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Combatant Protection and Nutrition Branch
Aeronautical and Maritime Research Laboratory

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ABSTRACT

This paper presents the results of a study comparing two systems of water carriage and delivery for use by infantry soldiers: A water bladder/tube and the current Army issue water bottles. The systems were compared for their effects on hydration status, thermal strain and acceptability, using a section of infantry engaged in simulated operations in a hot environment. The bladder/tube system was found to have slight (but not statistically-significant) positive effects on hydration status, was neutral with respect to thermal strain, and was unanimously preferred to water bottles as the primary means of water carriage. Therefore, the bladder/tube system has operational advantages over water bottles, is more acceptable to soldiers and may have a positive effect on hydration status. It is concluded that further studies are needed, both to determine the suitability of water canteens as the means of carriage but with a tube for delivery, and to determine the optimal formulation for a hydration beverage.

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Executive Summary

One of the major protective factors against heat illness is the maintenance of normal body water levels. Even relatively mild hypohydration will adversely affect performance when hard work is conducted in the heat. More severe hypohydration will cause more severe symptoms across a continuum, until, at high levels of hypohydration, heat-related illness (including life-threatening heat stroke) becomes inevitable. The system of water carriage and delivery used by the Army is based on water bottles. These do not allow soldiers to obtain water while moving and do not allow drinking to be hands-free. Commercially-available bladder/tube systems now exist that do allow such drinking.

In this trial, a section of infantry (n=10) conducted approximately the same activities over a four day period while drinking from either water bottles or a bladder/tube system (SportTank®, Ultimate Direction). While they were engaged in the simulated operations, changes to their hydration status were determined. Weight measurements were made to determine rates of water intake, sweating, weight loss and urine production. In addition, urine samples were analysed for indicators of dehydration (sodium concentration and specific gravity). Simultaneously, measurements were made of deep body core temperature, skin temperature and heart rate, as indicators of heat strain. Following the four-day trial, questionnaires were issued, requesting information on subjective acceptability of the two systems of water delivery.

Although a consistent trend to improved hydration status was associated with the use of the bladder/tube, the treatment effect did not reach statistical significance for any individual parameter. Similarly, while there was a trend toward less cardiovascular strain (indicative of less hypohydration), overall, there were no significant differences in thermal strain indices (heart rate, or core or skin temperatures). The results of the questionnaire survey showed that in this small sample of soldiers there was universal preference for the bladder/tube.

It is concluded that the bladder/tube system has operational advantages over water bottles, is more acceptable to soldiers, and does not adversely affect hydration status or thermal strain. It is further concluded that studies should be conducted, using the current issue Army water canteen as the sytem of water carriage but with a tube for delivery of water to the soldier, to determine if the suitability of this system equals that of the bladder/tube system. An advantage of the canteen/tube over the bladder/tube is that it would be less costly. It is also concluded that studies are needed to investigate the optimal formulation for a hydration beverage to be used on operations.

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BSc (Hons), Associate of the Australian Institute of Food Science and Technology, member of the Nutrition Society of Australia, of the Australian Society for the Study of Obesity and of the International Society for the Advancement of Kinanthropometry.
Trained as a biochemist, he has more than 25 years experience in food science and physiology. Since 1986 Chris has been Senior Nutritionist at the Defence Nutrition Research Centre. Since that time he has led a team that has conducted extensive research into food acceptability, food intake, energy expenditure and physical performance enhancement of ADF members. His areas of research interest have recently expanded to include hydration and thermal physiology.

James D. Cotter
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Jim graduated from the University of Otago (NZ) with a BSc in Physiology (1988), BPhEd in Kinesiology (1989) and MPhEd (1992) in physiological and epidemiological aspects of hypothermia. He moved to Australia (1993) and graduated from the University of Wollongong with a PhD in thermal physiology (1998). He was a lecturer (1997: physiology and exercise physiology) at the University of Wollongong, before joining the Personnel Protection and Performance Group of CPNB (1998) as a Research Scientist to examine thermal strain aspects of personnel protection and performance.

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Denys Amos graduated from the University of Durham (UK) in 1960 with a BSc (Hons) and MSc (1961) in organic chemistry. He has worked with ICI and the Science Research Council and has been attached to CBDE in the UK. At AMRL he has undertaken extensive research into decontamination and into protection of personnel against toxic chemicals. At present he is a Principal Research Scientist and manager of a program on personnel protection and physiological performance. Recently he has been the principal investigator into the physiological assessments of soldier performance in the tropics and the newly developed Chemical, Biological Combat Suit.

Wai-Man Lau

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Wai-Man (Tony) Lau graduated in Hong Kong in 1979 in Biology and Biochemistry and obtained his M.Phil in environmental biology in 1981. After winning a Croucher Foundation Scholarship (HK), he studied environmental toxicology at Melbourne University and was awarded a Ph.D degree in 1987. After a short period of employment with the Unipath Pathology Laboratory he joined AMRL in 1985 and conducted pharmacological studies leading to improved prophylaxis and therapy of nerve agents. He is currently a Senior Research Scientist involved in environmental physiology in the Personnel Protection and Performance Group of CPNB.

Contents

1. Introduction

The centre of gravity of the ADF is moving toward the hot northern half of the continent. This is the result of the Force Structure Review policy known as Army Presence In the North (APIN). One inadvertent consequence of this policy is that heat illness— already a major cause of casualties during training and on field exercises—will become an even greater problem, especially to infantry soldiers engaged in dismounted operations.

One of the major protective factors against heat illness is the maintenance of normal body water levels (ie, euhydration). According to Burr (1991), 'water losses can reach 15 litres per day per soldier' in hot environments. Even relatively mild hypohydration (e.g., loss of 2-3% of body weight) will adversely affect physical and cognitive performance when hard work is conducted in the heat (Burr, 1991). Mild hypohydration, combined with heat, may lead to symptoms such as disorientation, dizziness and heat syncope (fainting). More severe hypohydration will cause more severe symptoms across a continuum. Burr (1991) states that '5-6% dehydration is incompatible with further functioning'. If dehydration continues, the probability greatly increases that heat stroke will occur, with life-threatening consequences. The significance of heat illness to military training and operations should not be underestimated: for example, Porter (1993) reported that from 1942 to 1944 'there were...no fewer than 198 cases of deaths from heat illness suffered by soldiers in training in the United States.'

One impediment to maintaining euhydration may be the system of individual water carriage and delivery used by the Australian Army. Most of the infantry soldier's water intake comes from water bottles that are stored in pouches. For a soldier to obtain a drink the pouch must first be opened, the bottle removed and the lid unscrewed. This means that drinking cannot readily occur on the move and that it cannot be 'hands free'. This has both operational and physiological implications. Operationally, it would be preferable to use a method of water delivery that allows soldiers to drink while patrolling and that does not require them to divert their attention from their primary aim—detection of the enemy. A potential adverse physiological effect of using the current system is exacerbation of 'voluntary dehydration', that is, soldiers reducing water intake because of the inconvenience associated with drinking from water bottles.

Commercial companies catering to ultra-endurance athletes have devised a drinking system based on a plastic bladder with a flexible tube. At the end of the tube is a valve that allows water to be drunk on the move. For military use, the tube can be passed under the epaulette of the soldier's DPCU and the valve can be kept in close proximity to the soldier's mouth to allow largely hands-free drinking. The soldier can obtain water at any time by placing the valve in his mouth and sucking. Thus, the bladder/tube system shows promise as a means of promoting water intake while simultaneously improving operational effectiveness.

While there are theoretical operational advantages to this system, its superiority to the current method of water delivery has not been demonstrated. Thomson et al (1997), in their review of the literature on military hydration, recommended *inter alia,* that 'the effectiveness and service suitability of "bladder" style delivery systems...should be evaluated'. Studies are required to determine the acceptability to soldiers of this system of water delivery, its suitability in the military environment, its effects on the hydration status and how this impacts on physiological status of soldiers engaged in operations in the heat.

For a new system of water delivery to be considered for introduction into service, we believe that it should provide distinct advantages over the current system in at least one of the following areas, with no disadvantage in the others:

(i) Operational effectiveness;
(ii) Acceptability to users; and
(iii) Physiological effects.

The present report describes a study conducted at High Range Training Area (HRTA) in February 1998, to investigate these effects. The study was a component of the 1998 Soldier Combat System Evaluation Study (98SCSES), under Project Land125 (formerly Project Wundurra). This evaluation was conducted within the Human Factors (HF) experiments at HRTA. Other HF aspects of these studies have been reported by Amos et al (1998).

The Roll-Top SportTank® (Ultimate Direction, USA) is one of several bladder/tube drinking devices available on the market. It was chosen for evaluation of the bladder/tube concept because it appeared to provide the greatest protection against accidental spillage (additional protection is provided by the roll-top and a Velcro® seal). Other commercially available bladder/tube systems that were considered included the Oasis® (Macpac Wilderness Equipment Ltd, USA) and Camelbak® (Fastrak Systems Inc., USA). Because of the similarity of these products, it is considered that all references to "SportTank®" in this report would apply equally to the other commercially available products.

The acceptability and service suitability of the SportTank® relative to water bottles were also determined by questionnaire. In addition, objective measures were made of the hydration status and thermal strain of soldiers engaged in simulated operations in the heat, when obtaining water from SportTank® or from water bottles. Objective parameters of hydration status were water intake, weight change, sweat rate, rate of urine production, urine sodium concentration, and urine specific gravity. In addition, the effects of water delivery system on deep body and skin temperatures and heart rates were determined. During sustained work in the heat, there are normally gradual increases in heart rate and deep body temperature, referred to as cardiovascular and thermal drift, respectively. Both drifts are probably caused by dehydration. Therefore, deep body temperature and heart rate provide measures of the impact of hydration status on thermal strain.

2. Methods

2.1 Subjects

Ten male soldiers, comprising a Section within C Company, 1st Battalion Royal Australian Regiment (1RAR), 3 Brigade, provided informed consent to participate in the study. The study conformed to the ethical clearance granted by the Australian Defence Medical Ethics Committee.

