to the BDU group, both CS and FF groups consumed more water during the exercise periods; however, consumption by CS (0.28 $\pm$ 0.04 L/hr) was significantly less than FF (0.42 $\pm$ 0.06 L/hr). Because sweat losses were also greatly increased in CS and FF groups (0.84 L/hr), body weight deficits were double that of BDU. This may account for the performance decrements in the CS and FF trials in which an average of 210 and 231 min, respectively, out of a possible 300 exercise min were completed. When in MOPP IV only 37% using CS and 29% using FF completed the six exercise bouts.

Compared to the BDU trial, wearing MOPP IV without the mask (IC) elicited elevations in final exercise heart rate (HR) and further increments (25 BPM) were effected by adding the hooded mask. Final exercise rectal temperature (Tre) was not different between BDU and IC (37.6°C) but was increased in both the CS (38.0°C) and FF (38.3°C) trials. Final 3 point mean weighted skin temperature (Tsk; chest, arm, calf) rose significantly when the hooded mask was added (CS and FF) compared to both IC and BDU. Compared to the calculated change in heat storage (ΔS) in BDU (7$\pm$3 kcal/m^2), IC increased ΔS (16$\pm$3 kcal/m^2) and adding the hooded mask in both cases exacerbated this increment (CS: 34$\pm$4 kcal/m^2; FF: 32$\pm$3 kcal/m^2).

Although plasma volume (PV) increased during the BDU trial, donning the impermeable gear increased sweat rate and reduced fluid intake producing progressive PV deficits in IC (-2%), CS (-7.6%) and FF (-9.6%). The decrements in PV were accompanied by similar changes in the total content of plasma sodium and chloride, whereas total circulating potassium, magnesium, calcium and plasma proteins were unchanged. This reduction in plasma volume and total content of key plasma electrolytes was associated with sweat rates greater than 0.5 L/hr. The absence of a net change in total plasma proteins probably conferred some degree of intravascular volume stability.

As anticipated, soldiers using either the CS or FF systems perceived more symptoms of hyperthermia and dehydration, and rated their final walk as being as hard to very hard, and more difficult than walk 1.

The present study provided strong evidence of physiological and perceptional decrements when MOPP IV is worn during low intensity work in moderate climates. Compared to BDU and when chemical protective clothing was worn, adding the hooded mask to the chemical protective ensemble increased sweat loss, limited drinking and reduced work tolerance. Heat stress was increased when the chemical protective trousers, jacket, boots, and gloves were worn over the BDU, and adding the hooded mask to this configuration elicited further elevations in heat storage and hemoconcentration, and greater fluid deficits. Compared to the current system (CS), a FIST-FLEX (FF) type system of water delivery may elicit improved drinking during exercise/work thus reducing the physiological cost of work in the heat and improving physical performance in moderate to hot climates.

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DISCLAIMER

The views of the authors do not purport to reflect the positions of the Department of the Army or the Department of Defense. Human subjects participated in this study after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 in Use of Volunteers in Research. Citations of commercial organizations or trade names do not constitute an official Department of the Army endorsement or approval of the products or services of these organizations.

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ABSTRACT

The effects of MOPP IV configuration and the M17A1 face mask and two water delivery systems (CURRENT and FIST-FLEX type) on voluntary dehydration and fluid-electrolyte balance were evaluated. Testing was done in a climatic chamber in a temperate climate (dry bulb = 29.5°C (85.1°F), wet bulb = 18.3°C (65°F) and 33% R.H., producing a WBGT of 21.7°C or 71°F). Fifteen male subjects walked on a treadmill set on a flat grade at a rate of 4.02 km/hr for 50 min of each hr for up to 6 hrs. Each subject was randomly assigned to one of four groups as follows:

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Water, iodinated (16 mg I_2/liter) and at ambient temperature (30°C), was provided ad libitum in the appropriate canteen.

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body weight losses (BWL) of 0.24 $\pm$ 0.02 kg/hr. Although mean BWL in the IC group was not different from BDU, both mean sweat rate (0.53 L/hr) and fluid consumption (0.34 $\pm$ 0.03 L/hr) increased for similar exercise times. Compared to the BDU group, both CS and FF groups consumed more water during the exercise periods; however, consumption by CS (0.28 $\pm$ 0.04 L/hr) was significantly less than FF (0.42 $\pm$ 0.06 L/hr). Because sweat losses were also greatly increased in CS and FF groups (0.84 L/hr), body weight deficits were double that of BDU. This may account for the performance decrements in the CS and FF trials in which an average of 210 and 231 min, respectively, out of a possible 300 exercise min were completed. When in MOPP IV only 37% using CS and 29% using FF completed the six exercise bouts.

Compared to the BDU trial, wearing MOPP IV without the mask (IC) elicited elevations in final exercise heart rate (HR) and further increments (25 BPM) were effected by adding the hooded mask. Final exercise rectal temperature (Tre) was not different between BDU and IC (37.6^{o}C) but was increased in both the CS (38.0^{o}C) and FF (38.3^{o}C) trials. Final 3 point mean weighted skin temperature (Tsk; chest, arm, calf) rose significantly when the hooded mask was added (CS and FF) compared to both IC and BDU. Compared to the calculated change in heat storage (Δ S) in BDU (7$\pm$3 kcal/m^2), IC increased ΔS (16$\pm$3 kcal/m^2) and adding the hooded mask in both cases exacerbated this increment (CS: 34$\pm$4 kcal/m^2; FF: 32$\pm$3 kcal/m^2).

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As anticipated, soldiers using either the CS or FF systems perceived more symptoms of hyperthermia and dehydration, and rated their final walk as being as hard to very hard, and more difficult than walk 1.

The present study provided strong evidence of physiological and perceptional decrements when MOPP IV is worn during low intensity work in moderate climates. Compared to BDU and when chemical protective clothing was worn, adding the hooded mask to the chemical protective ensemble increased sweat loss, limited drinking and reduced work tolerance. Heat stress was increased when the chemical protective trousers, jacket, boots, and gloves were worn over the BDU, and adding the hooded mask to this configuration elicited further elevations in heat storage and hemoconcentration, and greater fluid deficits. Compared to the current system (CS), a FIST-FLEX (FF) type system of water delivery may elicit improved drinking during exercise/work thus reducing the physiological cost of work in the heat and improving physical performance in moderate to hot climates.

BACKGROUND

Use of chemical protective clothing in a contaminated environment poses many problems for the soldier. These problems include loss of flexibility and maneuverability, rapid onset of fatigue and difficulty in attending to personal needs. In addition, the permeability characteristics of chemical protective gear conferring protection to the wearer also contribute to increased heat storage, greater fatigue and reduced work performance. Even under moderate environmental conditions (70-85^{o}F), working at moderate work rates while dressed in MOPP IV configuration can result in dehydration and heat injury.

The casualties of dehydration are amply documented in scientific and historical monographs (1,15,17) Providing adequate supplies of potable water to meet the high, short term requirements of military operations is an obvious problem. During operations, particularly if conducted in a hot climate, ample time for drinking as well as adequate supplies of water are important. However, these alone do not insure that body water deficits will be replenished by drinking. Rothstein and coworkers (1947) (19) reported that troops marching in the desert become dehydrated, losing 1-4.5% body weight even when potable and palatable water was plentiful. This phenomenon has been called voluntary dehydration although it is not the result of planned behavior (1,17).

Voluntary dehydration increases with increased temperature and poor palatability of the drinking water, insufficient time allowed for consumption of food and fluids, increased sweat rate, and greater effort required to obtain the water (1). In a contaminated environment, an additional constraint to drinking is the face mask and the requisite through-mask drinking system. Recent estimates of water requirements in MOPP IV while working at moderate levels in moderate temperatures (70-85^{o}F) suggest a 1-2 qt per hour requirement. The current water delivery system for the M171A face mask of MOPP gear has been described as ıollows:

"... current procedures are time consuming and difficult to perform. Soldiers in stressful environments have been found to become frustrated and stop drinking the required amount of water." With the additional heat stress and the drinking constraints imposed by wearing chemical protective clothing and face mask, marked voluntary dehydration is expected to be a significant problem for the soldier working in MOPP IV.

The current mask and water delivery system has several shortcomings which include: 1) increased risk of contamination because the system requires connecting/disconnecting with each drink, 2) two-handed operation, 3) creating and then sucking against a positive pressure, and 4) difficulty when using under hot, dark or cramped conditions or when working or when injured (see Appendix A for steps required with drinking with the current system). The Fluid Intake Suction Tubing (FIST) - type hydration system uses hydraulics to draw water through tubing directly from the canteen into the mask (see Appendix B for a brief description). This FIST - type technology may be important in encouraging soldiers to drink, thereby reducing voluntary dehydration. Several features of the FIST-type system which lessen some of the problems associated with the current water delivery system are: 1) single-handed operation, 2) easy operability when working or sitting in less than optimal conditions and 3) no connecting/disconnecting with each drink.

MILITARY RELEVANCE AND PURPOSE

The Heat Research Division recently completed a pilot study evaluating the effect of the face mask and current water delivery system on fluid intake during a 5 hr simulated desert (40°C, 30% RH) march (4.83 km/hr on a 5% grade). Despite increased thermoregulatory demand, soldiers drank 43% less water during the five 30 min work periods when using the current water delivery system than when unmasked and unrestricted. This reduction in fluid intake during work was lessened when a FIST-FLEX type of water delivery system was used. However, soldiers were not in MOPP IV configuration and walked for only 30 min out of each hr for 5 hrs. Also, the repeated measures design elicited a learning effect whereby subjects consumed more fluid irrespective of the drinking system on the second test day.

Voluntary dehydration and an increased risk of heat injury are serious threats to the soldier in MOPP IV configuration while working in a contaminated environment, even under temperate conditions. The present study addressed the following three objectives in soldiers walking (4.02 km/hr at about 35% VO_2 max on a flat grade) for 6 hr (50 min walk/10 min rest) under moderate conditions (29.5°C d.b., 18.3°C w.b.; WBGT = 21.7°C [71°F]):

1. to measure the effect of wearing MOPP IV (without the chemical protective face mask) on fluid intake, body weight loss, sweat loss, temperature regulatory measures, and hormonal responses,
2. to evaluate the effects of using the hooded M17A1 face mask and current drinking system on those responses, and
3. to compare the responses when using the FIST-FLEX type of water delivery system to those seen when using the current drinking system or when unmasked.

TEST SUBJECTS

- Fifteen (15) male volunteers were recruited from the military test subject population at USANRDEC, Natick, MA.
- Subjects were not heat acclimated and were naive to the experimental design.
- Volunteers were thoroughly briefed on the nature and purpose of the study and informed of the medical risks and safety precautions involved.
- Subjects were instructed and had an opportunity to use the MASK and drinking systems prior to the actual testing.
- The subjects were screened (medical history and physical examination) for any condition that would preclude safe participation in this study (e.g. sensitivity to Cl_2 or I_2, heat and/or work intolerance, illness, recent immunization, etc.).
- To provide a state of adequate hydration, alcohol, drugs or medications and rigorous exercise were not allowed during the 24 hr period immediately prior to their participation. Subjects were prehydrated by drinking 0.9L during breakfast.
- Volunteers gave their written informed consent to participate in this study by signing a Volunteer Participation Agreement, and reserved the right to withdraw for any reason without retribution.

The physical characteristics of the 15 subjects are presented in Table 1.

TABLE I. PHYSICAL CHARACTERISTICS OF SUBJECTS

Variable	BDU	IC	CS	FF	MEAN±SE
Age, yrs	23±1	24±2	24±1	22±1	23±1
Height, cm	176.4±1.7	173.6±1.3	173.7±1.2	178.1±1.5	175.7±1.1
Weight, kg	73.3±3.7	70.7±3.6	69.6±3.8	74.1±2.0	72.0 ±2.2
Pre-exer USG	1.022±.003	1.024±.001	1.025±.004	1.024±.003	1.024±.001

USG is Urine Specific Gravity

EXPERIMENTAL DESIGN

Test Subject Preparation:

- Volunteers reported to the climatic chamber facility at 0645 hr in a 12 hr fasted (no breakfast) state. Breakfast consisted of 450 ml of instant breakfast, toast, butter, jam and 450 ml of orange juice and insured adequate prehydration and energy intake.

