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The Influence of a Calorie Supplement on the Consumption of the Meal, Ready-to-Eat in a Cold Environment

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There is a dichotomy between calories issued to soldiers in their daily field rations and the amounts actually consumed. Soldiers frequently consume insufficient calories to maintain body weight. A supplemental pack (740 kcal) was developed, to increase field calorie consumption, and tested with the old and new versions of the Meal, Ready-to-Eat on a 10-day field study in Alaska. Initial and final measurements included body weights, heights, blood, and urine parameters. Daily measurements included the collection of urine samples and completion of a dietary intake log. Energy intakes of the supplemented groups were 4%–11% higher ($p < 0.05$) although the calorie intakes were still below the recommended 4,500 kcal/day for cold weather operations. Mean body weight loss ranged from 3.0 lb (1.7%) to 4.8 lb (2.8%). Two groups of the four groups became hypohydrated by day 3, due to low water intake, and only improved after direct intervention to increase drinking. Water and food intakes were strongly correlated ($p < 0.05$). Results confirm the success of the supplemental pack as a means of increasing food intake and underscore the importance of water discipline in a cold environment.

Introduction

The standard individual field ration, the Meal, Ready-to-Eat (MRE) was type classified in 1975 and introduced into service in 1985 as a replacement for the Meal, Combat Individual (C-ration). It has undergone many modifications which have been evaluated in various field studies.[1–5] The current MRE (MRE VIII) consists of 12 menu varieties, is comprised mainly of thermo-processed (wet pack) food components, requires a minimum to no preparation, and utilizes flexible, high barrier packing materials.

The Recommended Dietary Standards for military personnel consuming operational rations are 3,600 kcal (3 MREs) in a temperate climate and 4,500 kcal (4 MREs) in a cold environment,[6] but these recommendations are seldom achieved. The mean daily caloric intake, during the first 3 days of a study in a temperate climate, when regular soldiers consumed the MRE was 2,445 kcal or 68% of the nutritional standard.[7] In another study over an extended period (34 days), the mean daily energy intake was 2,189 kcal or 60% of the available energy.[8] Special Operations Soldiers fared somewhat better on a 30-day field training exercise but still consumed only 2,782 kcal (77% of the nutritional standard).[9] In an evaluation of the improved MRE (MRE VIII), MRE VII, and MRE IV, mean caloric intake from both the MRE IV and MRE VII was 2,517 kcal and 2,842 kcal for the MRE VIII.[5] This shows a greater acceptability for the MRE VIII, but only represents 72% of available calories or 79% of the nutritional standard.

In a cold environment, observed energy intakes did not increase despite the higher energy requirement for cold weather operations (recommended intake of 4,500 kcal).[6] During a cold weather field exercise comparing the MRE with the Ration, Cold Weather,[1] the mean daily energy consumption for the MRE was 2,733 kcal representing 56% of the available energy or 61% of the nutritional standard. In a moderate altitude, cold weather environment where soldiers consumed either the MRE; Ration, Cold Weather; or the Ration, Lightweight,[10] mean energy intake for the MRE group was 3,217 kcal or 71% of the nutritional standard.

In an attempt to improve the overall consumption of the MRE, an in-depth study group in 1988 (Army Food 2000 Task Force[11]) recommended the development of a calorie supplemental pack containing highly palatable foods most often requested by soldiers. In response, two supplemental packs (740 kcal, Table I) were developed by the Natick Research, Development and Engineering Center and evaluated by the U.S. Army Research Institute of Environmental Medicine on a 10-day field study[12,13] conducted in Alaska using soldiers from the 6th Infantry Division (Light).

Methods

Test subjects were recruited from two battalions stationed at Fort Richardson, Alaska. Volunteers were randomly assigned to one of four test groups in order to provide approximately 35 in each group. The daily feeding regimen is shown in Table II.