An attempt was made to determine maximal oxygen uptake (V_{O2max}) for each soldier, using a stepped-work protocol, on an electromagnetically-braked cycle ergometer (Lode Excalibur, Netherlands) at James Cook University (JCU) prior to the study. V_{O2max} is generally regarded as the best all-round measure of an individual's potential to engage in sustained aerobic physical work. The protocol for estimating V_{O2max} involved an initial workload of 50 Watts at a cadence of 60 rpm, incrementing by 50 Watts every two minutes until volitional exhaustion. Oxygen consumption was calculated on-line (QMC, Quinton Instruments Co., USA) every 5 seconds, and the highest value for oxygen uptake was taken to be the highest reading obtained (Table 1).

However, the soldiers were not experienced cyclists. The V_{O2max} of non-cyclists is usually 6-10% higher than the peak oxygen uptake (V_{O2peak}) attained on a cycle ergometer. As shown in Table 1, mean V_{O2peak} was about 51 $mL \cdot min^{-1} \cdot kg^{-1}$. Therefore, it is likely that the results for oxygen uptake shown in Table 1 do not represent V_{O2max}. That is, V_{O2max} was not reached before volitional exhaustion occurred on the cycle ergometer. Another indication that V_{O2max} was not achieved is the relatively low peak heart rates (HRpeak), as shown in Table 1. Mean HRpeak was 185, while theoretical mean HRmax (calculated as 220 - age) is 198. Therefore, these soldiers probably had mean V_{O2max} ~ 54-56 $mL \cdot min^{-1} \cdot kg^{-1}$. This is indicative of greater aerobic fitness than typical age-matched civilians (44-51 $mL \cdot min^{-1} \cdot kg^{-1}$) (Astrand, 1960), but of lower fitness than male Olympic-calibre cyclists, speed skaters, middle distance runners or cross-country skiers (>75 $mL \cdot min^{-1} \cdot kg^{-1}$) (McArdle et al, 1991). Of note, there was a wide range of fitness levels determined within the section, from *sedentary* to *highly-trained.*

2.2 Activities

Four trials (denoted HF1-HF4) were conducted in a hot, relatively dry environment, at the Army's Military Operations in an Urban Environment (MOUT) village at HRTA. The study was balanced and crossover, ie, each soldier became his own control. On at least two of four successive days soldiers wore the normal Army disruptive pattern combat uniform (DPCU). On one of these two days they obtained water from the SportTank®, on the other day from water bottles.[1]

[1] As previously mentioned, this study was an element of a larger study aimed at determining, *inter alia*, the physiological effects of wearing Combat Body Armour or Chemical and Biological Combat Suit relative to DPCU. Therefore, on the other days soldiers wore those garment systems.

Table 1: Characteristics of soldiers

Soldier	Age (yrs)	Height (cm)	Mass (kg)	HR_{peak} (b min^{-1})	V_{O2peak} (L min^{-1})
S1	27	175.0	79.6	181	51.5
S2	22	164.8	73.4	192	48.7
S3	26	172.7	70.8	181	42.0
S4	21	178.4	75.8	201	51.2
S5	22	186.0	84.6	189	60.1
S6	23	173.2	77.5	NA	46.7
S7	24	175.7	70.4	182	51.0
S8	19	171.7	68.1	185	51.1
S9	20	183.0	91.2	178	49.5
S10	20	170.4	70.2	179	62.2
Mean	**22.4**	**175.1**	**76.2**	**185.3**	**51.4**
S.D.	**2.6**	**6.2**	**7.3**	**7.5**	**5.9**
Range	**8.0**	**21.2**	**23.1**	**23.0**	**20.2**

Note 1: *NA = Not Available*

Note 2: *HR_{peak} and V_{O2peak} refer to the highest heart rate and rate of oxygen consumption, respectively, obtained during an incremental exercise test to exhaustion on a cycle ergometer. The latter is a direct measure of aerobic fitness.*

The proposed schedule of activities is shown in Table 2. As far as possible the three experimental activities (patrol, set-up of observation post, and assault) were repeated at the same time for each of the four days. However, due to concern over the risk of heat illness, the OC of C Company required an earlier start for HF2-HF4 than for HF1 (following a case of heat-related illness during HF1). The time taken and distance patrolled during HF1 were also greater than for the other experiments. The significance of this to the trial outcome is discussed in Section 3.1.

Table 2:Proposed Schedule of Trials in Experiments HF1-HF4

Schedule	Activities
0445-0615	Obtain weights of soldiers and their ensembles; Instrument with temperature and heart rate equipment; Record water consumption and collect urine samples
0630-1000	Patrol a defined route of 6 km in open country
1000-1100	Set up an observation post; Collect urine samples; Obtain mass of soldier and ensemble system.
1100-1130	Assault an enemy position on higher ground
1130-1135	Return to base
1135-1300	De-instrument the soldiers; Obtain weights; Collect urine samples

2.3 Protocol

The following protocol addresses only the water delivery system aspect of 98SCSES. For a full description of the protocol used for the HF experiments see Amos et al (1998).

On each of the trial mornings, subjects presented to the preparation area at ~0500 —approximately two hours before the activity began. Each subject had either voided his bladder into a 500 mL screw-top specimen container on arising, or did so on arrival at the preparation area. Urine samples were packed in water ice for dispatch to the Physiology Laboratory at James Cook University (JCU) for analysis. Subjects were weighed in briefs ('semi-nude'). Full water containers (water bottles or SportTanks®) to be taken into the field were weighed. Subjects' water consumption between the time of initial weighing and the start of the activity was noted by weight difference of one specified water bottle. Initially the intention was to add this to the body weight of the soldier (thereby taking into account the additional water intake). However, it was considered that most soldiers were drinking before the patrol only to maintain euhydration (ie, they were not hyperhydrating). Therefore, the pre-patrol water intakes were not used in the calculation of hydration status.

For logistical reasons, experiments HF2-HF4 involved consumption of breakfast after the initial weighings and before commencement of the patrol. The weight of food eaten by each subject was estimated by noting the breakfast components he ate, and determining a mean weight for each component.

Each subject was issued with a 500 mL screwtop specimen container which was used (if necessary) to collect the urine produced during the first phase of the activity (a patrol of approximately 6 km). Start and finish times were recorded for each phase of the activity. At the mid-experiment point—the establishment of an observation post (OP)—urine was collected and empty containers were provided for the second phase. Water containers were weighed, refilled and weighed again.

After the final activity (a short patrol followed by an assault) subjects voided their bladders into specimen containers and were then weighed semi-nude. Water containers were also weighed.

At the Physiology Laboratory at JCU the volumes of all urine samples were measured and the samples were frozen at -18°C.

Following HF4, questionnaires on the suitability and acceptability of the two delivery systems (water bottles versus SportTank®) were distributed to all subjects. A copy of the questionnaire is shown at Appendix 1.

After all urine samples had been obtained from HF1-HF4, they were thawed. An aliquot of approximately 5 mL was retained and analysed for specific gravity (SG) by Unicon SG Urine Refractometer. Measurements of urine sodium concentrations (Synchron CX5 System, Beckman Instruments Inc., Fullerton, California) were also made for each urine sample. Staff experienced in the analytical method at the Pathology Laboratory of the Townsville General Hospital conducted the sodium analyses. Urine sodium and SG are indicators of hydration status — the onset of hypohydration is associated with increases in both of these values.

2.4 Calculations

Sweat rate cannot be determined directly in the field. It is most effectively estimated by weight loss (disregarding the small loss in weight attributable to CO_2 production that results from energy liberation). Total sweat loss (Sw_{TOTAL}) over the period of each study was calculated as:

Initial nude weight - final nude weight + water intake + solid intake - urine output.

2.5 Parameters of Hydration Status

Using Excel Spreadsheets, mean and standard deviation (SD) were calculated for each of the following parameters:

Water intake up to the end of the first patrol (L);
rate of water intake to the end of the first patrol ($L \cdot h^{-1}$);
water intake during the assault and second patrol (L);
rate of water intake during the assault and second patrol ($L \cdot h^{-1}$);
total water intake (L);
rate of total water intake ($L \cdot h^{-1}$);
Sw_{TOTAL}(L);
rate of Sw_{TOTAL} ($L \cdot h^{-1}$);
urine production to the end of the first patrol (L);
rate of urine production to the end of the first patrol ($L \cdot h^{-1}$);
total urine volume produced (L);
rate of total urine production ($L \cdot h^{-1}$);
specific gravity of urine before, during and after the experiment; and
sodium concentration in the urine ($mmol.L^{-1}$, before, during and after the experiment.

The probability that a difference between treatments (SportTank® versus water bottles) was due to chance was determined using Student's t Test. A difference between the treatments was considered to be statistically significant if the probability that it was due to chance was equal to or less than 0.05.

2.6 Deep Body Temperature, Skin Temperature and Heart Rate

Deep body temperature was measured rectally, using a flexible thermistor (YSI type 401, Yellow Springs Instruments, Ohio, USA) inserted by the soldier 10 cm beyond the external anal sphincter. Rectal thermistor leads were fitted with a bulb, made of Araldite epoxy, approximately 9 cm from the thermistor tip, to reduce dislodgment of the lead from the rectum during the trials. As further precaution against dislodgment, tape was wound around the lead after insertion, then fastened around the soldier's buttocks.

Skin temperature was measured from thermistors (Edale Instruments, Cambridge, U.K.), fastened by strapping tape (Leukoplast) at three, shaved sites: scapula, forearm and calf. Area-weighted mean skin temperature was later derived using the formula of Burton (1934):

$$\text{Mean Skin Temperature } (T_{msk}) = 0.50 \cdot T_{chest} + 0.16 \cdot T_{forearm} + 0.34 \cdot T_{calf} \text{ (°C).}$$

Hard-wired logging was used to collect and store temperature data in the field, prior to down load to a portable PC at the completion of each trial. The logger used was a Squirrel (1206 series, Grant Instruments Ltd, U.K.), which averaged the temperatures each minute.

