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CARBOHYDRATE-ELECTROLYTE SOLUTIONS
DURING FIELD TRAINING: INTRODUCTION

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HUMAN RESEARCH AND DISCLAIMER STATEMENTS

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.

ABSTRACT

The rationale and methods of evaluating two carbohydrate-electrolyte (CE) solutions at a field training exercise in hot weather are presented in this introductory article. Information on the development of the CE solutions are presented. The results are presented in a series of articles dealing with 1) acceptability of carbohydrate-electrolyte solutions and their effect on electrolyte homeostasis, 2) hypohydration during field training exercises in hot weather, and 3) field assessment of wet bulb globe temperature (WBGT).



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The ability of a field unit to determine the intensity of heat stress and to maintain water discipline under these conditions is essential to its efficiency in combat. Maintenance of normal fluid and electrolyte balance in the combat soldier is crucial, especially in hot environments. First, replacing sweat losses of both water and electrolytes with appropriate carbohydrate-electrolyte (CE) solutions may be necessary to maintain the integrity of the extracellular fluid compartment. Additionally, there are regions of the world where extreme heat conditions are coupled with a high likelihood of diarrheal diseases. Exposing dehydrated troops to additional gastrointestinal losses predisposes them to further dehydration, depletion of extracellular volume, and possibly shock. Finally, combat troops are obviously at risk for traumatic blood loss and hemorrhagic shock. The risk from hemorrhagic shock is magnified in the presence of preexisting volume depletion (1). Soldiers encapsulated in chemical/biological protective suits have high sweat rates due to the head load attendant with wearing this protective clothing. Replenishment of sodium and maintenance of blood glucose is difficult

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under these conditions since encapsulated soldiers are forced to fast until a protective shelter can be reached or until the threat has passed. In 1982 a National Research Council (NRC) advisory committee recommended a CE solution for consumption by these encapsulated troops (2). To distribute different solutions to meet all the above needs would be an overwhelming task and therefore we formulated and tested a multipurpose oral rehydration CE powder. The various uses of CE are: 1) primary replacement of fluid and electrolyte losses which occur while encapsulated in chemical protective gear; 2) supplemental replacement of heat-induced fluid and electrolyte losses; 3) treatment of mild heat casualties; and, 4) oral rehydration therapy for diarrheal losses.

The CE solution recommended by the NRC committee (CE2) was expected to replace minimal needs, not to replenish all fluid, carbohydrate, and sodium losses during encapsulation. Since soldiers working in the heat were expected to eat during the day, CE2 represented a basic solution. Additional electrolytes were added to CE2 to produce a solution (CE1) to treat

heat injuries. Doubling the strength of the CE1 solution (by reducing the amount of water mixed with the powder) would provide a solution that would be effective in treating diarrheal losses. The following information was taken into consideration when formulating CE1 (3-12): 1) sodium to maintain the integrity and volume of the extracellular fluid compartment; 2) potassium to assure intracellular volume and normal cardiovascular, neuromuscular, CNS, and gastrointestinal function; 3) magnesium to maintain normal intracellular enzyme activity and metabolism, prevent Mg-deficient hypokalemia, and maintain CNS function; and, 4) glucose as a modest source of energy under field conditions, to increase gastrointestinal absorption of Na and water, and to promote the active transport of K into cells.

For prevention and treatment of mild to moderate heat injuries in encapsulated or heat-stressed soldiers, an electrolyte concentration of 20, 10, and 2 mEq/L of Na^+ , K^+ , and Mg^{++} , respectively, with carbohydrate levels at 25 g/L appears to meet all needs. Doubling the strength of the CE1 solution would provide a solution with a composition very similar to

the oral rehydration solution recommended by the World Health Organization (13). The advantages of this multipurpose, oral rehydration powder are: 1) individual packaging to prevent contamination and errors in mixing; 2) multiple uses; 3) simplicity in diluting the powder in a canteen of water; and 4) ease of distribution through normal supply channels. In fact, constraints on the weight carried by the combat infantryman played a role in the formulation of a multi-use and multi-strength CE powder.

CE solutions may improve soldier performance and fluid consumption in the heat but weather also has a profound effect. The ability to measure heat stress levels across a large area would provide valuable information for optimizing soldier performance. A close correlation between field and satellite-derived WBGT readings would indicate significant potential for the use of satellite remote sensing technology to accurately assess WBGT in training/operational environments.