A winter field evaluation exercise conducted during the first 2 weeks of March 1989 in the training area of Fort Greely,

TABLE I

PROPOSED SUPPLEMENTAL PACKS

Supplemental Pack 1	Supplemental Pack 2
70 g Pouched bread[a]	70 g Pouched bread[a]
34 g Beverage base	34 g Beverage base
5 g Tabasco sauce	5 g Tabasco sauce
28 g Candy (Charms)	28 g Candy (Charms)
43 g Beef jerky	57 g Nuts & raisins

[a]Shelfstable bread in laminated foil.

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TABLE II

DAILY FEEDING REGIMEN

1 company			
Group 1	(MRE VI)	4 MRE VI/man/day	(4,816 kcal)
Group 2	(MRE VIII)	3.5 MRE VIII/man/day (7/2 days)	(4,571 kcal)
1 company			
Group 3	(MRE VI+)	3 MRE VI plus 1 supplemental pack/man/day	(4,352 kcal)
Group 4	(MRE VIII+)	3 MRE VIII plus 1 supplemental pack/man/day	(4,658 kcal)

Alaska, was used for the study and the units involved followed their own predetermined training and evaluation schedule.

Initial measurements of body weight, height, blood, and urine parameters were taken from all subjects and, on a subsample of 25, activity monitors were placed on the subjects' wrists to quantify activity. Daily measurements, taken for 10 days, included a urine sample, food and water intake, and food acceptability. Postmeasurements included a blood sample, body weight, and the administering of final questionnaires.

Blood Samples

Fasting blood samples (30 cc) were drawn by venipuncture. Hemoglobin and hematocrit were determined from a whole blood sample. Serum was used to assess both nutrition and hydration status and a standard panel of clinical tests were performed which included analysis for triglycerides, high density lipoprotein (HDL) cholesterol, and total cholesterol.

Urine Samples

A first void, morning, midstream urine sample was collected on each day of the field study and on the morning of the pre- and post-study measurements. Each sample was used to detect dietary (ketone and protein) and hydration (specific gravity, sodium, and potassium) changes.

Body Weight and Height

Body weights (±lb) were measured pre- and post-study using a Seca digital electronic battery-operated scales with subjects clad in underwear. Heights were measured (±cm) in stocking feet prior to deployment.

Activity Levels

Activity levels (Ambulatory Monitoring, Inc., Ardsley, NY) were measured to determine sleep/wake patterns in a subset of each group to allow a comparison among groups.[14] Data consisted of motor activity in 3-minute epochs for the 10-day period. Analysis of the data was performed using a sleep/wake algorithm for wrist activity.[15]

Food Intake and Acceptability

All subjects recorded their daily food intake using a 24-hour dietary log. Trained dietary data collectors interviewed subjects daily, at which time possible omissions, ambiguities, and queries were resolved and the next 24-hour dietary log and day's food were issued. Empty wrappers and unwanted food were collected in plastic trash bags and used to confirm entries in the dietary logs. Food acceptability (9-point hedonic scale) was assessed on a daily basis using the 24-hour dietary logs.

Water Consumption

Water consumption was ascertained using self-reporting procedures on the 24-hour dietary log. Subjects were asked to record the number of canteens of water consumed either as plain water, mixed with a beverage, or mixed with food during three time frames: morning, afternoon, and evening.

Final Questionnaires

Two questionnaires were administered on the last day of the study. These were designed to collect information that included demographics and soldiers' opinions on general aspects of the ration and supplemental packs.

Meteorological Data

Meteorological data were collected daily by the Atmospheric Science Laboratory, Alaska Meteorological Team, located at Fort Greely, as part of its routine weather forecasting operation. Hourly readings were taken of minimum and maximum temperatures, wind speed and direction, wind chill, solar radiation, and precipitation. Times of sunrise and sunset were also recorded.

Data Analysis

Means and standard deviations were calculated for the macronutrients obtained from the MREs, supplemental packs and for fluid consumption. Results were compared using a one-way analysis of variance in combination with Tukey HSD (SPSS-X Data Analysis System). Variations between food items and ration groups were determined using paired t-tests. The level of statistical significance chosen for the study was $p < 0.05$.