Heart rate (HR) was recorded at one-minute intervals from the R-wave frequency of ventricular depolarisation (Polar SportTester™, Electro Oy, Finland). The transmitter was fastened around the soldier's torso, and the receiver was insulated from physical harm, before being placed in a breast pocket in the DPCU. HR data were down loaded to a portable PC at the completion of each trial.

Statistical analysis of the results obtained for deep body temperature, skin temperature and HR was by Wilcoxon Rank Sum Test. A difference between the treatments was considered to be statistically significant if the probability that it was due to chance was equal to or less than 0.05.

3. Results and Discussion

3.1 Effects of HF1-HF4 on Hydration Status

The aim of the study design for the activities HF1-HF4 was to replicate conditions (other than treatments) on four successive days, to allow statistical analysis of the effects of treatments on hydration status. Appendix 3 shows the raw data and Appendix 4 shows the hydration summary obtained for each subject. Table 3 shows the mean and SD for each hydration parameter.

Unfortunately, as mentioned in Section 2.2, the timings and activities during the trial were not consistent from day to day, leading to different conditions for each of the trials HF1-HF4. For example, the rate of weight loss was apparently greater for HF1 than for HF2-HF4. This may relate to the later start time (leading to exposure to higher temperatures and greater solar load) for HF1, although this interpretation is not supported by the Wet Bulb Globe Temperature (WBGT[2]) results (Amos et al. 1998). Rates of sweating, water intake and urine production were very similar for all trials HF2-4.

[2] Wet Bulb Globe Temperature (WBGT) is calculated from three measured parameters: the Wet Bulb (WB) thermometer reads the temperature as reduced by natural evaporation of water/sweat; the black Globe Thermometer (GT) indicates radiant heat load; and the shaded Dry Bulb (DB) thermometer reads the actual air temperature. The WBGT index is calculated as 0.7 WB + 0.2 GT + 0.1 DB.

Table 3. Mean and SD for rates of weight loss, water intake, urine production and total sweat for HF1-HF4.

ACTIVITY		RATE OF WEIGHT LOSS ($kg.h^{-1}$)	RATE OF WATER INTAKE ($L.h^{-1}$)	RATE OF URINE PROD ($L.h^{-1}$)	TOTAL SWEAT RATE ($L.h^{-1}$)
HF1	Mean	0.37	0.67	0.05	0.99
	SD	0.20	0.18	0.03	0.29
HF2	Mean	0.24	0.66	0.06	0.92
	SD	0.26	0.15	0.05	0.24
HF3	Mean	0.22	0.73	0.09	0.93
	SD	0.20	0.25	0.07	0.17
HF4	Mean	0.26	0.68	0.08	0.97
	SD	0.17	0.20	0.08	0.13

At approximately 1.0 L per hour, sweat rates were not extreme and were comparable to those previously described for soldiers engaged in patrolling in the heat (Amos et al. 1996). At 50-90 mL per hour, mean urine production was quite low, but is still comfortably above the generally recognised minimum obligatory rate of about 15 mL per hour, indicating that marked hypohydration had not occurred. However, the mean result conceals a wide variation in urine production, since the high standard deviations (approximately equal to the means) show that urine production varied greatly between subjects. One subject (Subject 5) had consistently higher water intake and urine production than any other subject. He also *gained* weight during three of the four HF trials (Appendix 1). One subject (Subject 9) had consistently high weight *loss*, indicating a high rate of dehydration.

HF1-HF4 were conducted over relatively short time periods (~5 hours), so marked hypohydration was not observed. Whether or not the high rate of dehydration of Subject 9 would have continued if the patrolling phase had been long-term is not known. Many soldiers (and people in general) do not drink enough water to maintain euhydration in the heat. This phenomenon is termed 'voluntary dehydration', although it would perhaps be better named 'involuntary dehydration', because the subject is usually not aware of the extent of hypohydration that is occurring. It may be that the temperature of the water, a lack of flavouring and the method of delivery (water bottles for about 50% of the time) adversely affected water intake. The possible effects on intake of flavouring drinking water and using other delivery systems (e.g., a water bladder with tube) are discussed later in this report.

3.2 Comparison of SportTank® with Water Bottles - Hydration Status

Appendix 5 shows the results for hydration status of individual soldiers using SportTank® compared with water bottles as their system of individual water carriage and delivery. Table 4 shows the summary (mean and SD) for hydration effects of using SportTank® versus water bottles.

Although all parameters show a slight trend towards increased water intake when using the SportTank® (Table 4), none of the differences between treatments are statistically significant. This is perhaps surprising, considering the popularity of the bladder/tube system of water delivery (see next section). The only conclusion that can be drawn from the results is that the SportTank® did not lead to reduced water intake and may even have elicited slightly higher intakes than did the water bottles.

Table 4: Summary (Mean and SD) of differences in hydration parameters between soldiers using water bottles and SportTank® (a positive value implies that the SportTank led to the higher result)

Water Delivery		Rate of Weight Change ($kg \cdot h^{-1}$)	Rate of Water Intake ($L \cdot h^{-1}$)	Total Sweat Rate ($L \cdot h^{-1}$)	Rate of Urine Production ($L \cdot h^{-1}$)	Final Urine Sodium ($mmol \cdot L^{-1}$)	Final Urine Specific Gravity
SportTank®	Mean	0.19	0.72	0.90	0.08	38.9	1.023
	SD	0.18	0.16	0.16	0.05	47.3	0.008
Water Bottles	Mean	0.22	0.63	0.84	0.07	30.4	1.023
	SD	0.27	0.20	0.16	0.03	28.6	0.004
Difference	Mean	-0.03	0.09	0.06	-0.01	-8.5	0.000
	SD	0.23	0.21	0.13	0.04	52.5	0.007
P		0.38	0.20	0.12	0.26	0.33	0.46

3.3 Deep Body Temperature, Skin Temperature and Heart Rate

Table 5 shows the results for deep body temperature, mean skin temperature and HR. The increase in deep body temperature and mean skin temperature during the patrol and attack periods, as well as the decrease during the intervening observation period, was unaffected by the mode of fluid delivery (all $p > 0.05$; Table 5). Similarly, while there was a trend toward attenuated cardiovascular strain during patrolling (p=0.17) and assaulting (p=0.19) activities while using the SportTank®, these effects did not reach statistical significance (Table 5). Therefore, cardiovascular and temperature strain were not differentially affected by the method of fluid delivery. The trend toward lower cardiovascular strain with the SportTank® is consistent with the hydration results (see Table 4), indicating that the SportTank® does not exacerbate, and may even slightly reduce, the thermal strain arising from a fighting patrol or assault in the tropical environment of HRTA.

In summary, there was no increase in thermal strain attributable to the use of SportTank® relative to water bottles.

Table 5. Mean difference between the SportTank® and water bottle, in the change of deep body temperature, mean skin temperature and heart rate across each of four phases of the experimental trials.

	Mean diff	*p*	*n*
Deep body temperature (°C)			
Patrol	0.12	0.53	8
Observation Post	0.15	0.53	8
Assault	0.10	0.89	5
Entire operation	0.12	0.69	5
Mean skin temperature (°C)			
Patrol	0.3	0.21	8
Observation Post	0.4	0.05	9
Assault	0.3	0.07	9
Entire operation	0.1	0.67	8
Heart rate (beats·min^{-1})			
Patrol	-10.4	0.17	9
Observation Post	5.4	0.11	8
Assault	-6.2	0.19	9
Entire operation	--	--	--

Note: *Difference scores were calculated by subtracting the change for the water bottle from the corresponding change for the SportTank®. The Table shows that the progression of deep body and mean skin temperatures and heart rate were (statistically) equivalent for the two hydration systems, during each phase of the experimental trials. For example, although the increase in heart rate appeared to be approximately 10 beats·min^{-1} less for the SportTank® compared with the water bottle hydration system, this difference was not statistically significant.*

3.4 Questionnaire Survey Results - SportTank® Versus Water Bottles

Questionnaires (see Appendix 1) were completed and returned by all 10 members of the section. Appendix 2 shows the detailed results obtained from the questionnaire survey.

Highlights of the results are:

(i) Respondents were unanimous in their preference for the bladder/tube concept of water delivery, agreeing that the SportTank® is *easier to use, more comfortable to carry* and *it is always easy to get a drink from the bladder.*

(ii) There was strong disagreement with the statements that *it is always easy to get a drink from the canteen, canteens are easier to fill than bladders* and *I can easily keep my thirst at bay with the canteen.*

(iii) Opinions were divided on the ease of filling of water bottles compared to bladders, with the majority (7/10) favouring the bladder.

(iv) Suggestions by respondents for further improving the concept included:
'attach the bladder to the webbing rather than have it in the daypack';
' use a tube in the current one litre water bottle';

'use the current two litre water bottle as the water container and insert a tube into it';
'get rid of water bottles and replace with bladders'; and
'have a harness that can be used to hold the bladder when doing the BFA, as well as the daypack with pouch for operations'.

3.5 Choice of Water Delivery System

In Section 1 it was argued that for a new system of water delivery to be considered for introduction into service, it should provide distinct advantages over the current system in at least one of the following areas, with no disadvantage in the others:

(i) Operational effectiveness;
(ii) Acceptability to users; and
(iii) Physiological effects.

The bladder/tube system satisfies these criteria by:

(i) Allowing 'hands free' drinking while moving (an operational advantage not shared by water bottles);
(ii) Being more acceptable to soldiers than are water bottles (based on the results of the questionnaire survey); and
(iii) Not leading to reduced water intake, ie, at worst the bladder/tube system is neutral compared to the water bottle with respect to hydration status.

The bladder/tube may even encourage water intake, although in this study only a non-significant increase was found.

It is concluded that a bladder/tube system may be superior to water bottles as the primary means of individual water carriage and delivery for soldiers on operations.