- Subjects then proceeded to the tropic dressing room to provide measures of physical characteristics, be fitted with instrumentation required for monitoring several thermoregulatory variables, and be fitted with either modified BDU or BDU and MOPP.

Environmental Conditions:

- Testing was done in a climatic chamber with environmental conditions that simulate manuevers in a temperate climate. Air temperature was 29.5^{o}C (85.1^{o}F) d.b. and 18.3^{o}C (65^{o}F) w.b., the relative humidity 33%, and the windspeed 8.04 km/hr. This combination of conditions produced a WBGT of 21.7^{o}C (71^{o}F).

Work Rate and Duration:

- Each subject spent about 6.5 hours in the climatic chamber, although the actual time varied depending on their endurance capacity.

- On each test day, the subjects dressed in either modified BDU or MOPP IV, walked on one of two treadmills set on a flat grade at their walk stations for 50 min of each hr at a rate of 4.02 km/hr. During the remaining 10 min of each hr, subjects sat. At the end of the 6 hrs of intermittent exercise, each subject could have potentially walked 20.1 km while wearing MOPP gear in a temperate environment.

Assignment to the Four (4) Experimental Groups:

- Each subject was randomly assigned to one of four (4) groups.

- Three (3) groups were dressed in MOPP IV; the difference among the treatments for these three groups was the water delivery system available for drinking during the 6 hr. The groups were as follows:

IC: subjects dressed in MOPP IV without chemical protective hood and mask and drinking directly from canteen.

CS: subjects dressed in MOPP IV wearing the hooded mask and drinking with the current water delivery system.

FF: subjects dressed in MOPP IV using the hooded mask and a FIST-FLEX type of water delivery system.

- A fourth group (BDU), were dressed in modified Battle Dress Uniform (blouse, t-shirt, trousers, socks, underpants and sneakers) and drank directly from canteens. The BDU group served as a CONTROL.

Characteristics of Beverage:

The beverage was water, iodinated (16 mg I_2/L) and provided at ambient temperature (30^{o}C) in the appropriate rigid 1 qt (BDU, IC, and CS) or flexible 2 qt (FF) canteen.

Assessment of Objectives:

- Voluntary dehydration, physiological responses and fluid-electrolyte balance were evaluated through analyses of water intake, sweat rate, heart rate, rectal and skin temperatures, plasma indices and questionnaires.

- Data were analyzed for statistical significance using a two-way analysis of variance. Tukey's HSD post hoc tests were used to determine where differences occurred.

MEASUREMENTS AND TECHNIQUES

Initial Measures:

- Following breakfast subjects proceeded to the tropic dressing room to provide a pretest urine sample for specific gravity as an index of adequate prehydration. Any additional urine samples were collected and weighed.

- Initial nude body weight ($\pm$50g), age and height (cm) were recorded and then later used to calculate body surface area (m^2). Following the final walk, a final nude weight (Tropic dressing room) was obtained.

- Subjects were then fitted with instrumentation, dressed in appropriate attire (modified BDU or MOPP IV), and then all instrumentation was tested.

Heat Strain Indices:

- Subjects were fitted with a 3 point (chest, arm and leg) thermocouple skin harness and a thermistor rectal probe (inserted to a depth of 10 cm). Individual skin and rectal temperatures as well as ambient conditions were monitored, recorded and plotted at 4 min intervals for the duration of testing.

- ECG electrodes were placed on each subject's chest and connected to a battery-powered transmitter carried in a belt pouch for ECG telemetry. Each subjects' heart rate and electrocardiogram was continuously monitored, with heart rate recorded at 5 min intervals.

Fluid Intake:

- Water, iodinated (16 mgI_2/liter) and at ambient temperature (30^{o}C) was provided ad libitum in the appropriate canteen.

- Fluid intake was measured at the end of each 50 min walk and 10 min rest, or sooner if necessary, by weighing each canteen on an electronic balance ($\pm$ 1 g). At this time, canteens were refilled. Total fluid intake as well as differences in water intake between walk and rest intervals were computed.

- Webb gear and canteens were worn about each subject's waist but were not included in the initial or final instrumented-clothed body weight measures.

- Lunch was not provided since neither time nor provisions for eating are allotted while wearing a face mask.

Hematological Indices:

- Following initial entry into the climatic chamber, subjects remained standing for 20 min, after which a baseline (PRE) blood sample was drawn.

-Blood samples were taken via venipuncture from an antecubital vein by trained phlebotomists.

- After the sixth walk (6hr) or final walk if earlier, the subjects remained standing to obtain an intermediate post-exercise (POST) blood sample.

- The change in plasma volume (6 hr POST versus PRE-exercise) was calculated from the venous hematocrit and hemoglobin values (7). In addition, serum osmolarity and electrolytes (Na^+, K^+, Mg^{+2}, Cl^-), and total plasma proteins were determined.

Sweat Indices:

- Total sweat production was calculated as the difference between final and initial nude body weights, adjusted for water gains (fluid intake) and losses (urination, blood sampling, respiratory loss).

Questionnaires:

- Upon entering and before leaving the climatic chamber, each subject completed the Environmental Symptoms Questionnaire (Appendix C).

- During the last 5 min of each walk, subjects were asked to provide a rating of how difficult they perceived the walk (Appendix D).
- During the 2nd, 4th and 6th (final) rest, a questionnaire about the characteristics of each drinking system was given (Appendix E).

RESULTS

Work Endurance:

Subjects walked on one of two treadmills set on a flat grade for 50 min out of each hr at a rate of 4.02 km/hr. During the remaining 10 min of each hr, subjects sat. Subjects wearing BDU completed the 300 min of exercise (Table 2) and similar exercise times were seen when impermeable clothing was worn over the BDU (IC). Adding the hooded mask to this IC ensemble resulted in clear performance decrements since only 3 of the 8 using the current system (CS), and 2 of the 7 subjects using a fist-flex type (FF) of water delivery system completed the 6 work bouts. Exercise time dramatically decreased ($p<0.05$) to 210 and 231 min in subjects dressed in MOPP IV and drinking with CS and the FF water delivery system, respectively. These differences between CS and FF were not statistically significant.

TABLE 2. EXERCISE TIME (MIN)

	Group			
SUBJECT	BDU	IC	CS	FF
1	300	300	300	300
2	300	300	300	140
3	300	270	150	230
4	300	300	200	150
5	300	300	300	250
6	300	300	200	300
7	300	-	150	250
8	-	-	76	-
mean	300	295	210 BI	231 BI
SD	0	12	84	65
SE	0	5	30	23

B statistically significant ($p<0.02$) from BDU.
I statistically significant ($p<0.05$) from IC.

Fluid Balance:

Because of the significant differences in endurance time between groups, fluid balance measures are expressed per unit time. When performing intermittent work in a moderate climate, the BDU group consumed 0.25 L/hr (Table 3). Fluid intake (0.34 L/hr) was increased in IC for the similar endurance time. With the addition of the hooded mask to the IC ensemble (CS and FF), more water was consumed. Significant differences in total intake in FF were first observed during walk 4. Five of the seven subjects using the FF drank more water than those subjects using CS (Table 4), but the total average consumption rate was not statistically different between the two groups (Table 3).

Although the BDU group rehydrated about 70% (Table 3), average sweat losses of 0.37 L/hr contributed to a body weight loss of 0.24 kg/hr (0.32 %/hr of initial body weight). Mean sweat rate (0.53 L/hr) was increased in IC but the % rehydration and, as a consequence, the body weight losses, were not different from BDU. Body weight deficits in CS and FF were double that of BDU because the increased drinking by the latter two groups did not compensate (average rehydration = 50%) for the greatly increased sweat losses (0.84 L/hr) incurred when wearing the hooded mask. The slightly higher sweat and total fluid intake rates and the lower body weight loss in FF relative to CS were not statistically significant.

Walk versus Rest Intakes:

Rank ordering of fluid intakes during the walk and rest periods (Table 5) showed that compared to the CS group, 5 of the 7 individuals using FF consumed more water during the walks. This demarcation between groups was not as clear during the rest periods. As a consequence, a significant difference in water intake for CS and FF was only seen during the 50

TABLE 3. FLUID BALANCE

	Sweat Rate (L/hr)	Cum Fluid Intake (L/hr)	Urine Output (L/hr)	Rehydration[a] (%)	Body Weight Loss (kg/hr)	Body Weight Loss (%/hr)
BDU	0.37	0.25	0.12	70	0.24	0.32
	±0.11	±0.14	±0.09	±30	±0.06	±0.08
	±0.04	±0.05	±0.04	±11	±0.02	±0.03
IC	0.53	0.34	0.04 B	66	0.22	0.32
	±0.12	±0.07	±0.02	±13	±0.07	±0.09
	±0.05	±0.03	±0.005	±5	±0.03	±0.04
CS	0.79 BI	0.35	0.06	48	0.50 BI	0.68 BI
	±0.20	±0.11	±0.04	±27	±0.22	±0.25
	±0.07	±0.04	±0.02	±10	±0.08	±0.09
FF	0.89 BI	0.46 BI	0.05 B	53	0.49 BI	0.65 BI
	±0.10	±0.18	±0.03	±23	±0.24	±0.29
	±0.04	±0.07	±0.02	±9	±0.09	±0.11

Values are mean ± SD±SE.

[a] $\% \text{ Rehydration} = \frac{\text{Cumulative fluid intake}}{\text{Sweat loss}} \times 100$

B significantly different ($p<0.05$) from BDU
I significantly different ($p<0.05$) from IC.

TABLE 4. RANK ORDER OF TOTAL FLUID CONSUMPTION RATES.

Order	Group	Total Intake (L/hr)
1	FF	0.66
2	FF	0.58
3	FF	0.56
4	FF = CS	0.50
5	FF = CS	0.46
6	CS	0.40
7	CS = CS	0.36
8	FF = CS	0.32
9	CS	0.30
10	FF	0.14
11	CS	0.10

TABLE 5. RANK ORDER OF INTAKE RATES DURING WALK AND REST PERIODS.

Order	Group	Walk Intake (L/hr)
1	FF	0.60
2	FF	0.56
3	FF	0.48
4	FF	0.44
5	FF	0.43
6	CS	0.38
7	CS	0.37
8	FF = CS	0.33
9	CS	0.30
10	CS	0.29
11	CS	0.27
12	CS	0.25
13	FF	0.12
14	CS	0.06

Order	Group	Rest Intake (L/hr)
1	CS	1.76
2	CS	1.09
3	FF	0.97
4	FF	0.95
5	CS	0.85
6	FF	0.83
7	FF	0.57
8	CS	0.52
9	CS	0.45
10	CS	0.44
11	CS	0.39
12	FF	0.38
13	CS = FF	0.25
14	CS	0.10

min walks (Table 6). In addition, similar intake rates during the walks were seen in BDU, IC and CS groups, whereas higher rest intake rates were seen in CS and FF compared to BDU.

Figure 1 demonstrates that fluid intake rates tended to be higher during the rest than walk periods. This difference is most apparent in the CS group in which the rate of consumption was significantly greater (2.5-fold) during the 10 min rests than during the 50 min walk periods (Table 6).