Results

Meteorological Data

The lowest recorded temperature was −43°F and daily low temperatures were below −20°F for 7 consecutive days. The maximum temperature achieved during the day was +28°F although for 7 consecutive days it never exceeded +10°F. Total hours of daylight at the start of the study was 9 hours 59 minutes and rose daily by approximately 7 minutes. Precipitation, as snow, occurred on 4 days. However, this snow was particularly dry and when recorded each day as water, was either a trace or 0.01 inches. Solar radiation ranged from 59 Langleys (an electromagnetic radiation incident upon a surface: a value of energy per unit area equal to one calorie per square centimeter) on the day of deployment to 226 Langleys on day +7.

Activity Levels

The mean number of hours of sleep for the unsupplemented groups was 5.09 (SD 2.20) hours and ranged from 2.3 to 8 hours. The mean number of hours sleep for the supplemented groups was 4.17 (SD 1.21) hours. There were no significant differences between the two companies, although sleep patterns were intermittent and both companies experienced cyclic changes in the amount of work and rest they received.

Demographics

The majority of subjects (97%) were enlisted soldiers whose ranks ranged from E-1 to E-7; 75.5% had been in the Armed Services for 5 years or less. They were similar in terms of the type of climate they had lived in the longest: hot or mixed climate being most prevalent with only 18% having lived most of their lives in a cold climate. The overall mean height was 176.8 cm and the overall mean age was 24.6 years; there were no significant differences among the four groups.

Body Weight and Height

Body weights are presented in Table III. The overall mean preweight was 173.7 lb. There were no significant differences among the four groups. The overall mean postweight was 170.1 lb and again there were no significant differences between the groups. All groups lost significant ($p < 0.05$) amounts of body weight but there were no significant differences among groups. The overall mean weight loss was 3.6 lb with the highest, 4.8 lb, in group 1 (MRE VI) and the lowest, 3.0 lb, in group 4 (MRE VIII+). Percentage weight losses ranged from 2.8% in group 1 to 1.7% in group 4. These weight losses are within the generally accepted limits of not more than 3%.

Nutrient Intakes

The mean daily energy intakes and intakes of macronutrients (protein, fat, and carbohydrate) are given in Figures 1 and 2. With the exception of the groups consuming MRE VIII and MRE VI+, all are significantly ($p < 0.05$) different. The weights and percentage contribution of these nutrients to the total energy intake are given in Table IV. Mean daily energy intakes provided only by the MRE are presented in Figure 3: 215 kcal or 11% more of MRE VI and 111 kcal or 4% more of MRE VIII were consumed by the supplemented groups.

Nutritional Status as Determined by Blood Chemistries

Results for the triglycerides, HDL cholesterol, and total cholesterol are shown in Table V. Subjects were young and healthy and as anticipated all values were within the normal range. There were significant changes in some variables over the course of the study indicating changes in either nutritional or hydration status. The source of variation depends on intake and/or changes in clearance and could pinpoint possible long-term problems with the rations.

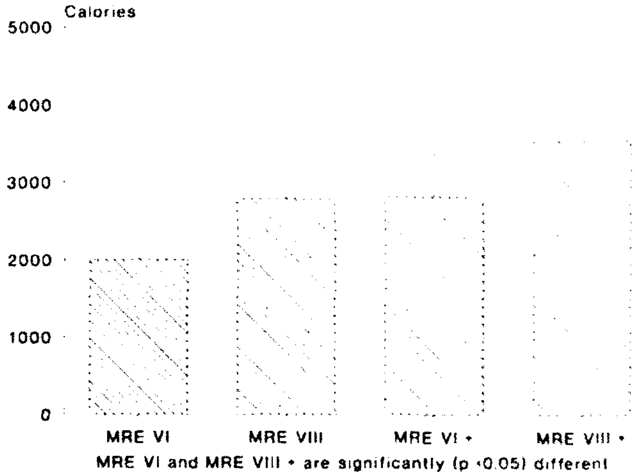

Fig. 1. Mean daily energy consumption (kcal).