Although this study indicates a possible overall superiority over the standard Army water bottle of the bladder/tube system, this superiority may be due to one or both of the following:

(i) Improved carriage of water;
(ii) Improved delivery of water to the soldier.

In this study, the possibility has not been explored that it is delivery only that is the major benefit to soldiers. It is possible that Army water bottles with a screw top containing a tube and valve are of similar suitability for delivery and are of satisfactory suitability for carriage of water. This system would not allow completely 'hands free' drinking, but it would negate the requirment to unscrew the lid of the water bottle and for the soldier to avert his gaze from his primary focus—looking for signs of the enemy. The major advantage of such a system over the bladder/tube concept is that the water bottles already exist; the only expense would be in developing and manufacturing the screwcap with tube and valve. A study is needed to determine if a suitably modified water bottle is of equal acceptability to ADF members in the field and has similar effects on hydration status to those of the bladder/tube.

3.6 Future Studies

Thomson et al (1997) recommended, *inter alia*, that 'The effectiveness and service suitability of "bladder" style delivery systems...should be evaluated'. From the results obtained in this study, it would appear that the bladder/tube system of water carriage and delivery is superior to the current system based on water bottles.

Thomson et al (1997) also recommended that:

'Consideration should be given to replacing the current beverage base powder in ration packs with a beverage based on sports drinks;

Field acceptability trials should be conducted to find the most acceptable sports drinks;

Laboratory trials to assess the influence of sports drinks on the efficacy of water purification tablets should be undertaken; and

The influence on performance in the heat of chronic hyperhydration should be investigated.'

These recommendations remain appropriate, with the following caveat: that laboratory and barracks trials should precede field testing of beverage formulations. Because of the huge range of possible formulations, and the difficulty of obtaining enough subjects for a statistically-designed field study, it is suggested that no more than three beverage formulations should be tested in the field. In addition to commercially-available sports drinks (which, at 6-8%, are relatively high in carbohydrate) these formulations should include powders that contain relatively low and moderate concentrations of carbohydrate (e.g, 2% and 4%) and constant levels of electrolytes, e.g., the levels recommended by TTCP-HUM-TP8 (1997). The inclusion of low and moderate carbohydrate concentrations is based on anecdotal reports that sports drinks may become less acceptable with chronic use.

Another variable to consider is the possible addition to some formulations of glycerol. This can be used to retain water in the body (ie, induce hyperhydration). There are theoretical reasons for believing that the addition of small amounts of glycerol may lead to better hydration status with chronic use.

Thomson et al (1997) concluded that the type and concentration of carbohydrate in a beverage formulation has little effect on the rate of gastric emptying or intestinal absorption of water unless the carbohydrate concentration is greater than about 6-8%. The major effect of varying beverage formulations appears to be on acceptability. Therefore, the laboratory studies suggested above would be concerned solely with short-term (acute) acceptability.

However, acute acceptability does not necessary equate with enhanced intake chronically. A study over several days is needed to determine which of the most acceptable formulations (from the laboratory trials) retain their acceptability with chronic use, and (more importantly), maximally promote water intake. This study would perhaps be most conveniently conducted in a barracks environment, with a large group of soldiers engaged in vigorous daily training in the heat. Parameters to be measured may include acceptability, fluid intake, weight loss and urine composition - e.g., initial and final specific gravity. Results of this study would be used to determine the three most appropriate formulations to trial in the field.

It is suggested that the field study should use the bladder/tube system of water carriage and delivery and should compare potential formulations with plain water. Parameters to be determined may include acceptability, total fluid intake, weight loss, urine production, urine specific gravity, sweat rate, and plasma sodium concentration.

The ADF recommends rates of water intake according to the level of work conducted and the heat stress to which soldiers are subjected. DI(G) PERS 16-9 (1995) bases recommended water intakes on Heat Stress Index levels which are determined according to the WBGT index. On each of the barracks and field studies, WBGT index should be determined. Intake of water would be compared with the recommended intake. The relationship between water intake, hydration status and the current recommended levels of water intake would be investigated.

4. Conclusions

Note 1: Reference to the section supporting each conclusion is given in parentheses following that conclusion.

Note 2: This study was conducted on a small sample of soldiers (n = 10). It is not considered appropriate that definitive conclusions be drawn on the hydration effects of the use of bladder/tube water delivery systems compared to water bottles. Nevertheless, based on the results of this study, the following trends are noted:

1. The water bladder/tube system of individual water delivery has operational advantages not shared by water bottles (Section 1).

2. In this study, the water bladder/tube system did not adversely affect water intake or hydration status (3.2).

3. The water bladder/tube system did not increase thermal strain (3.3)

4. The water bladder/tube system was more acceptable to soldiers than were water bottles (3.4).

5. A bladder/tube system may be superior to water bottles as the primary means of individual water carriage and delivery for soldiers on operations (3.5).

6. A field study is needed to investigate the Service suitability and effects on hydration status of using a water bottle with tube and valve, compared to standard water bottle and bladder/tube.

7. A laboratory study is needed to determine the most acceptable range of beverage formulations, including low-, medium- and high- carbohydrate powders, with

similar electrolyte levels in each formulation. Consideration should also be given to the addition of glycerol to some formulations to determine the effects of induced hyperhydration on hydration status (3.6).

8. Field studies using the bladder/tube system of water delivery are needed to determine if carbohydrate/electrolyte solutions with long-term acceptability are superior to plain water in helping to reduce or delay dehydration of soldiers engaged in arduous physical work in the heat. Water intake, acceptability and a wide range of parameters of hydration status should be measured over a period of at least one week on a field exercise in the heat (3.6).

9. Fluid intake on both the barracks and field trials should be compared with the current ADF recommended levels of water intake. The relationship between hydration status of soldiers and any differences between these two figures (if such differences exist) should be investigated (3.6).

5. Acknowledgments

The professional attitude of the subjects (soldiers of C Company, 1RAR) and their good-humoured tolerance of very trying conditions are gratefully acknowledged. So too is the assistance and, for one activity, the participation, of Major Damian Burton, Company Commander, C Company, 1RAR. The assistance of Dr Melissa Crowe of James Cook University in conducting fitness testing and urine analysis is also gratefully acknowledged. We also thank DTRIALS and DGLD for their contribution. Their success rate in 'herding the cats' is regarded as having been instrumental in allowing the studies to be successfully completed. The contribution of TTCP-HUM-TP8 must also be acknowledged. This study resulted from a suggestion by the UK DERA-CHS member at the 1995 meeting of TP8. Finally, our thanks go to Bernie Gray and Peter Sanders for advice and technical assistance with the field aspects of the study, and to Gary Thomson, Julia Carins, Vijay Jayasena and Tracey Stephenson for advice on the study protocol.

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Appendix 1: Water Container Comparison Questionnaire

Defence personnel involved in exercises, especially in the heat, run the risk of heat illnesses and decreased performance, and in cases of severe dehydration, incapacitation, injury and even death may occur. The Army's increasing presence in warmer climates such as Northern Australia intensifies this problem. To improve a soldier's ability to maintain his/her body's water reserves, we are comparing two water delivery systems—a form of bladder and the current issue water bottles ('canteens'). As a frequent participant in operations, you are in the best position to advise us on which is your preferred means of carrying water into the field. Please don't hesitate to give your real opinion on each of the following questions.

EXPLANATION OF QUESTIONS

This questionnaire uses three styles of questions, described below.

1) The 'rating scale' contains a series of descriptive words. You answer by shading the response which best represents your opinion.

Shade inside circle ① if you strongly disagree, ② if you disagree, ③ if you cannot decide, or have no strong opinion either way, ④ if you agree, or ⑤ if you strongly agree.

For example, if you respond to the following statement as shown -

This questionnaire is easy to follow.	① ② ③ ④ ⑤

By shading ②, you disagree with the statement, but not very strongly.

If you make an error, place a cross through the incorrect response and shade the correct answer.

2) A choice question, requiring you to indicate which item you prefer by ticking the box. For example, indicate which of the following beers you prefer:

☑ XXXX ☐ Fosters

This would mean that you prefer XXXX to Fosters

3) A written answer which requires you to comment. This is identified by a line.

Current issue 'Canteen'

1) This section contains a list of statements. Read each one carefully and shade the circle which best represents your opinion, making sure your answer is in the correct space.

① strongly disagree ② disagree ③ cannot decide/neutral ④ agree ⑤ strongly agree

Statement	
I think the canteen is easier to use than the bladder with tube.	①②③④⑤
It is always easy to get a drink from the canteen.	①②③④⑤
The water gets hotter in the canteen than in the bladder.	①②③④⑤
Canteens are uncomfortable or awkward to carry.	①②③④⑤
My duties are interrupted when I stop to drink from the canteen.	①②③④⑤
Canteens are easier to refill than bladders.	①②③④⑤
I can easily keep my thirst at bay by frequently using the canteen.	①②③④⑤
Other items I carry prevent me from getting out my canteen to drink.	①②③④⑤
The cap is hard to manage when participating in operations.	①②③④⑤
I think it is hard to keep the inside of the canteen clean.	①②③④⑤

2) If you have any comments about the canteen, additional information, or improvements that could be made to the canteen, please give details below.

Comments

____

____

____

____

Experimental issue 'Water bladder'

3) This section contains a list of statements. Read each one carefully and shade the circle which best represents your opinion, making sure your answer is in the correct space.

① strongly disagree ② disagree ③ cannot decide/neutral ④ agree ⑤ strongly agree

Statement	
I think the bladder with tube is easier to use than the canteen.	①②③④⑤
It is always easy to get a drink from the bladder.	①②③④⑤
The water gets hotter in the bladder than in the canteen.	①②③④⑤
Bladders are uncomfortable or awkward to carry.	①②③④⑤
My duties are interrupted when I stop to drink from the bladder.	①②③④⑤
Bladders are easier to refill than canteens.	①②③④⑤
I easily keep my thirst at bay by frequently using the bladder.	①②③④⑤
Other items I carry prevent me from getting a drink from the bladder.	①②③④⑤
The tube is hard to manage when participating in operations.	①②③④⑤
I think it would be hard to keep the bladder and tube clean.	①②③④⑤

4) If you have any comments about the bladder, additional information, or improvements that could be made to the bladder, please give details below.