<u>Heat Strain Indices:</u>

Minimal increases in heart rate (HR; 7 BPM) and rectal temperature (Tre; 0.39^{o}C) were seen in the BDU group during the course of 6 hr of intermittent exercise (Figures 2 and 3; Table 7). Wearing impermeable clothing over the BDU (IC) produced small but significant elevations in both HR (Figure 2) and Tre (Figure 3) within the first 50 min walk resulting in increments of 23 BPM and 0.53^{o}C from pre-exercise, respectively during the final walk. When the hooded mask was worn with the IC ensemble (CS and FF), progressive increases in HR and Tre were recorded from the onset of exercise and resulted in increments of 50 BPM and 1.03^{o}C after the 213 min of walking. The fall in both the absolute and change in rectal temperature (Figure 3) is primarily due to the loss of test subjects or sample number.

Although similar changes were noted for the CS and FF water delivery systems, differences in heat strain indices between the three clothing ensembles were remarkable. Relative to BDU, IC elicited elevations in final exercise HR (IC-BDU=19 BPM) (Table 7) and disproportionately greater increments in work HR ([CS and FF]-IC = 25 BPM) and Tre ([CS and FF]-IC = 0.43^{o}C) were affected when the hooded mask was added to the IC ensemble (Figure 3).

TABLE 6. COMPARISON OI FLUID CONSUMPTION DURING WALK AND REST PERIODS.

	Walk Intake (L/hr)	Rest Intake (L/hr)
BDU	0.25 ±0.12 ±0.05	0.27 C ±0.24 ±0.09
IC	0.32 ±0.11 ±0.04	0.46 ±0.25 ±0.10
CS	0.28 ±0.10 ±0.04	0.70 BW ±0.52 ±0.18
FF	0.42 BC ±0.16 ±0.06	0.60 B ±0.32 ±0.12

Values are mean ± SD ± SE.

B significantly different ($p<0.05$) from BDU.

C significantly different ($p<0.05$) from CS.

W significantly different ($p<0.05$) from corresponding Walk Intake.

Figure 1. Fluid Intake Rate (L/hr) during each Work and Rest cycle.

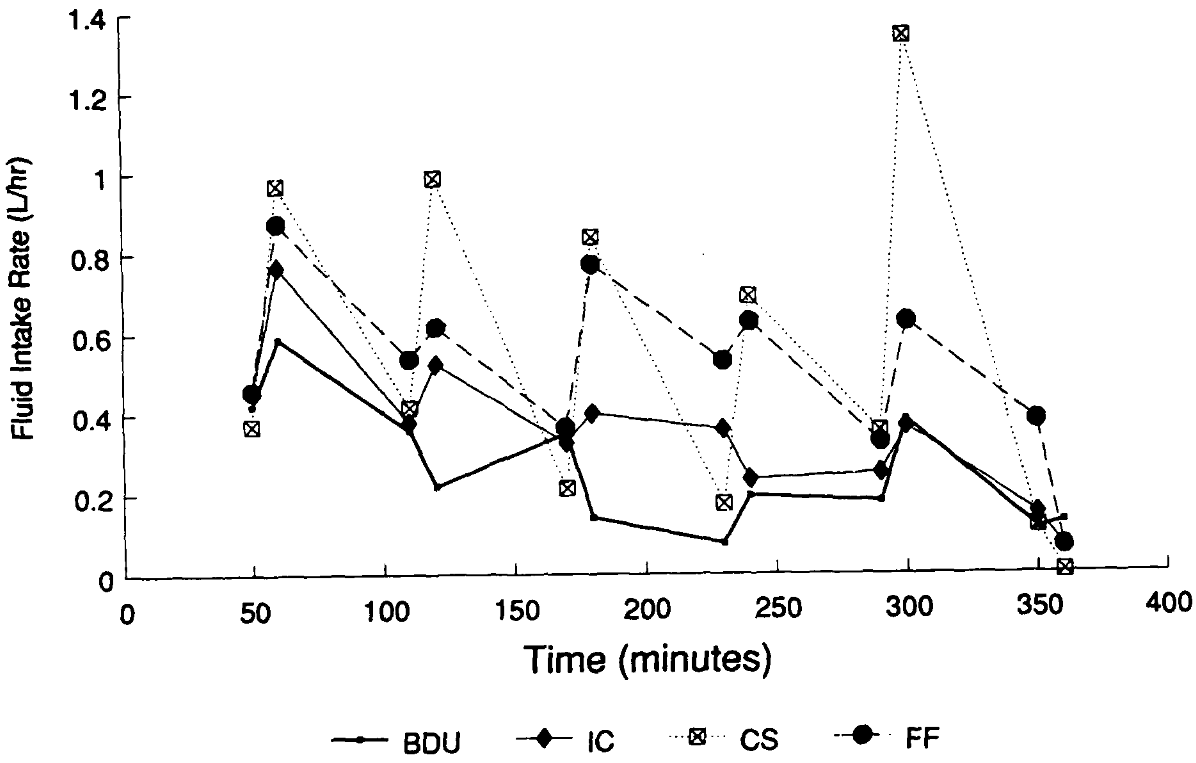


Figure 2. Top: Heart Rate (bpm) during each Work and Rest cycle.
Bottom: Change in Heart Rate from Pre-Exercise with each Work and Rest cycle.

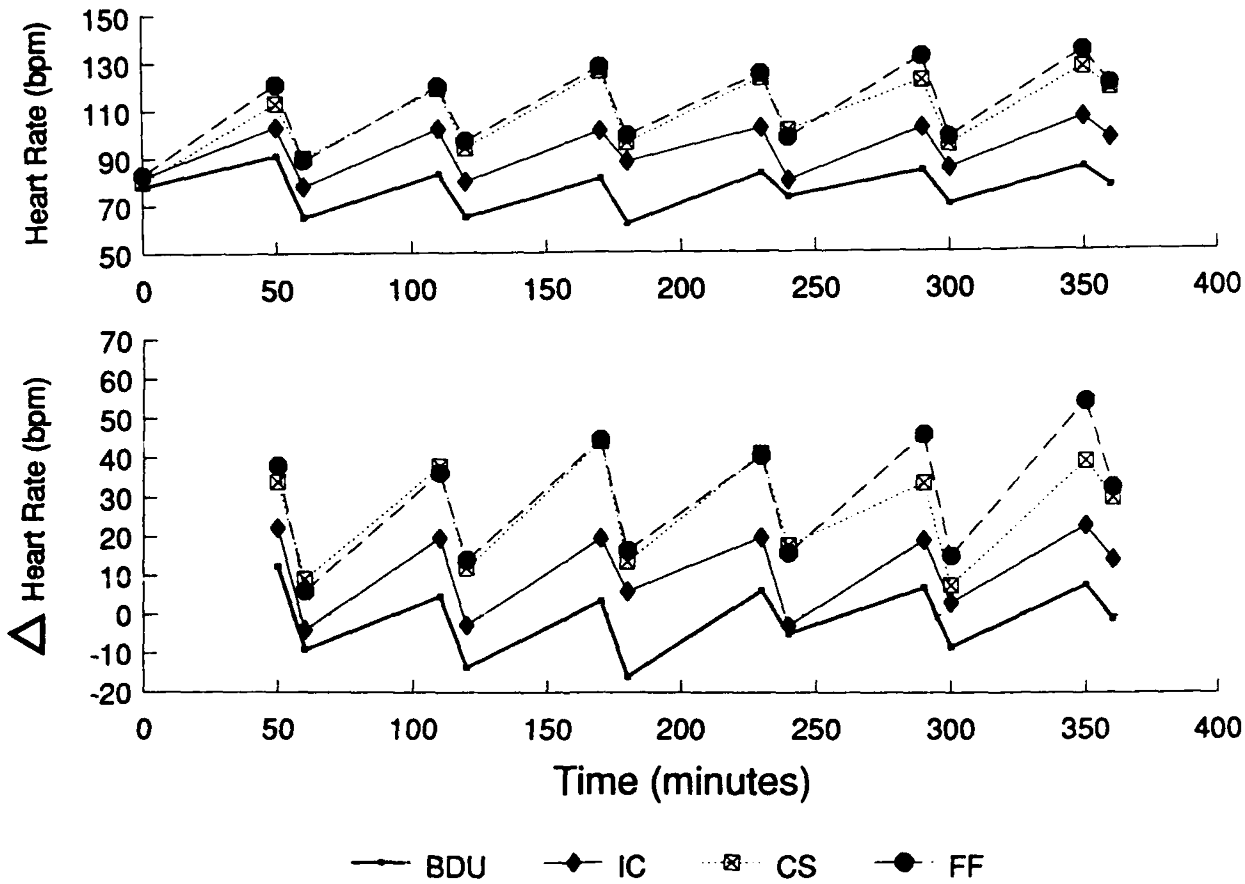


Figure 3. Top: Final Rectal Temperature during each Work and Rest cycle.
Bottom: Change in Rectal Temperature from Pre-Exercise with each Work and Rest cycle.