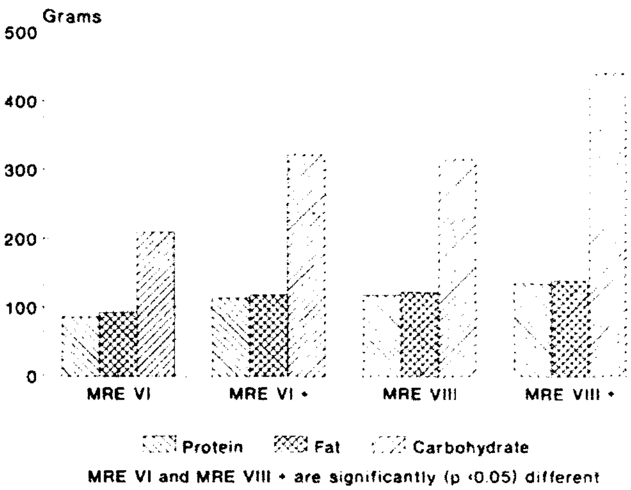

Fig. 2. Mean daily intakes of protein, fat, and carbohydrate.

TABLE III

CHANGES IN PRE- AND POSTWEIGHT OF GROUPS

	Group 1: MRE VI (n=32 lb)	Group 2: MRE VIII (n=31 lb)	Group 3: MRE VI + Supplement (n=30 lb)	Group 4: MRE VIII + Supplement (n=34 lb)
Preweight				
Mean	173.2	171.8	173.9	175.8
SD	21.2	26.5	24.2	25.3
Postweight				
Mean	168.4	168.3	170.6	172.8
SD	19.9	24.6	24.0	23.9
Changes[a]				
Mean	4.8	3.5	3.3	3.0
SD	4.0	4.2	6.0	3.5
	−2.8%	−2.0%	−1.9%	−1.7%

[a]Pre- and postweights are significantly ($p < 0.05$) different.

TABLE IV

WEIGHTS AND PERCENT DISTRIBUTION OF ENERGY OBTAINED FROM FAT, PROTEIN, AND CARBOHYDRATE

	Group 1: MRE VI		Group 2: MRE VIII		Group 3: MRE VI + Supplement		Group 4: MRE VIII + Supplement	
	g	%	g	%	g	%	g	%
Protein	86.6	16.9	113.7	16.0	118.1	16.7	135.7	15.2
Fat	93.2	41.8	118.3	37.7	122.6	38.9	139.7	35.4
Carbohydrate	209.6	41.9	322.6	46.5	316.3	44.8	440.5	49.6

Acceptability of the Rations

Mean acceptability ratings of the supplemental pack items are given in Table VI. The MRE VI, with few exceptions, gener-

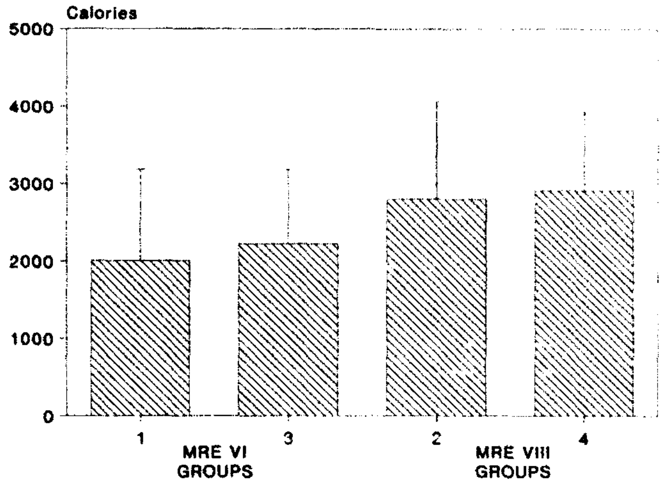

Fig. 3. Mean daily energy (kcal) provided only by the Meal, Ready-to-Eat.