Comments

____

____

____

____

5) Please indicate which you preferred to use, the bladder or the canteen, by placing a tick in the appropriate box.

❑ CANTEEN ❑ BLADDER

Please indicate the strength of your preference (shade one circle)

① very strong preference ② strong preference ③ cannot decide, or are neutral

6) Please indicate what features you based your decision on.

____

____

Thank you for taking the time to complete this questionnaire. Your cooperation is invaluable in helping us to decide on the system for water carriage for the soldier of the future.

Appendix 2: Results of Questionnaire Survey of Service Suitability of Water Canteen versus Bladder/Tube

The following table shows the frequency with which subjects agreed and the strength of agreement for the statements in Q.1 and Q.3 of the questionnaire shown in Appendix 1. A frequency of '10' indicates universal agreement by the section. Strength of agreement is from '5' (agree strongly) to '1' (disagree strongly).

	Frequency and Strength of Response				
Statement	**5**	**4**	**3**	**2**	**1**
I think the canteen is easier to use than the bladder with tube	10	-	-	-	-
It is always easy to get a drink from the canteen	2	2	1	2	3
The water gets hotter in the canteen than in the bladder	-	3	2	3	2
Canteens are uncomfortable or awkward to carry	1	3	3	2	1
My duties are interrupted when I stop to drink from the canteen	2	4	4	-	-
Canteens are easier to refill than bladders	2	5	2	2	-
I can easily keep my thirst at bay by frequently using the canteen	-	1	5	3	1
Other items I carry prevent me from getting my canteen to drink	5	3	2	-	-
The canteen cap is hard to manage when participating in operations	3	6	1	-	-
I think it is hard to keep the inside of the canteen clean					
I think the bladder with tube is easier to use than the canteen	10	-	-	-	-
It is always easy to get a drink from the bladder	10	-	-	-	-
The water gets hotter in the bladder than in the canteen	-	3	4	2	1
Bladders are uncomfortable or awkward to carry	1	2	4	1	2
My duties are interrupted when I stop to drink from the bladder	8	2	-	-	-
Bladders are easier to refill than canteens	-	3	5	1	1
I easily keep my thirst at bay by frequently using the bladder	8	2	-	-	-
Other items I carry prevent me getting a drink from the bladder	-	-	3	5	2
The tube is hard to manage when participating in operations	-	-	-	3	7
I think it would be hard to keep the bladder and tube clean	-	-	3	5	2

Appendix 3: Raw Data for HF1-HF-4

HF1, HRTA, 6 FEB 98, RAW DATA

PRE-PATROL (NOTE: SUBJECT # 3 WAS WITHDRAWN DUE TO HEAT STRESS)

NO	UNIFORM	WATER DELIVERY (Canteen or Sport Tank)	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER WEIGHT (KG)	BREAK-FAST EATEN (KG)	INITIAL WATER (L)	WATER DRUNK PRE-PATROL (L)
S1	DPCU	C	78.60	81.95	99.10	0.00	4.20	0.45
S2	DPCU	C	73.10	76.30	97.80	0.00	4.10	0.50
S4	DPCU	ST	75.50	79.05	103.95	0.00	4.25	1.00
S5	DPCU	ST	84.90	88.75	108.05	0.00	4.30	3.00
S6	CBCS	C	77.85	81.80	112.75	0.00	4.30	0.85
S7	CBCS	C	69.30	73.45	95.10	0.00	3.85	0.00
S8	CBA	C	68.10	73.50	92.55	0.00	4.20	0.95
S9	CBA	C	89.80	96.05	116.55	0.00	4.10	0.95
S10	CBA	C	71.55	77.20	93.10	0.00	4.35	0.00
MEAN			76.52	80.89	102.11	0.00	4.18	0.86
SD			7.19	7.43	8.73	0.00	0.15	0.89

MID EXPERIMENT (First phase - slow patrol - finished 4.27 hours after commencement)

NO	MAG (INITIAL) (KG)	URINE PRE-PATROL (L)	WEIGHT BEFORE RESUP (KG)	WEIGHT POST RESUP (KG)	WATER PRE-RESUP (KG)	WATER POST RESUP (KG)	WATER INTAKE TO OP (KG)	URINE PROD TO OP (KG)
S1	1.80	0.07	94.85	96.90	2.35	4.25	1.85	0.22
S2	1.80	0.04	93.80	97.15	0.45	4.35	3.65	0.14
S4	1.75	0.03	99.85	102.65	1.80	4.50	2.45	0.09
S5	1.80	0.04	102.05	104.70	2.00	4.15	2.30	0.66
S6	3.25	0.00	108.15	111.00	1.35	4.30	2.95	0.14
S7	2.10	0.12	91.45	95.00	0.75	4.30	3.10	0.17
S8	1.80	0.11	88.95	96.20	1.90	3.85	2.30	0.00
S9	1.80	0.07	109.25	113.00	0.45	4.25	3.65	0.12
S10	1.90	0.08	89.75	91.25	2.75	4.25	1.60	0.07
MEAN	2.00	0.06	97.57	100.87	1.53	4.24	2.65	0.18
SD	0.48	0.04	7.65	7.47	0.83	0.18	0.73	0.19

POST PATROL (Second phase consisted of 57 min of rest and 37 min of patrol/assault)

NO	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER WEIGHT (KG)	FINAL WATER (KG)	WATER INTAKE FROM OP (KG)	MAG FINAL (KG)	POST PATROL URINE (KG)	TOTAL WATER DRUNK (KG)	TOTAL SWEAT PROD (KG)	TOTAL URINE PROD (KG)
S1	76.20	80.50	94.75	2.55	1.70	1.30	0.04	3.55	5.62	0.33
S2	72.25	76.10	95.00	2.95	1.40	0.95	NA#	5.05	5.72	0.18
S4	74.05	78.15	100.85	2.80	1.70	1.75	0.19	4.15	5.29	0.31
S5	83.50	88.30	102.10	2.45	1.70	1.05	0.08	4.00	4.62	0.78
S6	74.85	79.80	105.15	3.55	0.75	1.70	0.02	3.70	6.54	0.16
S7	67.65	73.05	93.75	3.20	1.10	1.00	0.08	4.20	5.48	0.37
S8	66.35	72.05	92.90	2.40	1.45	4.25	0.07	3.75	5.32	0.18
S9	85.00	92.00	110.30	2.70	1.55	1.10	0.02	5.20	9.79	0.21
S10	69.35	75.70	88.15	4.25	0.00	0.95	0.05	1.60	3.60	0.20
MEAN	74.36	79.52	98.11	2.98	1.26	1.56	0.07	3.91	5.78	0.30
SD	6.51	6.71	6.96	0.60	0.57	1.05	0.05	1.04	1.71	0.19

Appendix 3 continued: Raw data for HF1-HF4

HF2, HRTA, 7 FEB 98, RAW DATA

PRE-PATROL

NO	UNIFORM	WATER DELIVERY (Canteen or Sport Tank)	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER WEIGHT (KG)	BREAK-FAST EATEN (KG)	INITIAL WATER (L)	WATER DRUNK PRE-PAT (L)	MAG (INITIAL) (KG)	URINE PRE-PATROL (L)#
S1	CBA	C	78.00	83.90	100.90	0.41	4.30	0.50	1.80	NA
S2	CBA	C	73.30	80.80	101.15	0.41	4.30	0.85	2.40	NA
S4	CBA	C	75.75	81.80	105.80	0.41	4.30	0.50	2.35	NA
S5	DPCU	C	83.85	87.75	106.00	0.41	4.30	3.00	2.25	NA
S6	DPCU	ST	76.30	79.30	106.45	0.41	4.30	0.50	7.30	NA
S7	DPCU	ST	68.30	71.30	91.20	0.35	4.30	0.50	2.45	NA
S8	CBCS	C	66.95	71.30	87.75	0.38	4.30	0.50	2.50	NA
S9	CBCS	C	87.15	92.05	113.55	0.41	4.30	0.50	2.25	NA
S10	CBCS	C	70.70	75.00	90.55	0.47	4.30	0.50	2.05	NA
MEAN			75.59	80.36	100.37	0.41	4.30	0.82	2.82	NA
SD			6.76	7.07	8.75	0.03	0.00	0.83	1.70	NA

Pre-patrol urine samples not collected

MID EXPERIMENT (First phase - slow patrol - finished 3.42 hours after commencement)

NO	WEIGHT BEFORE RESUP (KG)	WEIGHT POST RESUP (KG)	WATER PRE-RESUP (L)	WATER POST RESUP (L)	WATER INTAKE TO OP (L)	URINE PROD TO OP (L)
S1	98.85	101.20	1.95	4.30	2.35	0.08
S2	98.25	100.85	1.70	4.30	2.60	0.10
S4	103.65	106.65	1.30	4.30	3.00	0.22
S5	103.95	106.85	1.40	4.30	2.90	0.60
S6	104.20	106.83	1.95	4.58	2.35	0.07
S7	91.90	94.10	2.35	4.55	1.95	0.09
S8	85.90	87.50	2.70	4.30	1.60	0.16
S9	110.30	111.70	2.90	4.30	1.40	0.00
S10	89.45	91.30	2.45	4.30	1.85	0.13
MEAN	98.49	100.78	2.08	4.36	2.22	0.16
SD	8.00	8.20	0.56	0.12	0.56	0.18

POST PATROL (Second phase consisted of 1.08 hour of rest and .55 hour of patrol/assault)