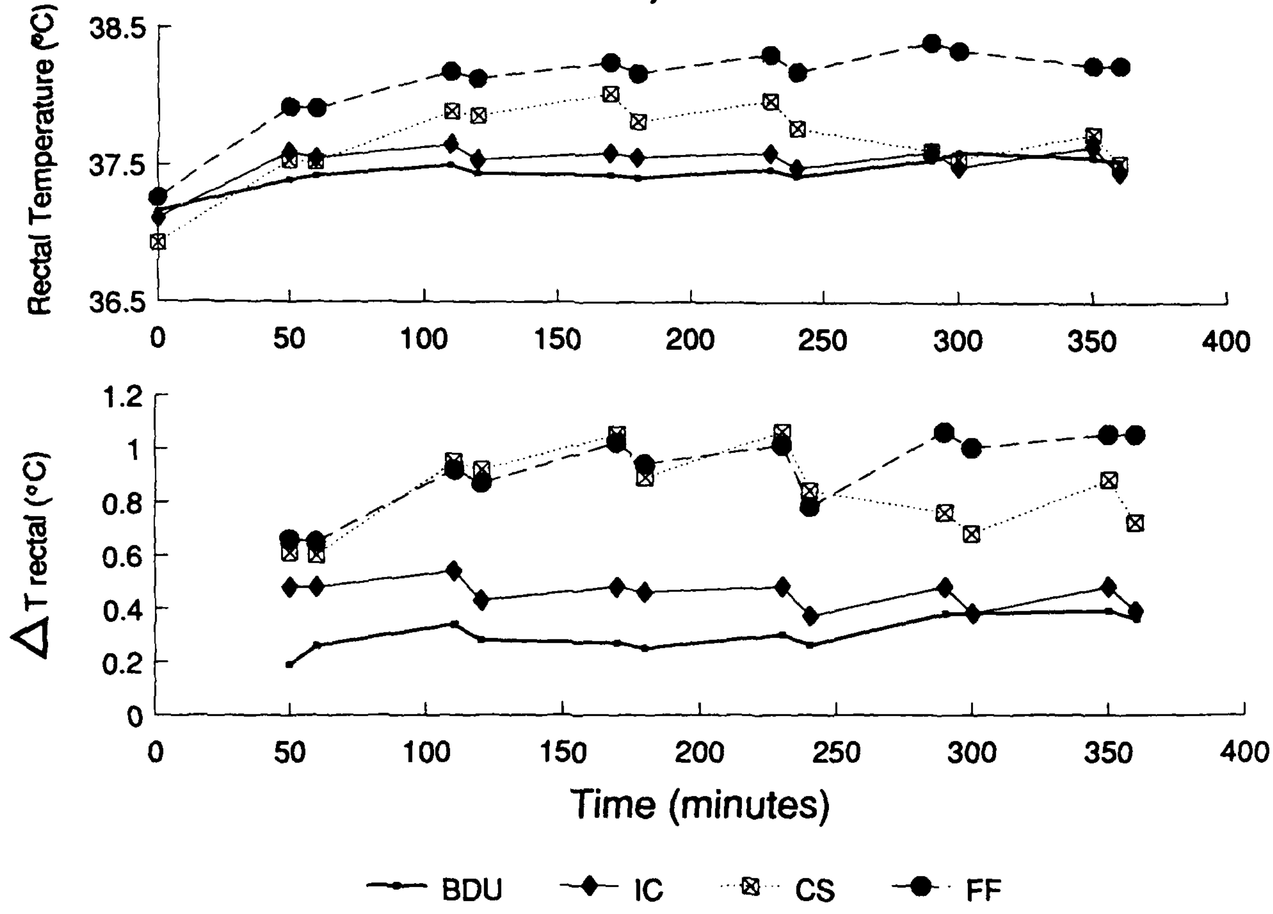
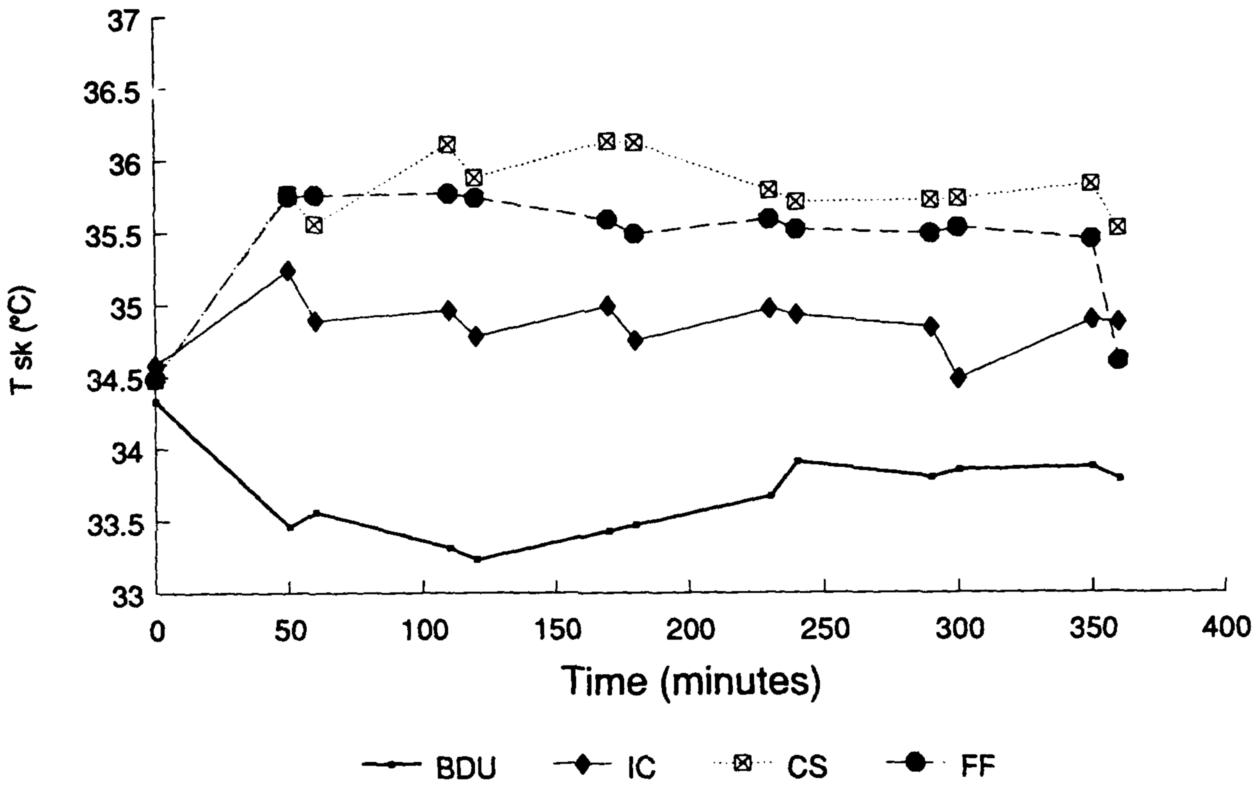


TABLE 7. EFFECT OF CLOTHING ENSEMBLES ON HEAT STRAIN INDICES

	Final Walk Heart Rate (HR) (BPM)	Δ HR (BPM)	Final Walk Rectal Temperature (Tre) (^{o}C)	Δ Tre (^{o}C)	Final Walk Skin Temperature (Tsk) (^{o}C)	Δ T_{sk} (^{o}C)
BDU	86	7	37.56	0.39	33.92	-0.45
	±9	±6	±0.20	±0.27	±0.46	±0.40
	±3	±2	±0.08	±0.10	±0.18	±0.15
IC	105 B	23	37.64	0.53	34.93 B	0.38B
	±13	±14	±0.28	±0.20	±0.10	±0.53
	±5	±6	±0.12	±0.08	±0.04	±0.21
CS	128 BI	46 BI	37.95	1.04 BI	35.69 BI	1.23B
	±14	±17	±0.37	±0.30	±0.51	±0.51
	±5	±6	±0.13	±0.11	±0.20	±0.20
FF	133 BI	52 BI	38.27 BI	1.01 BI	35.57 B	1.08B
	±12	±10	±0.34	±0.19	±0.70	±0.72
	±4	±4	±0.13	±0.07	±0.27	±0.27
IC-BDU	19	16	0.08	0.14	1.01	0.83
(CS+FF)-IC	25	26	0.43	0.49	0.72	0.78

Values are mean ± SD ± SE.
Δ = Final walk - pre-exercise
B statistically different ($p<0.05$) from BDU.
I statistically different ($p<0.05$) from IC.

Figure 4. Mean Weighted Skin Temperature (Tsk) (°C) at the end of each Work and Rest cycle.



Mean weighted skin temperature (Tsk) fell during the 6 work/rest cycles (Figure 4) in the BDU group. In contrast, Tsk rose and remained significantly elevated for the duration of intermittent exercise in the IC, CS and FF groups. The final Tsk was statistically different between the BDU, IC and (CS and FF) groups (Table 7).

Hematological Indices:

Blood samples taken prior to Walk 1 and immediately following the sixth or final walk were used to assess changes in plasma volume and constituents effected by wearing the three clothing ensembles and using the two water delivery systems when exercising in the heat. These data are presented in Table 8. While the BDU group had an increase in plasma volume (PV), donning the impermeable gear (IC) and then adding the hooded mask, produced progressively greater PV deficits. The hemoconcentration in the CS and FF groups was derived from the changes in hemoglobin (HB) and hematocrit (Hct). Increments in plasma protein concentration (TP) paralleled the intensity of hemoconcentration, although total circulating levels of plasma proteins (Table 10) were minimally changed. No significant differences in the percent change in PV were measured between the two mask water delivery systems (CS and FF).

The only statistically significant change in serum electrolyte concentration was the increase in plasma calcium (P_{Ca}++) in the CS group (Table 9); however, this change was well within physiological range. Total circulating plasma sodium (P_{Na}+) (PV*[electrolyte]) rose in the BDU group (5$\pm$7 mEq) but significantly decreased in IC (-10$\pm$5 mEq), CS (-28$\pm$10 mEq) and FF (-40$\pm$13 mEq) (Table 10). Total circulating plasma chloride (P_{Cl}-) also fell (BDU:-4.3$\pm$7.7 mEq; IC:-10.1$\pm$2.9 mEq; CS:-23.8$\pm$7.9 mEq; FF:-28.6$\pm$8.1 mEq) whereas circulating plasma potassium (P_{K^+}), magnesium ($P_{Mg^{++}}$), and Ca^{++} remained unchanged with each additional clothing component.

TABLE 8. COMPARISON OF PRE AND POST EXERCISE VALUES FOR HEMATOCRIT (HCT), HEMOGLOBIN (HB), PLASMA PROTEIN (TP), AND PLASMA VOLUME (PV)

		Hct (%RBC)	Hb (g/dl)	TP (g/dl)	Δ PV (%)	P_{Osm} (mOsm/kg H2O)
BDU	PRE	42.4 ±2.8 ±1.1	15.4 ±0.6 ±0.2	7.3 ±0.4 ±0.1		294 ±4 ±2
	POST	41.5 ±3.1 ±1.2	15.5 ±0.7 ±0.3	7.4 ±0.3 ±0.1	1.11 ±4.08 ±1.54	293 ±3 ±1
IC	PRE	44.6 ±2.6 ±1.1	16.1 ±0.9 ±0.4	7.3 ±0.2 ±0.1		293 ±3 ±1
	POST	45.1 ±2.6 ±1.0	16.3 ±0.7 ±0.3	7.6 P ±0.2 ±0.1	-1.98 ±3.28 ±1.34	293 ±7 ±3
CS	PRE	42.9 ±2.5 ±0.9	15.8 ±1.0 ±0.3	7.4 ±0.2 ±0.1		295 ±2 ±1
	POST	44.4 ±2.3 ±0.8	16.7 ±0.7 ±0.3	8.2 P ±0.5 ±0.2	-7.61 ±5.43 ±1.92	294 ±5 ±2
FF	PRE	43.3 ±1.8 ±0.7	16.1 ±0.6 ±0.2	7.3 ±0.3 ±0.1		294 ±3 ±1
	POST	45.4 P ±2.8 ±1.0	17.3 P ±0.7 ±0.3	8.0 P ±0.3 ±0.1	-9.61 ±7.33 ±2.77	297 ±7 ±2

Values are mean ± SD ± SE.
P significantly different ($p<0.05$) from PRE value.
B significantly different ($p<0.05$) from BDU.
I significantly different ($p<0.05$) from IC.

TABLE 9. COMPARISON OF PRE AND POST EXERCISE PLASMA CHEMISTRIES.

		P_{Na+} (mEq/L)	P_{K+} (mEq/L)	P_{Cl-} (mEq/L)	P_{Mg++} (mEq/L)	P_{Ca++} (mEq/L)
BDU	PRE	142	4.4	99.2	1.7	9.5
		±2	±0.3	±2.4	±0.1	±0.4
		±1	±0.1	±0.9	±0.04	±0.2
	POST	143	4.6	96.8	1.7	9.3
		±2	±0.3	±3.5	±0.1	±0.2
		±1	±0.1	±1.3	±0.04	±0.1
IC	PRE	142	4.7	98.3	1.7	9.7
		±2	±0.4	±1.4	±0.1	±0.8
		±1	±0.2	±0.6	±0.05	±0.3
	POST	141	4.7	96.6	1.6	9.6
		±3	±0.4	±2.4	±0.1	±0.5
		±1	±0.2	±1.0	±0.03	±0.2
CS	PRE	143	4.4	96.4	1.7	9.5
		±3	±0.3	±3.9	±0.2	±0.6
		±1	±0.1	±1.4	±0.08	±0.2
	POST	145	4.7	95.9	1.7	10.2 P
		±5	±0.3	±2.2	±0.2	±0.7
		±2	±0.1	±0.8	±0.06	±0.3
FF	PRE	143	4.6	97.0	1.7	9.4
		±3	±0.2	±2.7	±0.2	±0.6
		±1	±0.1	±1.0	±0.1	±0.2
	POST	143	4.9	96.6	1.7	9.7
		±6	±0.5	±3.1	±0.1	±0.5
		±2	±0.2	±1.2	±0.1	±0.2

Values are mean ± SD ± SE.

B Statistically different ($p<0.05$) from BDU.

I Statistically different ($p<0.05$) from IC.

P Statistically different ($p<0.05$) from PRE.

TABLE 10. TOTAL CONTENT OF PLASMA PROTEINS AND ELECTROLYTES.