TABLE V

A COMPARISON OF PRE- AND POSTBLOOD VALUES

	Total Cholesterol (mg/dl)	Triglycerides (mg/dl)	HDL Cholesterol (mg/dl)	Cholesterol/HDL (mg/dl)
Group 1: MRE VI				
Pre	195 ± 35	148 ± 56	50 ± 11	4.1 ± 1.0
Post	179 ± 31[a]	78 ± 32[a]	57 ± 11[a]	3.2 ± 0.9[a]
Group 2: MRE VIII				
Pre	187 ± 77	141 ± 77	51 ± 14	3.9 ± 1.1
Post	176 ± 22[a]	87 ± 42[a]	56 ± 9[a]	3.2 ± 0.6[a]
Group 3: MRE VI +				
Pre	190 ± 33	111 ± 55	45 ± 8	4.2 ± 1.0
Post	169 ± 25[a]	117 ± 60	49 ± 10	4.4 ± 5.3
Group 4: MRE VIII +				
Pre	194 ± 38	110 ± 53	48 ± 10	4.1 ± 0.9
Post	165 ± 26[a]	120 ± 48	53 ± 10[a]	3.2 ± 0.6[a]

Values are mean ± SD.
[a]$p < 0.05$.

ally received neutral ratings. However, these were improved slightly (33 of 40 items received improved ratings) but not significantly by the addition of the supplemental pack. The MRE VIII, as should be expected, received significantly higher ratings than the MRE VI and in all but five items was improved still further with the addition of a supplemental pack. The supplemental pack received very favorable ratings with the lowest rated item, hot pepper sauce, being rated "like moderately." With the exception of raisin nut trail mix, the MRE VIII group gave more favorable ratings, two of which were significantly better.

TABLE VI

MEAN ACCEPTABILITY RATINGS OF THE SUPPLEMENTAL PACK ITEMS[a]

	Group 3: MRE VI + Supplement	Group 4: MRE VIII + t-Test Supplement Results	
Pouched bread	8.32 (0.15)[b]	8.75 (0.06)	$p < 0.05$
Cold beverage powder	8.15 (0.16)	8.14 (0.11)	NS
Hot pepper sauce	7.18 (0.55)	7.51 (0.43)	NS
Charms	8.35 (0.14)	8.67 (0.12)	NS
Beef jerky	8.30 (0.16)	8.86 (0.05)	$p < 0.01$
Raisin & nut trail mix	8.43 (0.14)	8.36 (0.14)	NS

[a]Rating scale: 1 = dislike extremely . . . 5 = neither like nor dislike . . . 9 = like extremely.
[b]Numbers in parentheses are standard errors.

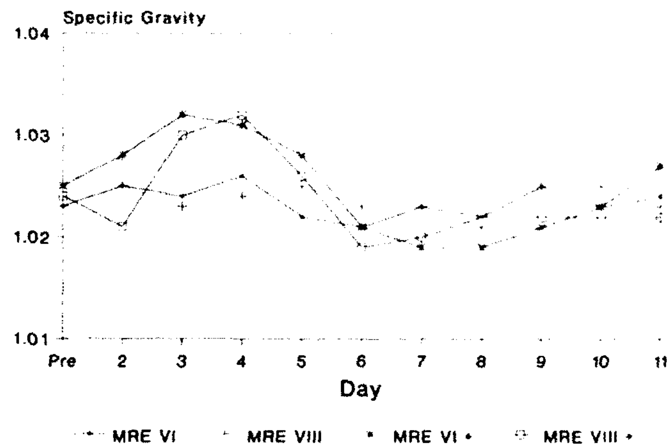

Fig. 4. Mean daily urine specific gravity.

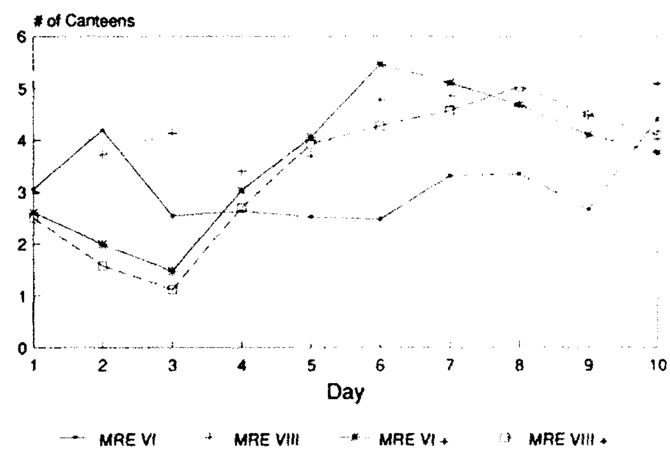

Fig. 5. Mean total daily water intake.