NO	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER WEIGHT (KG)	FINAL WATER (L)	WATER INTAKE FROM OP (L)	MAG FINAL (KG)	POST PATROL URINE (L)	TOTAL WATER DRUNK (L)	TOTAL SWEAT PROD (L)#	TOTAL URINE PROD (L)#
S1	76.45	84.00	99.15	2.90	1.40	1.75	0.05	3.75	5.58	0.13
S2	71.95	78.65	98.85	3.90	0.40	1.60	0.04	3.00	4.62	0.14
S4	74.50	81.60	105.35	3.20	1.10	2.35	0.09	4.10	5.45	0.31
S5	85.35	90.25	104.60	2.35	1.95	1.15	0.36	4.85	2.80	0.96
S6	74.75	78.50	103.20	3.75	0.83	5.30	0.05	3.18	5.02	0.12
S7	67.45	71.20	89.35	3.30	1.25	2.00	0.18	3.20	4.13	0.27
S8	65.80	71.35	86.00	3.40	0.90	2.05	0.05	2.50	3.82	0.21
S9	83.45	90.05	109.40	2.80	1.50	1.65	0.13	2.90	6.88	0.13
S10	69.80	75.00	89.55	3.60	0.70	1.20	0.11	2.55	3.68	0.24
MEAN	74.39	80.07	98.38	3.24	1.11	2.12	0.12	3.34	4.66	0.28
SD	6.67	7.12	8.26	0.49	0.47	1.25	0.10	0.77	1.22	0.26

Appendix 3 continued: Raw data for HF1-HF4

HF # 3, 8 FEB 98, RAW DATA

PRE-PATROL

NO	UNIFORM	WATER DELIVERY (Canteen or Sport Tank)	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER (KG)	BREAK-FAST EATEN (KG)	INITIAL WATER (L)	WATER DRUNK PRE-PATROL (L)	MAG (INITIAL) (KG)	URINE PRE-PATROL (L)
1	CBCS	C	79.05	83.40	100.45	0.27	4.30	0.55	1.80	0.41
2	CBCS	C	73.65	78.25	99.45	0.27	4.30	0.80	2.40	0.23
3	CBA	C	69.60	73.95	97.80	0.27	4.30	0.30	5.50	0.00
4	DPCU	C	76.15	79.55	104.05	0.27	4.30	0.00	2.30	0.00
5	CBA	C	85.30	92.10	109.50	0.27	4.30	3.00	2.25	0.69
6	DPCU	ST	76.40	79.60	106.75	0.27	4.30	0.00	7.20	0.00
7	DPCU	C	67.85	71.20	90.55	0.27	4.30	0.50	2.50	0.36
8	DPCU	ST	67.35	70.55	86.90	0.27	4.80	0.55	2.50	0.15
9	DPCU	ST	87.20	90.90	112.85	0.27	4.35	0.35	2.25	0.12
10	DPCU	ST	70.85	74.10	89.50	0.27	4.45	0.00	2.10	0.00
MEAN			75.34	79.36	99.78	0.27	4.37	0.61	3.08	0.20
SD			6.92	7.56	8.78	0.00	0.16	0.88	1.78	0.23

HF# 3 MID EXPERIMENT (First phase - slow patrol - finished 3.20 hours after commencement of patrol)

NO	WEIGHT BEFORE RESUP (KG)	WEIGHT POST RESUP (KG)	WATER PRE-RESUP (L)	WATER POST RESUP (L)	WATER INTAKE TO OP (L)	URINE PROD TO OP (L)
1	98.55	100.50	2.35	4.30	1.95	0.00
2	98.00	99.85	2.45	4.30	1.85	0.00
3	95.95	97.95	2.30	4.30	2.00	0.21
4	102.50	103.50	3.30	4.30	1.00	0.24
5	107.35	111.05	0.60	4.30	3.70	0.26
6	104.30	106.80	2.10	4.60	2.20	0.12
7	88.55	90.15	2.70	4.30	1.60	0.08
8	85.05	86.40	3.35	4.70	1.45	0.07
9	109.15	111.00	2.75	4.60	1.60	0.06
10	88.80	89.70	3.15	4.05	1.30	0.11
MEAN	97.82	99.69	2.51	4.38	1.87	0.11
SD	8.28	8.78	0.80	0.20	0.74	0.09

POST PATROL (Second phase consisted of 1.0 hr of rest and 0.5 hr of patrol/assault)

NO	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER (KG)	FINAL WATER (KG)	WATER INTAKE FROM OP (KG)	MAG FINAL (KG)	POST PATROL URINE (L)	TOTAL WATER DRUNK (L)	TOTAL SWEAT PROD (L)	TOTAL URINE PROD (L)
1	78.00	83.60	98.90	2.70	1.60	1.75	0.15	3.55	4.31	0.56
2	72.95	78.75	98.05	2.95	1.35	1.75	0.05	3.20	3.89	0.28
3	67.35	73.65	94.20	3.25	1.05	1.95	0.02	3.05	5.35	0.23
4	74.80	78.65	103.25	3.10	1.20	2.30	0.09	2.20	3.49	0.33
5	85.90	93.60	108.00	1.55	2.75	1.50	0.37	6.45	4.81	1.31
6	75.00	78.90	103.35	3.50	1.10	5.10	0.06	3.30	4.79	0.18
7	66.30	70.50	88.70	3.50	0.80	1.85	0.03	2.40	3.75	0.47
8	67.05	70.80	84.85	2.90	1.80	1.95	0.04	3.25	3.56	0.26
9	84.80	90.60	109.15	2.85	1.75	2.00	0.03	3.35	5.82	0.21
10	70.80	74.75	88.60	1.65	2.40	1.00	0.13	3.70	3.78	0.24

Appendix 3 continued: Raw data for HF1-HF4

HF4, 9 FEB 98 - RAW DATA

PRE-PATROL

NO	UNIFORM	WATER DELIVERY (Canteen or Sport Tank)	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER (KG)	BREAK-FAST EATEN (KG)	INITIAL WATER (L)	WATER DRUNK PRE-PATROL (L)	MAG (INITIAL) (KG)	URINE PRE-PATROL (L)
S1	DPCU	ST	79.00	82.05	98.50	0.50	4.30	0.60	1.75	0.00
S2	DPCU	ST	73.30	76.65	97.55	0.50	4.25	0.80	2.00	0.00
S3	DPCU	ST	68.85	72.15	93.30	0.50	4.80	0.00	5.05	0.00
S4	CBCS	C	75.10	79.55	103.60	0.50	4.30	0.00	1.75	0.00
S5	CBCS	C	85.50	90.25	106.55	0.50	4.30	3.00	1.80	0.37
S6	CBA	C	76.30	81.35	106.20	0.50	4.30	0.00	5.00	0.00
S7	CBA	C	66.85	72.55	91.60	0.50	4.30	0.40	2.05	0.00
S8	DPCU	C	67.35	70.30	86.05	0.50	4.30	0.60	2.10	0.00
S9	DPCU	C	86.60	90.35	111.10	0.50	4.30	0.55	2.05	0.00
S10	DPCU	C	71.30	74.35	89.95	0.50	4.30	0.75	1.85	0.00
MEAN			75.02	78.96	98.44	0.50	4.35	0.67	2.54	0.04
SD			7.01	7.16	8.25	0.00	0.16	0.88	1.32	0.12

MID EXPERIMENT (First phase - slow patrol - finished 3.33 hours after commencement of patrol)

NO	WEIGHT BEFORE RESUP	WEIGHT POST RESUP	WATER PRE-RESUP	WATER POST RESUP	WATER INTAKE TO OP	URINE PROD TO OP
S1	96.70	98.15	2.95	4.40	1.35	0.18
S2	95.90	98.20	2.00	4.30	2.25	0.36
S3	94.10	96.00	2.75	4.65	2.05	0.12
S4	101.70	103.85	2.15	4.30	2.15	0.19
S5	104.05	106.55	1.80	4.30	2.50	0.64
S6	103.80	107.00	1.10	4.30	3.20	0.12
S7	89.70	92.05	1.95	4.30	2.35	0.10
S8	84.75	85.85	3.20	4.30	1.10	0.18
S9	108.55	110.65	2.20	4.30	2.10	0.15
S10	89.05	90.25	3.10	4.30	1.20	0.12
MEAN	96.83	98.86	2.32	4.35	2.03	0.22
SD	7.66	8.08	0.67	0.11	0.65	0.17

POST PATROL (Second phase consisted of 0.73 hr of rest and 0.80 hr of patrol/assault)

NO	NUDE WEIGHT (KG)	CLOTHED WEIGHT (KG)	PATROL ORDER (KG)	FINAL WATER (L)	WATER INTAKE FROM OP (L)	MAG FINAL (KG)	POST PATROL URINE (L)	TOTAL WATER DRUNK (L)	TOTAL SWEAT PROD (L)	TOTAL URINE PROD (L)
S1	77.35	81.55	96.90	3.45	0.95	1.40	0.15	2.30	4.12	0.33
S2	73.45	77.35	94.80	1.55	2.75	1.25	0.06	5.00	4.93	0.42
S3	67.10	70.95	92.05	3.10	1.55	2.55	0.05	3.60	5.68	0.17
S4	74.00	78.95	102.45	3.40	0.90	1.75	0.05	3.05	4.41	0.24
S5	84.05	90.35	104.30	2.40	1.90	1.25	0.42	4.40	4.92	1.43
S6	74.95	80.90	102.90	3.80	0.50	2.55	0.06	3.70	5.37	0.18
S7	65.45	72.60	90.15	3.40	0.90	1.40	0.04	3.25	5.01	0.14
S8	66.80	70.35	84.60	3.00	1.30	1.80	0.06	3.40	4.21	0.24
S9	83.60	88.30	108.40	3.80	0.50	1.70	0.06	1.70	4.99	0.21
S10	70.65	74.25	88.25	3.50	0.80	0.85	0.22	2.87	3.68	0.34
MEAN	73.74	78.56	96.48	3.14	1.21	1.65	0.12	3.33	4.73	0.37
SD	6.57	6.91	7.83	0.69	0.70	0.55	0.12	0.95	0.61	0.38