		TP (g)	P_{Na+} (mEq)	P_{K}^{+} (mEq)	P_{Cl-} (mEq)	P_{Mg++} (mEq)	P_{Ca++} (mEq)
BDU	PRE	216.7	422	13.0	293.7	5.0	28.3
		±29.8	±51	±1.0	±31.2	±0.8	±3.8
		±11.2	±19	±0.4	±1.8	±0.3	±1.4
	POST	219.4	427	13.7	289.4	5.0	27.8
		±28.2	±52	±1.7	±34.5	±0.7	±3.5
		±10.7	±20	±0.7	±13.0	±0.3	±1.3
IC	PRE	201.0	390	13.0	270.6	4.6	26.8
		±8.7	±16	±1.1	±12.0	±0.4	±1.9
		±3.6	±7	±0.4	±4.9	±0.2	±0.8
	POST	205.7	379 P	12.9	260.6 P	4.4	26.0
		±14.2	±22	±1.6	±8.3	±0.4	±2.0
		±5.8	±9	±0.7	±3.4	±0.2	±0.8
CS	PRE	207.4	403	12.0	272.1	4.9	26.8
		±25.0	±45	±2.0	±35.7	±0.8	±3.0
		±8.8	±16	±0.7	±12.6	±0.3	±1.1
	POST	211.8 P	375 P	12.2	248.3 P	4.5	26.4
		±25.8	±44	±1.5	±20.4	±0.6	±3.2
		±9.1	±12	±0.5	±7.2	±0.2	±1.1
FF	PRE	217.2	423	13.7	287.6	5.0	27.8
		±16.3	±31	±1.1	±23.1	±0.5	±1.8
		±6.2	±12	±0.4	±8.7	±0.2	±0.7
	POST	214.5	383 P	13.1	259.0 P	4.6	25.9
		±16.8	±35	±1.3	±29.4	±0.6	±3.1
		±6.3	±13	±0.5	±11.1	±0.2	±1.2

Values are mean ± SD ± SE.
B Significantly different ($p<0.05$) from BDU.
I Significantly different ($p<0.05$) from IC.
P Significantly different ($p<0.05$) from PRE.

Questionnaires:

Water Delivery System:

All subjects were asked to evaluate their drinking system at the end of their second, fourth and sixth (or final) walk periods. BDU and IC subjects drank directly from a canteen and were asked 8 questions, whereas CS and FF subjects used the current system and a fist-flex type of water hydraulics system, respectively, and answered 14 questions. Each question required subjects to circle a rating on a nine-point scale that best represented their response (Appendix E). For example, a rating of one (1) corresponded to "extremely easy", "extremely dislike" or "extremely cold", while a rating of nine (9) corresponded to "extremely difficult", "extremely like" or "extremely hot". Responses were considered "neutral" if subjects circled 4, 5, or 6 to a question.

As reported in Table 11, all groups rated the water temperature as being either neutral or slightly hot, and either highly or moderately disliked the taste of the water. On average, subjects in all four groups rendered similar ratings for water temperature in their final questionnaire as in their initial questionnaire. When rating the taste of the water, CS subjects on average did not change their final rating from their initial score. The average final rating received from FF users was less favorable than their initial rating. However, when BDU and IC subjects' initial and final scores were compared, 5/7 BDU subjects and 3/6 IC subjects rated the taste of the water one or two points higher from their initial ratings.

Subjects in both BDU and IC groups responded that drinking directly from the canteen was, on average, quite easy when walking as well as when resting. BDU and IC experienced no difficulty holding the canteen above their heads to take a drink during either work or rest cycles, and their responses to this level of difficulty did not vary across time.

TABLE 11.

CANTEEN QUESTIONNAIRE: TASTE AND TEMPERATURE PERCEPTION DURING EXERCISE

GROUP	#SUBJECTS	TIME	TASTE[1] RATING	TEMPERATURE[2] RATING
BDU	7	R2	1.6	6.7
	7	R4	2.3	6.1
	7	FINAL	2.6	6.4
IC	6	R2	1.8	7.5
	6	R4	3.0	7.5
	6	FINAL	3.7	7.5
CS	8	R2	3.3	7.5
	7	R4	3.3	7.3
	8	FINAL	3.3	7.6
FF	7	R2	3.0	6.3
	6	R4	2.2	6.3
	7	FINAL	2.3	6.1

Values represent the average response from all respondants.
1 On a scale from 1 to 9; 1= extremely dislike; 4-6= neutral, 9= extremely like
2 On a scale from 1 to 9; 1= extremely cold; 4-6 = neutral; 9= extremely hot

Although only three out of the eight subjects completed the entire six work bouts, responses from subjects using the current drinking system (CS) for MOPP IV indicated that with time they did not experience any increased difficulty (Table 12). They indicated that the level of difficulty in connecting and disconnecting the canteen from the mask tubing remained, on average, relatively constant with each passing work/rest cycle. CS subjects perceived that the flow of the water from the canteen to their mouth during the walks and rests was slightly slow and that leakage of water inside the mask was minimal.

On average, individuals using the FF hydraulic water delivery system also indicated that the flow of water from the canteen was slightly slow. However, these individuals also indicated that the system was neither too easy or too difficult to use. Subjects using the FF system did not detect any significant leakage of water using this system (Table 12). Subjects rated the FF as being both easier to use and easier to disconnect than the CS system during both walk and rest periods.

TABLE 12.
CANTEEN QUESTIONNAIRE: EASE OF USE AND FLUID FLOW RESPONSES.[1]

GROUP	TIME	# SUBJECTS	EASE OF USE DURING WALK	EASE OF USE DURING REST	FLOW OF WATER DURING WALK	FLOW OF WATER DURING REST
BDU	R2	7	1.9	1.4		
	R4	7	2.6	2.6	NOT APPLICABLE	
	FINAL	7	3.0	3.0		
IC	R2	6	2.5	2.2		
	R4	6	2.8	1.7	NOT APPLICABLE	
	FINAL	6	2.5	2.2		
CS	R2	8	6.5	5.8	3.1	3.5
	R4	7	6.7	6.3	3.3	3.6
	FINAL	8	6.5	5.6	3.4	3.4
FF	R2	7	4.4	4.1	3.6	3.9
	R4	6	5.0	5.0	3.6	3.7
	FINAL	7	4.6	4.4	3.7	3.6

GROUP	TIME	# SUBJECTS	EASE OF CONNECTING AND DISCONNECTING CANTEEN FROM MASK WALK	EASE OF CONNECTING AND DISCONNECTING CANTEEN FROM MASK REST	DETECTION OF LEAKAGE DURING WALK	DETECTION OF LEAKAGE DURING REST
CS	R2	8	6.8	5.3	1.1	0.8
	R4	7	6.9	6.3	2.3	0.9
	FINAL	8	6.6	5.9	2.5	1.4
FF	R2	7			1.1	0.7
	R4	6	NOT APPLICABLE		1.0	1.0
	FINAL	7			1.6	1.6

Values represent average ratings given by group.
1 On a 9-point rating scale, 1 = extremely easy; 4-6= neutral; 9= extremely hard.
For leakage, a 9-point scale was used and 1= very little; 4-6= neutral; 9= too much.

TABLE 12 (CONTINUED)

GROUP	TIME	# SUBJECTS	EASE OF HOLDING CANTEEN ABOVE HEAD DURING WALK	REST
BDU	R2	7	2.2	1.7
	R4	7	3.1	2.4
	FINAL	7	3.0	3.0
IC	R2	6	2.7	2.0
	R4	6	2.5	2.0
	FINAL	6	2.5	2.2
CS	R2	8	6.4	5.0
	R4	7	6.7	6.0
	FINAL	8	7.7	7.3
FF	R2	7		
	R4	6	NOT APPLICABLE	
	FINAL	7		

Values represent average ratings given by group.
On a 9-point rating scale, 1= extremely easy; 4-6= neutral; 9= extremely hard.

Environmental Symptoms Questionnaire:

An Environmental Symptoms Questionnaire (ESQ) was administered to each subject dressed in MOPP IV configuration before entering the test chamber, and then again after completing the day's trial. The ESQ consisted of 68 questions which were answered on a 6-point scale that ranged from "not at all" to "extreme" (Appendix C). These responses reflected the subjects' perceptions of their status of well-being before and after completing the MOPP IV heat/exercise scenario. Questions were grouped into larger categories, and six specific areas were assessed: weariness, headache, heat, bodily aches, light-headedness, and thirst.

Table 13 depicts the responses rendered by the subjects from each group before starting their 6 hour trial. While the vast majority of responses fell into the "not at all" or "slight" categories, there were one or two individuals who responded that they were quite weary or thirsty prior to the start of the study. Of interest however, is the increased perception of hyperthermia among groups before their treadmill walks. Only 8% of BDU subjects perceived any signs of feeling sweaty, feverish or simply warm while 37% of IC, 21% of FF and 43% of CS subjects noted these complaints prior to starting the first walk cycle.

After completion of the chamber trial, subjects again filled out the ESQ, and their post-trial responses are shown in Table 14. Not suprisingly, there was a marked increase in the incidence of symptoms rated in the "moderate" to "extreme" categories with each added level of stress due to clothing or difficulty in drinking water. BDU subjects rendered responses that were similar to their pre-exercise answers, while IC subjects rated their levels of wearlness, headache, perception of heat, bodily aches, light-headedness and thirst slightly worse, with a greater number of responses in the "quite a bit" to "extreme" range. When subjects were fully

TABLE 13.
ENVIRONMENTAL SYMPTOMS QUESTIONNAIRE: PRE EXERCISE.

COMPLAINT	# OF QUESTIONS	GROUP (N)	RESPONSE %0	%1,2	%3	%4,5
WEARINESS	7	BDU (6)	86	14	0	0
		IC (6)	74	24	0	2
		FF (7)	88	10	0	2
		CS (7)	71	20	4	4
HEADACHE	2	BDU	92	8	0	0
		IC	67	25	8	0
		FF	86	14	0	0
		CS	71	22	7	0
HEAT	4	BDU	92	8	0	0
		IC	63	25	8	4
		FF	79	21	0	0
		CS	57	39	4	0
BODILY ACHES	7	BDU	100	0	0	0
		IC	83	17	0	0
		FF	94	6	0	0
		CS	80	16	2	2
LIGHT-HEADEDNESS	5	BDU	100	0	0	0
		IC	93	7	0	0
		FF	100	0	0	0
		CS	69	31	0	0
THIRST	5	BDU	70	13	13	3
		IC	63	27	3	7
		FF	83	17	0	0
		CS	69	31	0	0

Values indicate percentage of responses from all questions about the complaint for which group members rendered that numeric reply.

On a 6-point scale, the following responses correspond to the numbers;

0, not at all; 1, slight; 2, somewhat; 3, moderate; 4, quite a bit; 5, extreme.

TABLE 14.
ENVIRONMENTAL SYMPTOMS QUESTIONNAIRE: POST EXERCISE.

COMPLAINT	# OF QUESTIONS	GROUP (N)	RESPONSE %0	%1,2	%3	%4,5
WEARINESS	7	BDU (6)	76	14	5	5
		IC (6)	60	21	7	12
		FF (7)	51	24	6	18
		CS (7)	39	41	2	18
HEADACHE	2	BDU	83	17	0	0
		IC	25	50	8	17
		FF	43	28	14	14
		CS	8	54	8	31
HEAT	4	BDU	63	25	12	0
		IC	33	33	21	12
		FF	46	14	4	36
		CS	18	25	11	46
BODILY ACHES	7	BDU	83	10	5	2
		IC	60	21	7	12
		FF	57	20	8	16
		CS	41	41	2	16
LIGHT-HEADEDNESS	5	BDU	80	20	0	0
		IC	67	20	3	10
		FF	40	34	6	20
		CS	17	54	11	17
THIRST	5	BDU	80	7	13	0
		IC	53	33	3	10
		FF	60	23	6	11
		CS	60	17	3	20

Values indicate percentage of responses from all questions about a complaint for which group members rendered that numeric reply.
On a 6-point ESQ scale, the following responses correspond to the numbers:
0, not at all; 1, slight; 2, somewhat; 3, moderate; 4, quite a bit; 5, extreme.

encapsulated and drinking with either CS or FF, perceptions of all heat related symptoms shifted from "slight" and "somewhat" pre-exercise responses to "quite a bit" and "extreme" post-exercise. While responses for weariness, bodily aches, and light-headedness were similar among those using CS and FF, CS subjects related that they experienced more headaches, thirst and heat related symptoms.