Urinary Specific Gravity and Water Intake

The mean daily urinary specific gravity (SG) values for all groups are shown in Figure 4. A normal SG range of an overnight urine for a well-hydrated subject is 1.015 to 1.022. Values of 1.030 or greater are indicative of hypohydration.[16]

The mean daily total water intakes calculated from water consumed either as plain water, mixed with a beverage, or mixed with food are given in Figure 5. The data are presented as the number of canteens consumed; each canteen holds 960 ml when full.

Discussion

In a cold environment, the issue of three MREs is generally increased to four, thereby meeting, or in the case of the new

MRE (MRE VIII), exceeding the Military Recommended Dietary Allowance of 4,500 kcal.[6] Even so, soldiers fail to consume adequate quantities of food and hence are in negative energy balance. In this current study, the use of a supplemental pack in place of a fourth MRE was investigated for supplementing both the old (MRE VI) and new MRE (MRE VIII).

Nutrient Intakes

It is clear from these results that not only does food consumption increase in both the supplemented groups but that this consumption can partly be attributed to the supplemental pack and partly to consumption of more of the MRE. The concern that provision of a supplemental pack would cause soldiers to eat less of the MRE, in preference for the supplemental pack, is not supported by the results of this study.

The percentages of energy obtained from protein (Table IV) remains fairly constant but is slightly lower for the MRE VIII+ group. The higher percentage of energy obtained from carbohydrate at the expense of fat observed in the MRE VIII group can mainly be attributed to the inherent changes in the MRE. MRE VI provides 40.4% of its energy from fat and 42.8% from carbohydrate while MRE VIII provides 35.8 and 49.4%, respectively. Differences between the supplemented and unsupplemented groups can be attributed to the supplemental pack which provides on average 27.6% of its energy from fat and 60.0% from carbohydrate.

In situations where water supply may be limited, the consumption of large amounts of protein may not be advisable, partly because of the reduced volume of water liberated during metabolism (metabolic water) for protein as compared with carbohydrate and partly the increased water requirements needed for excretion of urea nitrogen (obligatory water). A further concern when the water supply is limited is salt consumption. Using the calculations of Baker et al.[17] water requirements have been estimated as 3.55 l in the MRE VIII group and 3.86 l in the MRE VIII+ group. Although these differences appear to be small, they may be important where the water supply is limited.

The mean frequency of MRE entree consumption/availability ranges from 2.1/4.0 in the MRE VI, 2.6/3.5 in the MRE VIII, 2.3/3.0 in the MRE VI+ and 2.7/3.0 in the MRE VIII+ group. Significant ($p < 0.05$) differences were found between MRE VI+ and MRE VIII+ and between MRE VI+ and MRE VIII+. It is important to note that no significant differences ($p < 0.05$) were observed in the mean amounts consumed in MRE VIII and MRE VIII+ groups. Results were similar for other food categories indicating that while the MRE VIII group was issued, on average, 3.4 MREs and the other group 3 MREs, the frequency of consumption was similar. As would be expected, more differences were found between the MRE VI and MRE VIII groups.

Blood Chemistries

Cholesterol was within the high normal range for this age group in the pretest which was possibly due to the prefield study loading of "favorite foods." The usual pattern is for these values to decrease during a field study and all groups followed this pattern. Similarly, triglycerides usually show dramatic reductions over the study since the total fat intake is reduced. The unsupplemented groups showed this reduction but the supplemented groups did not. Although the percentages of energy obtained from fat were less for the supplemented groups, the total fat consumption was greater. HDL cholesterol was increased in groups 1, 2, and 4. The increase in group 3 was not significant. These increased levels were possibly the result of the elevated work levels being performed during the evaluation exercise and it has been shown[18-20] that an increased level of exercise can produce positive changes in HDL cholesterol. Other factors that have been implicated in increasing the HDL fraction are cold exposure[17] and weight loss by dieting.[18] In this group, the level of work was greater than normal and they were exposed to cold stress. All groups lost some weight because of the lowered caloric intake. The increased HDL fraction and reduction in cholesterol combined to produce significant decreases in their ratio, which is indicative of lower cardiovascular risk.