Appendix 4: Hydration Summaries for HF1-HF4

HF1, HRTA, 6 FEB 98 : SUMMARY OF WATER INTAKE, URINE PRODUCTION AND SWEAT RATES

NO	UNIFORM	WATER DELIVERY (Canteen or Sport Tank)	WATER INTAKE TO OP (L)	RATE OF INTAKE TO OP (L/HR)	INTAKE FROM OP (L)	RATE OF INTAKE FROM OP (L/HR)	TOTAL WATER INTAKE (L)	RATE OF TOTAL INTAKE (L/HR)
S1	DPCU	C	1.85	0.43	1.70	1.08	3.55	0.61
S2	DPCU	C	3.65	0.85	1.40	0.89	5.05	0.86
S4	DPCU	ST	2.45	0.57	1.70	1.08	4.15	0.71
S5	DPCU	ST	2.30	0.54	1.70	1.08	4.00	0.68
S6	CBCS	C	2.95	0.69	0.75	0.48	3.70	0.63
S7	CBCS	C	3.10	0.73	1.10	0.70	4.20	0.72
S8	CBA	C	2.30	0.54	1.45	0.92	3.75	0.64
S9	CBA	C	3.65	0.85	1.55	0.99	5.20	0.89
S10	CBA	C	1.60	0.37	0.00	0.00	1.60	0.27
MEAN			2.65	0.62	1.26	0.80	3.91	0.67
SD			0.73	0.17	0.57	0.36	1.04	0.18

NO	TOTAL WEIGHT LOSS (KG)	RATE OF WEIGHT LOSS (KG/HR)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	TOTAL SWEAT PROD (L)	TOTAL SWEAT RATE (L/HR)	NON-EVAP SWEAT (L)	NON-EVAP SWEAT RATE (L/HR)	EVAP SWEAT (L)	EVAP SWEAT RATE (L/HR)
S1	2.40	0.41	0.33	0.06	5.62	0.96	0.95	0.16	4.67	0.80
S2	0.85	0.15	0.18	0.03	5.72	0.98	0.65	0.11	5.07	0.87
S4	1.45	0.25	0.31	0.05	5.29	0.91	0.55	0.09	4.74	0.81
S5	1.40	0.24	0.78	0.13	4.62	0.79	0.95	0.16	3.67	0.63
S6	3.00	0.51	0.16	0.03	6.54	1.12	1.00	0.17	5.54	0.95
S7	1.65	0.28	0.37	0.06	5.48	0.94	1.25	0.21	4.23	0.72
S8	1.75	0.30	0.18	0.03	5.32	0.91	0.30	0.05	5.02	0.86
S9	4.80	0.82	0.21	0.04	9.79	1.68	0.75	0.13	9.04	1.55
S10	2.20	0.38	0.20	0.03	3.60	0.62	0.70	0.12	2.90	0.50
MEA	2.17	0.37	0.30	0.05	5.78	0.99	0.79	0.14	4.99	0.85
SD	1.17	0.20	0.19	0.03	1.71	0.29	0.28	0.05	1.72	0.29

TIME OF INITIAL PATROL (TO OP)	4.27
TIME SPENT AT REST AT OP	0.95
TIME FOR PATROL/ASSAULT (FROM OP TO FINISH)	0.62

Appendix 4 continued: Hydration summaries for HF1-HF4

HF2, HRTA, 7 FEB 98 : SUMMARY OF WATER INTAKE, URINE PRODUCTION AND SWEAT RATES

NO	UNIFORM	DELIVERY (Canteen or Sport Tank)	WATER INTAKE TO OP (L)	RATE OF INTAKE TO OP (L/HR)	WATER INTAKE FROM OP (L)	RATE OF INTAKE FROM OP (L/HR)	TOTAL WATER INTAKE (L)	RATE OF TOTAL INTAKE (L/HR)
S1	CBA	C	2.35	0.69	1.40	0.86	3.75	0.74
S2	CBA	C	2.60	0.76	0.40	0.25	3.00	0.59
S4	CBA	C	3.00	0.88	1.10	0.67	4.10	0.81
S5	DPCU	C	2.90	0.85	1.95	1.20	4.85	0.96
S6	DPCU	ST	2.35	0.69	0.83	0.51	3.18	0.63
S7	DPCU	ST	1.95	0.57	1.25	0.77	3.20	0.63
S8	CBCS	C	1.60	0.47	0.90	0.55	2.50	0.50
S9	CBCS	C	1.40	0.41	1.50	0.92	2.90	0.57
S10	CBCS	C	1.85	0.54	0.70	0.43	2.55	0.50
MEAN			2.22	0.65	1.11	0.68	3.34	0.66
SD			0.56	0.16	0.47	0.29	0.77	0.15

NO	TOTAL WEIGHT LOSS (KG)	RATE OF WEIGHT LOSS (KG/HR)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	TOTAL SWEAT PROD (L)	TOTAL SWEAT RATE (L/HR)	TOTAL NON-EVAP SWEAT (L)	NON-EVAP SWEAT RATE (L/HR)	TOTAL EVAP SWEAT (L)	EVAP SWEAT RATE (L/HR)
S1	1.55	0.31	0.13	0.03	5.58	1.10	1.65	0.33	3.93	0.78
S2#	1.35	0.27	0.14	0.03	4.62	0.91	1.13	0.22	3.49	0.69
S4	1.25	0.25	0.31	0.06	5.45	1.08	1.05	0.21	4.40	0.87
S5	-1.50	-0.30	0.96	0.19	2.80	0.55	1.00	0.20	1.80	0.36
S6	1.55	0.31	0.12	0.02	5.02	0.99	0.75	0.15	4.27	0.85
S7	0.85	0.17	0.27	0.05	4.13	0.82	0.75	0.15	3.38	0.67
S8	1.15	0.23	0.21	0.04	3.82	0.76	1.20	0.24	2.62	0.52
S9	3.70	0.73	0.13	0.03	6.88	1.36	1.70	0.34	5.18	1.03
S10	0.90	0.18	0.24	0.05	3.68	0.73	0.90	0.18	2.78	0.55
MEA	1.20	0.24	0.28	0.06	4.66	0.92	1.13	0.22	3.54	0.70
SD	1.32	0.26	0.26	0.05	1.22	0.24	0.35	0.07	1.04	0.21

NOTE: An anomalous result was obtained for non-evaporative sweat (negative value) for subject 2. The result reported is the mean for the other 8 subjects.

TIME OF INITIAL PATROL (TO OP)	3.42
TIME SPENT AT REST AT OP	1.08

Appendix 4 continued: Hydration summaries for HF1-HF4

HF3, HRTA, 8 FEB 98: SUMMARY OF WATER INTAKE, URINE PRODUCTION AND SWEAT RATES

NO	UNIFORM	WATER DELIVERY (Canteen or Sport Tank)	WATER INTAKE TO OP (L)	RATE OF INTAKE TO OP (L/HR)	WATER INTAKE FROM OP (L)	RATE OF INTAKE FROM OP (L/HR)	TOTAL WATER INTAKE (L)	RATE OF TOTAL INTAKE (L/HR)
S1	CBCS	C	1.95	0.61	1.60	1.07	3.55	0.76
S2	CBCS	C	1.85	0.58	1.35	0.90	3.20	0.68
S3	CBA	C	2.00	0.63	1.05	0.70	3.05	0.65
S4	DPCU	C	1.00	0.31	1.20	0.80	2.20	0.47
S5	CBA	C	3.70	1.16	2.75	1.83	6.45	1.37
S6	DPCU	ST	2.20	0.69	1.10	0.73	3.30	0.70
S7	DPCU	C	1.60	0.50	0.80	0.53	2.40	0.51
S8	DPCU	ST	1.45	0.45	1.80	1.20	3.25	0.69
S9	DPCU	ST	1.60	0.50	1.75	1.17	3.35	0.71
S10	DPCU	ST	1.30	0.41	2.40	1.60	3.70	0.79
MEAN			1.87	0.58	1.58	1.05	3.45	0.73
SD			0.74	0.23	0.62	0.41	1.16	0.25

NO	TOTAL WEIGHT LOSS (KG)	RATE OF WEIGHT LOSS (KG/HR)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	TOTAL SWEAT PROD (L)	TOTAL SWEAT RATE (L/HR)	NON-EVAP SWEAT (L)	NON-EVAP SWEAT RATE (L/HR)	EVAP SWEAT (L)	EVAP SWEAT RATE (L/HR)
S1	1.05	0.22	0.56	0.12	4.31	0.92	1.25	0.27	3.06	0.65
S2	0.70	0.15	0.28	0.06	3.89	0.83	1.20	0.26	2.69	0.57
S3	2.25	0.48	0.23	0.05	5.35	1.14	1.95	0.41	3.40	0.72
S4	1.35	0.29	0.33	0.07	3.49	0.74	0.45	0.10	3.04	0.65
S5	-0.60	-0.13	1.31	0.28	4.81	1.02	0.90	0.19	3.91	0.83
S6	1.40	0.30	0.18	0.04	4.79	1.02	0.70	0.15	4.09	0.87
S7	1.55	0.33	0.47	0.10	3.75	0.80	0.85	0.18	2.90	0.62
S8	0.30	0.06	0.26	0.05	3.56	0.76	0.55	0.12	3.01	0.64
S9	2.40	0.51	0.21	0.04	5.82	1.24	2.10	0.45	3.72	0.79
S10	0.05	0.01	0.24	0.05	3.78	0.80	0.70	0.15	3.08	0.66
MEA	1.05	0.22	0.40	0.09	4.36	0.93	1.07	0.23	3.29	0.70
SD	0.95	0.20	0.34	0.07	0.80	0.17	0.57	0.12	0.47	0.10