DISCUSSION

When working in MOPP IV configuration under hot and even temperate conditions, dehydration is a significant problem. Typically, the risk of dehydration is increased with poor palatability of drinking water, insufficient time for rehydration and difficulty in obtaining beverage. When wearing impermeable protective gear and hooded mask, the risk is heightened due to the difficulty of obtaining sufficient fluid through the protective mask without exposure to chemical or biological contaminants.

Because the work rate (4.02 km/hr) and the environmental conditions (29.5^{O}C d.b., 33% R.H., 8.04 km/hr windspeed) chosen for the present study are considered to be mild to moderate, we anticipated completion of the six 50/10 min work/rest cycles by all subjects in all clothing ensembles. All subjects dressed in the BDU and five of six subjects wearing the chemical protective trousers, jacket, gloves and boots over the BDU (IC) completed the six 50 min work bouts (300 min). Work performance was remarkably and significantly reduced to about 4.25 work bouts (213 min) when the hooded mask was worn with the IC ensemble and subjects drank using either the CS or FF water delivery system; only 5 of 15 subjects finished all six work bouts. Other investigators have reported marked reductions in tolerance/exercise time in subjects working in hot humid climates (3,12,14,23,24). Avellini (3) reported that even at moderate climatic temperatures, wearing impermeable chemical protective gear elicited heat stress severe enough to reduce exercise tolerance by 49%. In comparison, Wenger and Santee (30) observed no difference in exercise time of four subjects in MOPP IV and MOPP II (trousers, jacket and boots, but no mask, hood or gloves) at about 5.63 km/hr on a 5% incline under similar environmental conditions. However, the total time worked by subjects in

Wenger's study was only 125 min which is less than all but one of our subjects' exercise times (Table 2).

The FIST-FLEX water delivery system (FF) was designed to reduce the limitations of the current system (CS) to drinking and lessen dehydration in soldiers encapsulated in chemical protective gear. If exercise time as measured by the time walked on the treadmill is used as an indicator of performance, the FF system provided an advantage of only 21 min over the CS system and this was not statistically significant.

Impermeable protective clothing worn over the BDU (IC) increased mean sweat rate for similar exercise times. However, fluid consumption also increased and replaced the additional fluid losses such that body weight loss was not different in IC and BDU. With the addition of the hooded mask to the IC ensemble (CS and FF), mean sweat rate was about 57% and 126% greater than than IC and BDU, respectively. Although significantly more water was consumed by subjects in MOPP IV configuration (CS and FF; approximately 0.40 L/hr) relative to both BDU (0.25 L/hr) and IC (0.34 L/hr) groups, body weight loss was 38% greater in CS and FF. A significant increase in the perceived exertion rating (Appendix D) was reported during the final walk in the CS and FF groups relative to the BDU and IC (Table 15). It is noteworthy that the subject's perceived exertion reflected the intensity of the heat strain indices, most notably sweat loss, heat storage, % rehydration, and HR.

It is of interest to note that subjects wearing BDU had the highest urine output (Table 3) that was at minimum, double that of any other group. In addition, specific gravity of post-exercise urine samples actually dropped in the BDU group, and either rose or remained unchanged in the IC, CS and FF groups (Table 16). All but one subject reduced their urine output during the CS and FF trials; this reduction in urine output paralleled the % rehydration

TABLE 15. RATINGS OF PERCEIVED EXERTION.

GROUP	WALK 1	FINAL WALK
BDU	10	12
	±3	±3
	±1	±1
IC	10	12.5
	±2	±3
	±1	±1
CS	14[BI]	16.5[*B]
	±3	±2
	±1	±1
FF	11	16[*]
	±2	±3
	±1	±1

Values are Mean ± SD ± SE.

B Significantly different ($p<0.05$) from BDU.

I Significantly different ($p<0.05$) from IC.

* Significantly different ($p<0.05$) from Walk 1.

Values: 6-7 = very very light; 8-9 = very light; 10-11 = fairly light; 12-13 = somewhat hard; 14-15 = hard; 16-17 = very hard; 18-19-20 = very very hard.

(CS<FF<IC<BDU). The increase in urine specific gravity and reduced urine volume in IC, CS and FF suggest some hypohydration or impending hypohydration or reflect renal adaptations to prevent hypohydration. Although the reduced fluid intake and consequent lower urine output in the CS and FF trials is a potential decrement to performance, no provisions for performing bodily functions such as urination, defecation and eating are currently available to the soldier in MOPP IV configuration.

Even under the moderate environmental conditions of this study, subjects in MOPP IV configuration would have had to consume about 0.84 L of fluid per hour to maintain euhydration. This fluid requirement is 2.3-fold greater than that when wearing the BDU under identical work and climatic conditions. A 37% drop in water requirements and a 38% increase in work tolerance was elicited by removing the hooded mask (IC). Nunneley (16) recommended a minimum allotment of 0.5 qts/hr for low intensity chemical defense operations at ambient temperatures above 26.6^{O}C (80^{O}F). No requirements were predicted for higher work loads at these temperatures since work tolerance is expected to be limited by hyperthermia irrespective of consumption. For comparison, Gooderson and Hopkinson (8) observed average 24 hr sweat losses of about 4 L in soldiers dressed in chemical protective gear in climates similar to our study. In addition, sweat losses, and hence, fluid requirements were reduced when the level of chemical protection was reduced. However, since the work intensity and duration were not indicated, comparison of absolute values between studies is difficult.

Our results indicate that subjects working in chemical protective clothing and mask rehydrate only about 50% of total water losses. In a recent study using climatic conditions similar to the present protocol, Wenger and Santee (30) reported that subjects dressed in MOPP IV and walking at 5.6 km/hr for 2.1 hr sweated about 1.2 L/hr and rehydrated about 65%. The reasons for the higher rehydration in the latter study are unknown but several possible explanations are that Wenger's subjects may have removed or lifted the M17A mask to drink or the drinking apparatus was altered to facilitate drinking whereas our subjects connected the canteens to the mask's external tubing. Also, the temperature of drinking water in Wenger's study is unknown, whereas we used 30°C water because it represents ambient temperature. The preferred temperature for human consumption is 10°-22°C as measured by intake (2,4,11,21,25) and palatibility (4,21).

Subject preference (5,21) and perception of drinking water temperature (21) may be altered by exercise, hydration level and body temperature. None of the groups perceived a change in beverage temperature during the course of the present experiments. Also, CS and FF subjects noted no change in taste ratings whereas subjects in BDU and IC reported a more favorable rating with time, although they reported disliking the water.

During the first three 50 min walks (Figure 1), fluid intake rate was similar for all four groups. Thereafter, intake rate declined in the BDU and IC groups. By walk 4, intake rates were greater in CS and FF ($p<0.05$) and this was not expected based upon the responses to the canteen questionnaires (Tables 11 and 12) but expected from the increased heat strain of MOPP IV. CS and FF rated the overall use of their systems as 2-3 times more difficult than that rated by BDU and IC for drinking directly from a canteen. In addition, relative to both BDU and IC, the CS group reported a 3-fold higher rating in difficulty for holding the canteen above the head while drinking. Thus, subjects in the CS group made up about half of their fluid deficits with higher intake rates despite the greater difficulty in using their water delivery system.

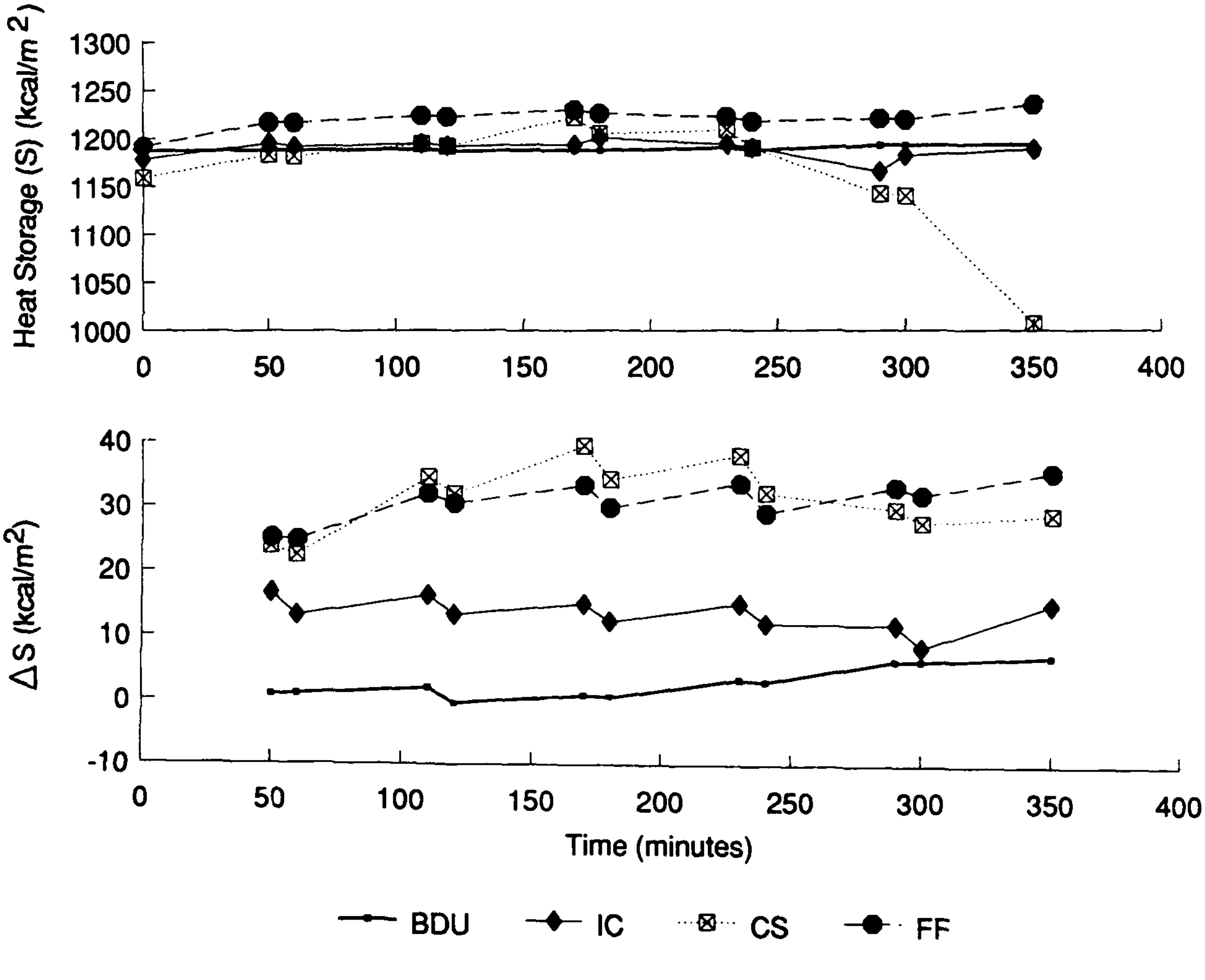
Because of the large number and ackwardness of steps required to drink with the CS compared to the few steps needed with the FF water delivery system, it was anticipated that drinking would be easier and therefore, fluid intake would be markedly greater in FF. Although higher in FF, the fluid intakes (corrected for tolerance time) were not statistically different between CS and FF (Table 3). The difference in intake rates was about 0.11 L/hr, which would amount to about 0.39 L for the approximate 4 work bouts completed by the two groups. Also, the perception of the ease of use, water flow rate, leakage of water into the mask, and ease of connecting/disconnectioning the canteen did not change with time, and were not different between the two groups (Table 12). It was also expected that the CS group would consume more water during the rests than walks. In fact, a 2.5-fold greater intake during rest compared to walk periods was measured (Table 6) despite the fact that the CS delivery system was rated only minimally easier to use during rest (Table 12). Subjects rated the FF system easier to use than the CS system during the walk. A significantly higher fluid intake rate during the walks was measured in FF compared to CS. This is an important observation when considering the need to drink during active work scenarios.