The blood chemistries displayed no group differences in the prestudy measurement, but differences were shown pre- to postevaluation exercise reflecting the influence of the ration supplement.

Hydration Status

Increases in urinary SG can reflect hypohydration, impending hypohydration, or renal adaptations to prevent hypohydration. The mean SG values indicate that the supplemented group exceeded the limits (1.030) on the mornings of days 3 and 4. At that time, it was unclear why the soldiers were hypohydrated, and positive intervention (soldiers were instructed through command channels to drink more water) was ordered. When the water intake figures were examined, the reason for the high urine SGs was low water consumption. Hydration status only improved once more water was made available and forced drinking implemented.

Dehydration causes drowsiness, impatience, discomfort, weariness, irritability, reduced work efficiency, reduced cognitive ability, and reduced resistance to cold exposure.[21-23] It is clear that this incident of hypohydration was the result of water logistics and leadership and was not related to the consumption of the rations. It further demonstrates the importance of maintaining a viable water supply system, transporting water in an unfrozen state in an arctic environment, and the problems that can arise when the supply is compromised for any reason.

Food and Water Consumption

It has been shown in both animal[24-26] and laboratory human studies[27] that eating and drinking are closely related events. If this assumption can be extended into a field environment, then the amount of food consumed could well influence the amounts of water consumed and vice versa.

The relationship between calories consumed and water consumption in this study shows a very strong, significant ($p < 0.01$) correlation ($r = 0.7592$). What is not clear is whether food induced water consumption or water induced food consumption. Engell[27] found that 68% of drinking occurred when food was available at mealtimes when drinking was ad libitum. When fluid was limited, subjects voluntarily reduced their food intake. From these studies it could be concluded that if water is made readily available, the consumption of calories could be increased. Similarly, if ample opportunity is given to consume food, and water is readily available, then the consumption of water could be increased to prevent dehydration.

Summary

In an Arctic environment where temperatures fell to below −40°F, the nutrient intake and acceptability of a proposed supplemental pack were assessed on a 10-day exercise.

Four groups of soldiers, each approximately 35 strong with broadly similar sleep-wake patterns were assessed: one group ate the old version of the MRE (MRE VI), a second group MRE VI with a supplemental pack, a third group the new MRE (MRE VIII), and a fourth group MRE VIII with a supplemental pack. Prior to deployment initial measurements were taken. Thereafter, daily food intakes, food acceptability, and water intakes were recorded in 24-hour Dietary Logs and hydration status was ascertained from urine samples. At the end of the study further measurements were taken to ascertain what physiological changes had taken place.

The results clearly demonstrate the success of the supplemental pack. Energy and nutritional intake were higher in the supplemented groups. Caloric intake was approximately 41% higher in the groups consuming MRE VI and 27% higher in the groups consuming MRE VIII. When the effects of the supplemental pack are removed, energy intake was still 11% and 4% higher in the MRE VI and MRE VIII groups, respectively. However, what is of concern is the low energy consumption of all groups (2,009 kcal–3,553 kcal) when compared with energy expenditure and a recommendation of 4,500 kcal/day for cold weather operations and accounted for body weight losses ranging from 3.0 (1.7%) to 4.8 lb (2.8%).

The supplemental pack items were rated very favorably by both test groups. Adding a supplemental pack to the MRE ration enhanced the acceptability of MRE VIII but not MRE VI. This was probably due to a "halo" effect.

Water intake was not generally good and by the morning of days 3 and 4, urine SGs of the supplemented groups had exceeded the limits of 1.030. It was not until positive intervention was ordered did water consumption and SG improve. Water and food intakes were also strongly correlated ($p < 0.05$).

It can be concluded that, in a cold environment, the replacement of a fourth MRE with a supplemental pack increases food acceptance and overall energy intake.

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