A series of studies were conducted in collaboration with reservists of the 44th Evacuation Hospital, 807th Medical Brigade during field training

exercises (FTX) in June 1988. A team of military scientists and laboratory technicians from the US Army Research Institute of Environmental Medicine, Natick, MA studied the daily food intakes, serum changes pre- to post-FTX, and urinary variables twice daily of reservists doing moderate work under variable heat stress conditions at Fort Hood, Texas. Results of the studies are presented in the following series of articles dealing with 1) acceptability of CE solutions and their effect on electrolyte homeostasis, 2) hypohydration during field training exercises in hot weather, and 3) field assessment of wet bulb globe temperature (WBGT).

METHODS

Sixty-one reservists of the 44th Evacuation Hospital (Oklahoma City, OK and El Paso, TX), 807th Medical Brigade, participated in an 8 day field training exercise (FTX) at Fort Hood, TX during June 1988. All subjects were briefed on the design, testing procedures and risks, and signed a statement of informed consent retaining the right to withdraw from the study at any time without retribution. To make the

groups comparable in terms of activity level, age, gender, and work experience, subject assignment to the test beverage groups was made according to military rank, gender, age, and Military Occupational Specialty. Demographics and physical characteristics are presented in Table 1.

Table 1
Descriptive Characteristics of Reservists

		CE1 (n=14)	CE2 (n=18)	W (n=17)	FW (n=12)	COMBINED (n=61)
Age (yrs)		34.3 ±2.6	33.3 ±2.1	34.1 ±2.5	37.3 ±2.6	34.6 ±1.2
Height (cm)		169.2 ±1.8	176.6 ±2.6	178.4 ±3.3	175.6 ±3.1	173.5 ±1.5
Weight (kg)		68.4 ±3.1	78.5 ±3.7	78.4 ±4.2	74.9 ±4.2	75.4 ±2.0
Sex:						
Male	No.	7	11	8	6	32
Female	No.	7	7	9	6	29
Point of Origin:						
El Paso	No.	6	3	6	3	18
OK City	No.	8	14	11	9	42
Other	No.	0	1	0	0	1

We evaluated two CE (CE1 and CE2) solutions, a flavored water placebo (FW), and chlorinated Water (W) in the current field trial (Table 2). Subjects were assigned to one of the 4 test groups which differed only in the test beverage assigned for ad libitum consumption. Subjects were also allowed to drink field chlorinated water or other beverages (juice, soda, milk, etc.).

Table 2
Composition of Solutions Provided
During 8-days of Field Training

Beverage	Electrolytes (mEq/L)						Glucose (g/L)
	Na ⁺	Cl ⁻	Mg ⁺⁺	PO ₄ ⁻³	HCO ₃ ⁻	K ⁺	
CE1	22.8	24	5.2	3.2	10	9.5	25
CE2	25.0	24	0.14	2.0	0	0.02	25
FW	0	0	0	0	0	0	0
W	0	0	0	0	0	0	0

CE1 was composed of 2.5% maltodextrins with an osmolality of 127 mOsm/kg. CE2 contained a 2.5% fructose/maltodextrin mixture with an osmolality of 166 mOsm/kg. FW was a colored, lemon-lime flavored, low caloric (aspartame) drink which was similar in appearance and flavor to the CE1 and CE2 solutions. The FW group was included to determine the effects of coloring and flavoring on fluid intake. Packets of CE1 and CE2 powder were issued to the subjects twice daily. FW was pre-mixed and available at three locations in thermos jugs. All water consumed was field grade water treated by chlorination and stored in water buffalos and 36 gallon lyster bags. Subjects were instructed to consume their assigned beverage ad libitum but were also allowed to drink any other available fluids.

Soldiers lived in tents for 8 days during the FTX at Fort Hood, TX. During this time, they constructed an Evacuation Hospital, attended training sessions (Days 1-5) in air-conditioned classrooms, and participated in an FTX (Days 6-8). During the afternoon (1400-2200 hrs) of Day 5, most soldiers were allowed free time and many were transported to the main post. The physical activity of the soldiers ranged

from light to heavy (classroom lectures to setting up hospital tents) exertion with the overall pattern in the moderate range. Heat stress was variable with periods of mild to intense heat stress (maximum WBGT, 78.5°-90.3°F) encountered during the 8 days in the field.

The first article of this series covers the acceptability of carbohydrate-electrolyte solutions and their effects on blood indices (14); hypohydration during field training exercises in hot weather is the topic of the second article (15); and the final article covers heat casualties and field assessment of WBGT (16). The presentation of temperature as degrees Fahrenheit in these articles is a departure from scientific convention but was done to be consistent with current military terms of reference on heat stress and instrument scales.

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