Thermal balance is determined by three factors: metabolic heat production, heat exchange between man and his environment and heat loss by the evaporation of sweat. The two major avenues for heat exchange in man are through the skin and the respiratory tract, with the skin being far more important. The capacity to dissipate heat when working in impermeable protective clothing may be severely limited by the minimal evaporation so that under these moderate work and environmental conditions, heat is stored (6,24). Skin temperatures were significantly elevated within the first 50 min walk in those wearing the impermeable gear (IC) and were further increased when the hooded mask was worn with the IC ensemble (ICM). Rectal temperature responses in IC, although initially elevated, were not different from BDU but the change in heat storage (16 ± 3 kcal/m^2) was significantly higher (Figure 5). In comparison, soldiers dressed in chemical protective clothing and hooded mask (CS and FF) had significantly higher skin and rectal temperatures and an exacerbated increment in heat storage (33 $\pm$ 3 kcal/m^2) (Figure 5). The fall in heat storage in CS at about 270 min was mainly due to the loss of test subjects.

Thus, masking the head and neck has a significant effect on heat load in an individual working in a warm climate, and suggests that cooling the head and neck may be beneficial. Removal of the hooded mask confers some benefit for heat dissipation when working in impermeable protective gear. Wenger and Santee (30) reported marked differences in heat exchange between MOPP II (jacket closed, trousers and overboots) and MOPP IV which they stated were entirely due to heat loss from the head and neck. However, these authors excluded the possibility of heat loss through the hands, which was prevented in our gloved subjects. Joy and Goldman (12) also reported that when soldiers were allowed to work with the impermeable suit open, the minimal opportunity to evaporate sweat and dissipate body heat provided appreciable survival (tolerance) time.

To the best of our knowledge, this is the first study to measure changes in plasma volume and constituents in soldiers working in various clothing ensembles. The loss of plasma volume during exercise in hot environments is primarily determined by the shift of plasma from intra- to extra-vascular space due to increased perfusion pressure and by water loss via sweat secretion. Plasma volume was relatively unaffected during the 6 hr BDU trial (Table 8). The greater loss of plasma volume observed when the impermeable chemical protective clothing was worn, was further exacerbated when the hooded mask was added and reflected the increased heat stress and consequent marked sweat losses. Plasma volume deficits in the MOPP IV configuration (CS and FF) were 4-fold greater than those of the BDU and IC ensembles. Although this

Figure 5. Top: Heat Storage (S) at the end of each Work and Rest cycle.
Bottom: Change in Heat Storage (ΔS) from Pre-Exercise at the end of each Work and Rest cycle.



hemoconcentration was derived from changes in hemoglobin and hematocrit, the % changes in hematocrit were generally smaller than the % changes in plasma volume (Table 8). This absence of significant correlation between hematocrit and plasma volume during dehydration has been reported by others (22,28).

We also observed that the % changes in plasma protein concentration during exercise in a hot humid micro-climate are greater than those in hematocrit, this is similar to that reported for exercise in a comfortable environment (28). In the present study, no net change in total circulating plasma proteins occurred (Table 10), and this probably contributed to the relative stability of the intravascular volume.

The effect of the reduction in plasma volume on the concentration of plasma constituents (Table 9) was minimal in all three clothing ensembles. However, total circulating plasma sodium and chloride fell in the subjects wearing the impermeable gear over the BDU (IC, CS and FF; Table 10) and having sweat rates greater than 0.5 Liters per hour. Our results are in agreement with those of Van Beaumont and coworkers (29) who reported reductions in plasma content of several key electrolyes during the first 30 min of recovery following short bouts of intense exercise.

It is not surprising that heart rate (Table 7 and Figure 2) disproportionately increased when the hooded mask was worn with the chemical protective clothing. Although the average increment in exercise heart rate was about 48 BPM in the CS and FF groups, cardiac output most likely was maintained at a level lower than that in hydrated normo-thermic subjects (13). However, further research is required to assess circulatory performance when working in impermeable clothing, with and without the hooded mask.

Responses from the pre-exercise Environmental Symptoms Questionnaire showed no marked differences between groups (Table 13). While a small percentage of individuals responded in their pre-exercise questionnaire that they were somewhat to moderately thirsty, such responses are not unexpected since intersubject variability in fluid intake to a given stimulus has been reported (9,26). All subjects consumed a minimum of 0.90 L of juice and milk during breakfast to insure adequate initial hydration. Average urine specific gravity obtained from samples post-breakfast was 1.024 (Table 16), and pre-exercise plasma osmolarities (Table 8) and chemistries (Table 9) indicated adequate pre-experimental hydration in all of our subjects. An increased incidence of pre-exercise heat-related complaints by subjects dressed in the chemical protective clothing both with (CS and FF) and without (IC) the hooded mask relative to the BDU group was observed, and most probably resulted from wearing the impermeable clothing in the chamber ($T_{amb} = 29.5^{o}C$) for about 30 min prior to the start of the first treadmill walk.

Subjects dressed in BDU responded similarly to their pre- and post-exercise Environmental Symptoms Questionnaire (Tables 13 & 14) while having the best exercise time (300 min) for the 4 groups. Consistent with these minimal changes in the ESQ responses were the small changes in heat strain indices (Table 7) and low ratings of perceived exertion (Table 15) following the completion of 6 work bouts. Wearing the chemical protective clothing over the BDU without the mask (IC) for 6 work cycles elicited an increased number of complaints of weariness, dehydration and hyperthermia (Table 14). These findings were unexpected since % rehydration, body weight loss and rectal temperature were not different from BDU. However skin temperature and sweat rate were higher in IC producing a hot humid microclimate under the ensemble which probably contributed to their ratings of increased discomfort.

Both physiological and psychological decrements were effected when soldiers walked in MOPP IV configuration (CS and FF) under these moderate environmental conditions. The ESQ responses (Tables 13 & 14) indicating a greater number of responses of "quite a bit" and "extreme" for hyperthermia, headache, light-headedness and thirst were noted although CS and FF completed only 70% of the work done by BDU and IC. Consistent with these ESQ responses were the decrements in fluid balance and heat strain indices elicited by wearing the hooded mask with the impermeable clothing ensemble. Lesser rehydration and greater body weight loss, heart rate, %ΔPV, skin and rectal temperatures, and heat storage were measured in CS and FF relative to BDU and IC.

A comparison of final ESQ results between the CS and FF trials indicated that subjects showed similar responses for weariness, bodily aches and light-headedness. However, individuals using CS perceived a higher incidence of severe headache, heat, and thirst related symptoms than those using the FF. This may be accounted for in part by the slightly higher total fluid intake and lower body weight loss experienced by FF relative to CS. In addition, both CS and FF responded that their respective drinking systems were neither too easy nor too difficult to use and rendered, on average, neutral responses. However, average CS scores were on the upper end of this scale, bordering on "slightly difficult" while responses from FF users were on the lower end of this scale and bordered on "slightly easy". Such differences, although minor, may contribute to explaining why CS individuals perceived a higher intensity of heat, thirst and headache.

The increase in symptoms of hyperthermia and dehydration in our exercising CS and FF subjects were similar to the trends seen by Ryman et al. (20) who found more symptoms of sleepiness, negative mood, headache, and general feelings of discomfort in subjects dressed in

MOPP IV with the hooded mask compared to the no mask condition. Rauch and coworkers (18) found that perceptions of psychological rather than muscular fatigue were the primary factors affecting sustained artillery performance in a simulated chemical warfare environment. This group (27) also reported that under these conditions, extreme symptom and mood changes resulted in medical casualties, combat ineffectiveness, and voluntary termination of duties.

SUMMARY

1. All subjects dressed in BDU completed the 6 work bouts, consumed about 70% of fluids lost in sweat, and displayed minimal increases in heat stress indices.

2. Wearing the impermeable chemical protective gear (trousers, jacket, boots, and gloves) over the BDU (IC) minimally elevated sweat rate, heart rate and rectal temperature. These individuals rehydrated about 66% to produce body weight losses and exercise times similar to the BDU group.

3. Addition of the hooded mask to the chemical protective ensembles (ICM) limited drinking (rehydration= 50%), reduced exercise tolerance to about 213 out of a possible 300 min and disproportionately increased sweat rate, heart rate and rectal temperature. Compared to the BDU and IC groups, exercise in MOPP IV configuration elicited further increases in heat storage, hypohydration and feelings of weariness, hyperthermia, thirst, and fatigue.

4. Because sweat rates were elevated and rehydration was inadequate, deficits in plasma volume were observed when chemical protective clothing was worn over the BDU. In comparison, four-fold decrements in plasma volume were elicited in only 2/3 of the work time when the hooded mask was added to the protective clothing ensemble.

5. The only statistically significant differences between the Current and the Fist-Flex type water delivery systems were: 1) the higher rate of fluid consumption during walking in FF and 2) the 2.5-fold greater intake rate during rest compared to walk periods in CS.

6. From our sweat loss and fluid intake data, we predict an average tolerance for soldiers in MOPP IV configuration marching in a warm environment to be about 3.5 hrs.

7. In addition, our results indicate that masking the head and neck has a significant effect on the thermal load in an individual working in a warm climate, and suggest that cooling the

head and neck may be more beneficial in preventing excessive heat storage than cooling an equivalently sized area of the body.

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Appendix A

CURRENT METHOD OF DRINKING WATER WHILE MASKED

1. IAW TM 3-4240-279-10, actions taken prior to entering a contaminated area.

   a. Check drinking system for leaks.

   b. Fill canteen with water.

2. IAW TM 3-4240-279-10, actions taken prior to using drinking system - use M8 or M9 paper to check for contamination on all mating surfaces of the canteen and drinking tube prior to use.

3. Procedures for drinking while masked.

   a. Steady mask and withdraw drinking coupling half from cover pocket.

   b. Let coupling hang free.

   c. Get canteen from its cover. Flip open protective cover of cap and hold canteen in one palm near your mask.

   d. Push couple half in and turn to connect it to cap.

   e. Check that connections are tight.

   f. If pin in cap is off center, insert coupling to angle to pick-up pin.

   g. Turn and hold level all the way toward voicemitter.

   h. Open your mouth and hold drinking mouth piece between you teeth.

   i. Blow to create positive pressure.

   j. If resistance is not felt, your drinking sytem leaks - don't drink.

   k. Replace mask as soon as conditions permit.

   l. If system doesn't leak, raise and invert canteen.

   m. Keep lever turned and drink water from canteen by mouth sucking.

   n. Do not tilt head back while drinking. Repeat this as required.

o. When finished, turn canteen upright and after several swallows allow air in mask to enter canteen.

p. Blow into mouthpiece.

q. Return lever to vertical position.

r. Pull coupling half from cup.