TIME OF INITIAL PATROL (TO OP)	3.2	hr
TIME SPENT AT REST AT OP	1.0	hr
TIME FOR PATROL/ASSAULT (FROM OP TO FINISH)	0.5	hr

Appendix 4 continued: Hydration summaries for HF1-HF4

HF4, 9 FEB 98: SUMMARY OF WATER INTAKE AND SWEAT RATES

NO	UNIFORM	WATER DELIVERY (Canteen or Sport Tank)	WATER INTAKE TO OP (L)	RATE OF INTAKE TO OP (L/HR)	WATER INTAKE FROM OP (L)	RATE OF INTAKE FROM OP (L/HR)	TOTAL WATER INTAKE (L)	RATE OF TOTAL INTAKE (L/HR)
S1	DPCU	ST	1.35	0.41	0.95	1.30	2.30	0.47
S2	DPCU	ST	2.25	0.68	2.75	3.77	5.00	1.03
S3	DPCU	ST	2.05	0.62	1.55	2.12	3.60	0.74
S4	CBCS	C	2.15	0.65	0.90	1.23	3.05	0.63
S5	CBCS	C	2.50	0.75	1.90	2.60	4.40	0.91
S6	CBA	C	3.20	0.96	0.50	0.68	3.70	0.76
S7	CBA	C	2.35	0.71	0.90	1.23	3.25	0.67
S8	DPCU	C	1.10	0.33	1.30	1.78	3.40	0.70
S9	DPCU	C	2.10	0.63	0.50	0.68	1.70	0.35
S10	DPCU	C	1.20	0.36	0.80	1.10	2.87	0.59
MEAN			2.03	0.61	1.21	1.65	3.33	0.68
SD			0.65	0.19	0.70	0.96	0.95	0.20

NO	TOTAL WEIGHT LOSS (KG)	RATE OF WEIGHT LOSS (KG/HR)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	TOTAL SWEAT PROD (L)	TOTAL SWEAT RATE (L/HR)	NON-EVAP SWEAT PROD (L)	NON-EVAP SWEAT RATE (L/HR)	EVAP SWEAT (L)	EVAP SWEAT RATE (L/HR)
S1	1.65	0.34	0.33	0.07	4.12	0.85	1.15	0.24	3.57	0.73
S2	-0.15	-0.03	0.42	0.09	4.93	1.01	0.55	0.11	4.38	0.90
S3	1.75	0.36	0.17	0.03	5.68	1.17	0.55	0.11	5.18	1.07
S4	1.10	0.23	0.24	0.05	4.41	0.91	0.50	0.10	2.86	0.59
S5	1.45	0.30	1.43	0.29	4.92	1.01	1.55	0.32	4.02	0.83
S6	1.35	0.28	0.18	0.04	5.37	1.10	0.90	0.19	3.92	0.81
S7	1.40	0.29	0.14	0.03	5.01	1.03	1.45	0.30	4.41	0.91
S8	0.55	0.11	0.24	0.05	4.21	0.87	0.60	0.12	3.26	0.67
S9	3.00	0.62	0.21	0.04	4.99	1.03	0.95	0.20	4.44	0.91
S10	0.65	0.13	0.34	0.07	3.68	0.76	0.55	0.11	2.80	0.58
MEAN	1.28	0.26	0.37	0.08	4.73	0.97	0.87	0.18	3.88	0.80
SD	0.84	0.17	0.38	0.08	0.61	0.13	0.39	0.08	0.76	0.16

TIME OF INITIAL PATROL (TO OP)	3.33	hr
TIME SPENT AT REST AT OP	0.73	hr
TIME FOR PATROL/ASSAULT (FROM OP TO FINISH)	0.80	hr

Appendix 5: Hydration Effects of Using Water Bottle versus SportTank

1. WATER BOTTLE PLUS DPCU

NO	CHANGE IN WEIGHT (KG)	RATE OF WEIGHT CHANGE (KG/HR)	TOTAL WATER INTAKE (L)	RATE OF WATER INTAKE (L/HR)	TOTAL SWEAT PROD (L)	SWEAT RATE (L/HR)	EVAP SWEAT RATE (L/Hr)	NON-EVAP SWEAT RATE (L/Hr)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	FINAL URINE SODIUM (mmol/L)	FINAL URINE SG
S1	2.40	0.41	3.55	0.61	5.62	0.96	0.80	0.16	0.33	0.06	82	1.028
S2	0.85	0.15	5.05	0.86	5.72	0.98	0.87	0.11	0.18	0.03	15	1.026
S4	1.35	0.29	2.20	0.47	3.49	0.74	0.65	0.10	0.33	0.07	131	1.021
S5	-1.50	-0.30	4.85	0.96	2.80	0.55	0.36	0.20	0.96	0.19	0	1.004
S7	1.55	0.33	2.40	0.51	3.75	0.80	0.62	0.18	0.47	0.10	0	1.029
S8	0.55	0.12	3.40	0.70	4.21	0.87	0.67	0.12	0.24	0.05	51	1.027
S9	3.00	0.63	1.70	0.35	4.99	1.03	0.91	0.20	0.21	0.04	0	1.027
S10	0.65	0.14	2.87	0.59	3.68	0.76	0.58	0.11	0.34	0.07	32	1.020
MEAN	1.11	0.22	3.25	0.63	4.28	0.84	0.681	0.148	0.38	0.08	38.88	1.023
SD	1.36	0.27	1.21	0.20	1.06	0.16	0.179	0.041	0.25	0.05	47.28	0.008

2. SPORT TANK PLUS DPCU

NO	CHANGE IN WEIGHT (KG)	RATE OF WEIGHT CHANGE (KG/HR)	TOTAL WATER INTAKE (L)	RATE OF WATER INTAKE (L/HR)	TOTAL SWEAT PROD (L)	SWEAT RATE (L/HR)	EVAP SWEAT RATE (L/Hr)	NON-EVAP SWEAT RATE (L/Hr)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	FINAL URINE SODIUM (mmol/L)	FINAL URINE SG
S1	1.65	0.35	2.30	0.47	4.12	0.85	0.73	0.24	0.33	0.07	77	1.021
S2	-0.15	-0.03	5.00	1.03	4.93	1.01	0.90	0.11	0.42	0.09	0	1.022
S4	1.45	0.25	4.15	0.71	5.29	0.91	0.81	0.09	0.31	0.05	15	1.026
S5	1.40	0.24	4.00	0.68	4.62	0.79	0.63	0.16	0.78	0.13	62	1.018
S7	0.85	0.17	3.20	0.63	4.13	0.82	0.67	0.15	0.27	0.05	33	1.024
S8	0.30	0.06	3.25	0.69	3.56	0.76	0.64	0.12	0.26	0.05	43	1.025
S9	2.40	0.51	3.35	0.71	5.82	1.24	0.79	0.45	0.21	0.04	13	1.027
S10	0.05	0.01	3.70	0.79	3.78	0.80	0.66	0.15	0.24	0.05	0	1.017
MEAN	0.99	0.19	3.62	0.72	4.53	0.90	0.729	0.183	0.35	0.07	30.38	1.023
SD	0.88	0.18	0.80	0.16	0.78	0.16	0.098	0.115	0.19	0.03	28.60	0.004

DIFFERENCE BETWEEN SPORTTANK AND WATER BOTTLE (+ RESULT IMPLIES SPORTTANK LED TO THE HIGHER RESULT)

NO	CHANGE IN WEIGHT (KG)	RATE OF WEIGHT CHANGE (KG/HR)	TOTAL WATER INTAKE (L)	RATE OF WATER INTAKE (L/HR)	TOTAL SWEAT PROD (L)	SWEAT RATE (L/HR)	EVAP SWEAT RATE (L/Hr)	NON-EVAP SWEAT RATE (L/Hr)	TOTAL URINE PROD (L)	RATE OF URINE PROD (L/HR)	FINAL URINE SODIUM (mmol/L)	URINE SG
S1	-0.75	-0.06	-1.25	-0.13	-1.50	-0.11	-0.065	0.074	0.00	0.01	-5.00	-0.007
S2	-1.00	-0.18	-0.05	0.16	-0.79	0.03	0.033	0.002	0.24	0.06	-15.00	-0.004
S4	0.10	-0.04	1.95	0.24	1.80	0.16	0.165	-0.002	-0.02	-0.02	-116.00	0.005
S5	2.90	0.54	-0.85	-0.28	1.82	0.24	0.272	-0.035	-0.18	-0.06	62.00	0.014
S7	-0.70	-0.16	0.80	0.12	0.38	0.02	0.051	-0.032	-0.20	-0.05	33.00	-0.005
S8	-0.25	-0.05	-0.15	-0.01	-0.65	-0.11	-0.030	-0.006	0.02	0.01	-8.00	-0.002
S9	-0.60	-0.12	1.65	0.36	0.83	0.21	-0.123	0.251	-0.01	0.00	13.00	0.000
S10	-0.60	-0.13	0.83	0.20	0.10	0.05	0.079	0.036	-0.10	-0.02	-32.00	-0.003
MEAN	-0.11	-0.03	0.37	0.08	0.25	0.06	0.048	0.036	-0.03	-0.01	-8.50	0.000
SD	1.26	0.23	1.14	0.21	1.21	0.13	0.127	0.094	0.14	0.04	52.53	0.007
Prob (1 tail) TTEST)	0.404	0.382	0.197	0.148	0.289	0.119	0.161	0.158	0.272	0.263	0.331	0.460

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Christopher H. Forbes-Ewan, James D. Cotter, Denys Amos and Wai-Man Lau

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16. DELIBERATE ANNOUNCEMENT

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Water containers; Beverage containers; Flasks, Infantry; Tubes; Hydration

19. ABSTRACT

This paper presents the results of a study comparing two systems of water carriage and delivery for use by infantry soldiers: A water bladder/tube and the current Army issue water bottles. The systems were compared for their effects on hydration status, thermal strain and acceptability, using a section of infantry engaged in simulated operations in a hot environment. The bladder/tube system was found to have slight (but not statistically-significant) positive effects on hydration status, was neutral with respect to thermal strain, and was unanimously preferred to water bottles as the primary means of water carriage. Therefore, the bladder/tube system has operational advantages over water bottles, is more acceptable to soldiers and may have a positive effect on hydration status. It is concluded that further studies are needed, both to determine the suitability of water canteens as the means of carriage but with a tube for delivery, and to determine the optimal formulation for a hydration beverage.

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