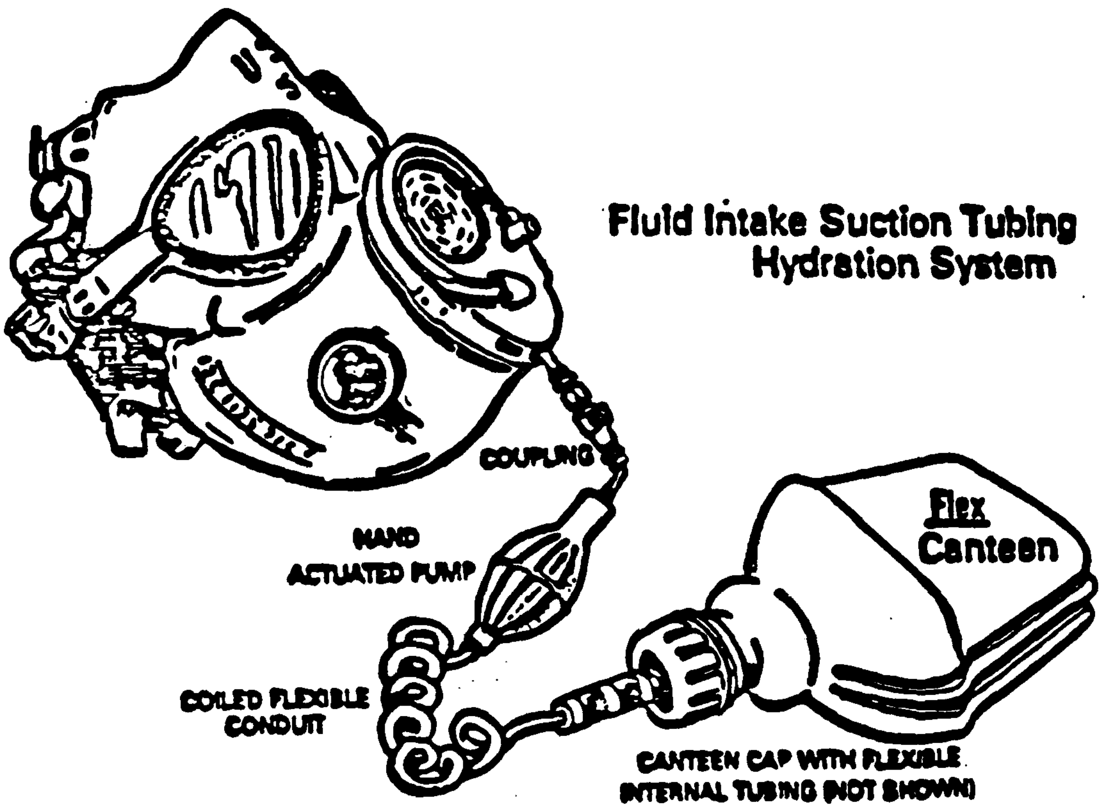
s. Close protective water cap cover.

t. Stow canteen.

u. Return coupling half to pocket an depress hose into groove at side of voicemitter pouch.

Appendix B.

The Fluid Intake Suction Tubing (FIST) hydration system utilizes tubing which connects the MOPP gear M17A1 face mask directly to the soldier's canteen (figure 1). It includes check values, quick disconnects, a squeeze bulb and a



flexible 2 quart canteen. Stainless steel parts and polysulfinated rubber blends are NBC safe materials.

The FIST-type system appears to provide some significant features including: 1. Single-handed operation. 2. Improved operability while walking or sitting in enclosed spaces. 3. The system should encourage drinking in a contaminated environment because the system is not breeched for every drink. 4. The system can deliver up to 250 ml of water per minute which allow 1 to 2 qts of fluid to be consumed in as little as 4 to 8 minutes. This is well within the 10 min rest per hour usually provided. 5. The soldier does not have to add to his respiratory distress in an attempt to suck water against a negative pressure.

Appendix C

ENVIRONMENTAL SYMPTOMS QUESTIONNAIRE (FORM FW)

NAME:________________________ TEST DAY:__________

INSTRUCTIONS: For each item, circle the rating number (for example, 0,1,2,3,4,or5) that corresponds to how you felt while in the wind tunnel today.

	NOT AT ALL	SLIGHT	SOMEWHAT	MODERATE	QUITE A BIT	EXTREME
1. I FELT LIGHTHEADED	0	1	2	3	4	5
2. I HAD A HEADACHE	0	1	2	3	4	5
3. I FELT SINUS PRESSURE	0	1	2	3	4	5
4. I FELT DIZZY	0	1	2	3	4	5
5. I FELT FAINT	0	1	2	3	4	5
6. MY VISION WAS DIM	0	1	2	3	4	5
7. MY COORDINATION WAS OFF	0	1	2	3	4	5
8. I WAS SHORT OF BREATH	0	1	2	3	4	5
9. IT WAS HARD TO BREATHE	0	1	2	3	4	5
10. IT HURT TO BREATHE	0	1	2	3	4	5
11. MY HEART WAS BEATING FAST	0	1	2	3	4	5
12. MY HEART WAS POUNDING	0	1	2	3	4	5
13. I HAD A CHEST PAIN	0	1	2	3	4	5
14. I HAD CHEST PRESSURE	0	1	2	3	4	5
15. MY HANDS WERE SHAKING OR TREMBLING	0	1	2	3	4	5
16. I HAD A MUSCLE CRAMP	0	1	2	3	4	5
17. I HAD STOMACH CRAMPS	0	1	2	3	4	5
18. MY MUSCLES FELT TIGHT OR STIFF	0	1	2	3	4	5
19. I FELT WEAK	0	1	2	3	4	5
20. MY LEGS OR FEET ACHED	0	1	2	3	4	5
21. MY HANDS, ARMS OR SHOULDERS ACHED	0	1	2	3	4	5
22. MY BACK ACHED	0	1	2	3	4	5
23. I HAD A STOMACH ACHE	0	1	2	3	4	5
24. I FELT SICK TO MY STOMACH	0	1	2	3	4	5
25. I HAD GAS PRESSURE	0	1	2	3	4	5
26. I HAD DIARRHEA	0	1	2	3	4	5
27. I FELT CONSTIPATED	0	1	2	3	4	5
28. I HAD TO URINATE MORE THAN USUAL	0	1	2	3	4	5

	NOT AT ALL	SLIGHT	SOMEWHAT	MODERATE	QUITE A BIT	EXTREME
29. I HAD TO URINATE <u>LESS</u> THAN USUAL	0	1	2	3	4	5
30. I FELT WARM	0	1	2	3	4	5
31. I FELT FEVERISH	0	1	2	3	4	5
32. MY FEET WERE SWEATY	0	1	2	3	4	5
33. I WAS SWEATING ALL OVER	0	1	2	3	4	5
34. MY HANDS WERE COLD	0	1	2	3	4	5
35. MY FEET WERE COLD	0	1	2	3	4	5
36. I FELT CHILLY	0	1	2	3	4	5
37. I WAS SHIVERING	0	1	2	3	4	5
38. PARTS OF MY BODY FELT NUMB	0	1	2	3	4	5
39. MY SKIN WAS BURNING OR ITCHY	0	1	2	3	4	5
40. MY EYES FELT IRRITATED	0	1	2	3	4	5
41 MY VISION WAS BLURRY	0	1	2	3	4	5
42. MY EARS FELT BLOCKED UP	0	1	2	3	4	5
43. MY EARS ACHED	0	1	2	3	4	5
44. I COULDN'T HEAR WELL	0	1	2	3	4	5
45. MY EARS WERE RINGING	0	1	2	3	4	5
46. MY NOSE FELT STUFFED UP	0	1	2	3	4	5
47. I HAD A RUNNY NOSE	0	1	2	3	4	5
48. I HAD A NOSE BLEED	0	1	2	3	4	5
49. MY MOUTH WAS DRY	0	1	2	3	4	5
50. MY THROAT WAS SORE	0	1	2	3	4	5
51. I WAS COUGHING	0	1	2	3	4	5
52. I LOST MY APPETITE	0	1	2	3	4	5
53. I FELT SICK	0	1	2	3	4	5
54. I FELT HUNGOVER	0	1	2	3	4	5
55. I WAS THIRSTY	0	1	2	3	4	5
56. I FELT TIRED	0	1	2	3	4	5
57. I FELT SLEEPY	0	1	2	3	4	5
58. I FELT WIDE AWAKE	0	1	2	3	4	5
59. MY CONCENTRATION WAS OFF	0	1	2	3	4	5
60. I WAS MORE FORGETFUL THAN USUAL	0	1	2	3	4	5
61. I FELT WORRIED OR NERVOUS	0	1	2	3	4	5
62. I FELT IRRITABLE	0	1	2	3	4	5
63. I FELT RESTLESS	0	1	2	3	4	5
64. I WAS BORED	0	1	2	3	4	5
65. I FELT DEPRESSED	0	1	2	3	4	5
66. I FELT ALERT	0	1	2	3	4	5
67. I FELT GOOD	0	1	2	3	4	5

RATING OF PERCEIVED EXERTION

6
7 VERY, VERY LIGHT
8
9 VERY LIGHT
10
11 FAIRLY LIGHT
12
13 SOMEWHAT HARD
14
15 HARD
16
17 VERY HARD
18
19 VERY, VERY HARD
20

Appendix E.

CURRENT DRINKING SYSTEM

QUESTIONNAIRE 2

Name____________________ Time___

Date____________________.

Please answer the following questions by circling the number on each scale that best expresses your opinion.

1. How easy or difficult is it to connect the drinking tube to the canteen when walking?

extremely easy 1 2 3 4 5 6 7 8 9 very difficult

during rest periods?

extremely easy 1 2 3 4 5 6 7 8 9 very difficult

2. How easy or difficult is it to hold the canteen of water above your head when walking?

extremely easy 1 2 3 4 5 6 7 8 9 very difficult

during rest periods?

extremely easy 1 2 3 4 5 6 7 8 9 very difficult

3. Is there any leakage of water into the inside of your mask when you're drinking?

When walking? YES NO: If yes, how much

very little 1 2 3 4 5 6 7 8 9 very much

during rest periods? YES NO: if yes, how much

very little 1 2 3 4 5 6 7 8 9 very much

4. How slowly or quickly does the water flow into your mouth when walking?

too slowly 1 2 3 4 5 6 7 8 9 too quickly

during rest periods?

too slowly 1 2 3 4 5 6 7 8 9 too quickly

5. Overall, how easy or difficult is it to drink from the system that you're using when walking?

extremely easy 1 2 3 4 5 6 7 8 9 very difficult

during rest periods?

extremely easy 1 2 3 4 5 6 7 8 9 very difficult

6. How much do you like the taste of the water when walking?

extremely dislike 1 2 3 4 5 6 7 8 9 extremely like

neutral

during rest periods?

extremely dislike 1 2 3 4 5 6 7 8 9 extremely like

neutral

7. How would you rate the temperature of the water when walking?

extremely cold 1 2 3 4 5 6 7 8 9 extremely hot

neutral

during rest periods?

extremely cold 1 2 3 4 5 6 7 8 9 extremely hot

neutral

FIST-FLEX TYPE SYSTEM

QUESTIONNAIRE 3

Name____________________ Time____

Date____________________.

Please answer the following questions by circling the number one each scale that best expresses your opinion.

1. How easy or difficult is it to connect the drinking tube to the canteen when walking?

extremely easy 1 2 3 4 5 6 7 8 9 very difficult

during rest periods?

extremely easy 1 2 3 4 5 6 7 8 9 very difficult

2. How easy or difficult is it to pump water into your mouth when walking

extremely easy 1 2 3 4 5 6 7 8 9 very difficult

during rest periods?

extremely easy 1 2 3 4 5 6 7 8 9 very difficult

3 Is there any leakage of water into the inside of your mask when you're drinking? (circle one)

when walking? YES NO: if yes, how much

very little 1 2 3 4 5 6 7 8 9 very much

during rest periods? YES NO: if yes, how much

very little 1 2 3 4 5 6 7 8 9 very much

4. How slowly or quickly does the water flow into your mouth when walking?

too slow 1 2 3 4 5 6 7 8 9 too quickly

during rest periods?

too slow 1 2 3 4 5 6 7 8 9 too quickly

5. Overall, how easy or difficult is it to drink from the system that you're using when walking?

extremely easy 1 2 3 4 5 6 7 8 9 very difficult

during rest periods?

extremely easy 1 2 3 4 5 6 7 8 9 very difficult

6. How much do you like the taste of the water when walking?

extremely dislike 1 2 3 <u>4 5 6</u> 7 8 9 extremely like

neutral

during rest periods?

extremely dislike 1 2 3 <u>4 5 6</u> 7 8 9 extremely like

neutral

7. How would you rate the temperature of the water when walking?

extremely cold 1 2 3 <u>4 5 6</u> 7 8 9 extremely hot

neutral

during rest periods?

extremely cold 1 2 3 <u>4 5 6</u> 7 8 9 extremely hot

neutral

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