Chapter 17

NUTRITIONAL CONSIDERATIONS FOR MILITARY DEPLOYMENT

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INTRODUCTION

Deployment of military personnel, either for armed conflict or humanitarian assistance operations, inevitably requires large numbers of people to be fed. Military operations, often in hostile environments, combine periods of strenuous physical activity with periods of minimal activity or isolation. Such alternations in rest and activity impose perturbations in the body's homeostasis, with particular strains on the circulatory, respiratory, metabolic, and hormonal systems.[1] Thus, nutritional considerations for service members during deployment are complex and require awareness of environmental issues, as well as knowledge of physical demands.[2] Nutritional issues of particular importance in extreme environments include energy balance, hydration status, substrate utilization, and micronutrient needs. If these nutritional issues are not considered, fatigue may ensue, and both physical and cognitive performance may become limiting.

Although the importance of nutrition and dietary patterns in sustaining physical and cognitive performance has been recognized for many centuries, only in recent years have investigators attempted to document the dietary interventions that are most effective. Initial investigations focused on dietary manipulations for sustaining physical activity under thermoneutral environments; more recently, interactions between nutrition and physical activity under various environmental extremes have been considered. This chapter will first provide a brief overview of the physiological adaptations to physical activity, followed by a discussion of nutritional considerations for military operations. Specific nutritional issues of military operations under various environmental conditions, including heat and cold, and during acute exposure to altitude will be presented. Finally, military rations and what types of rations are available for various military operations are discussed.

PHYSIOLOGICAL RESPONSES TO PHYSICAL ACTIVITY

When physical activity is of low intensity and short duration, the strain on various physiological systems may be minimal, but when physical activity is prolonged or sustained, the strains are more pronounced and adaptations become more apparent. With both extended submaximal and extended high-intensity resistive activities, strains on the circulatory, respiratory, and energy balance systems are paramount. During the early phase of submaximal, steady-state activity, transient strains on oxygen delivery stress oxygen balance. Until the circulatory system adapts and the flow of substrate increases, anaerobic glycolysis is the initial system that provides energy. As soon as fuel and oxygen delivery capabilities respond, however, the individual adapts to the strain, and metabolic substrates are delivered aerobically to the working muscle. In contrast, when the activity is anaerobic, such as during heavy lifting activities, strains on the circulatory, respiratory, and energy balance systems may be significant. Such activities are of extremely short duration, and adaptations are limited.

In all environments, maintenance of blood glucose within a physiologic range, of adequate carbohydrate stores in the form of muscle and liver glycogen, and of plasma volume are essential. For example, if troops have been marching for 2 to 3 hours without a carbohydrate source, blood glucose levels will typically fall and fatigue will ensue.[3–5] Moreover, both prolonged marches and moving heavy gear for extended periods can result in significant decreases in muscle glycogen,[6] an indication of diminishing energy stores. Thus, dietary measures that strive to maximize glycogen stores in preparation for physically demanding tasks will reduce strains on energy metabolism. Similarly, drinking fluids at regular intervals during exercise will minimize strain on the circulatory system and help maintain plasma volume.

NUTRITIONAL CONSIDERATIONS FOR MILITARY OPERATIONS

The stress of deployment, in particular during prolonged marching, multiple shorter bouts of activity, and extreme thermal conditions, can impose significant demands on the fluid balance and energy stores of service members. Commencing any type of military operation in a compromised nutritional status, such as with inadequate glycogen stores or having failed to restore energy or replace fluids lost during previous operations, can affect how the body adapts to strains on the system. Unless service members are adequately nourished, physiological sequelae (eg, hypoglycemia, hypovolemia, dehydration, glycogen depletion, hyponatremia) and performance decrements can ensue.[7–10] For sustained operations in which physical effort is low (< 50% of $\dot{V}O_2max$) to moderate (50% to 70% of $\dot{V}O_2max$), hypoglycemia, hypovolemia, and dehydration are of the greatest concern. The nutrients of greatest importance for maintaining hydration status and energy balance include water, electrolytes, and the energy-providing nutrients: carbohydrate (CHO), fatty acids, and protein.

Hydration Status

Water is considered the most essential nutrient, and when hydration status becomes compromised, decrements in cognitive and physical performance are inevitable (Figure 17-1). Fluid within cells and tissues maintains plasma volume and serves as the medium wherein metabolic reactions proceed; given that physical exertion and cold exposure can increase metabolic activity 5- to 20-fold, fluid requirements under such conditions can be substantial.

Hydration status should be a primary consideration during exercise of all types. Assessing hydration status is best accomplished by observing urine color and monitoring body weight, which should be 0.5 to 1.5 kg higher than usual. Clear to light urine suggests a well-hydrated state, while dark or odorous urine suggests a degree of dehydration unless vitamin B supplements are being taken.[11] Frequency of urination can also be used as an indicator of hydration status.

The major determinant of fluid loss during physically demanding tasks is sweat rate; the amount of sweat lost depends on ambient temperature, radiant load, air velocity, clothing, exercise intensity, and physical conditioning. Many studies demonstrate marked variability in sweat rates and emphasize the importance of exercise intensity in determining the volume of sweat lost.[12] Figure 17-2 provides an approximation of sweat rates in liters per hour; these estimates can serve as guidelines for amounts of fluid to drink during and after exercise. If sweat and urine losses are not replaced by drinking water and other beverages, dehydration will become a significant problem. Dehydration may occur at any temperature and even under conditions when physical activity levels are low. Mild dehydration can decrease appetite and cause lethargy, moderate dehydration decreases work capacity, and severe dehydration can be fatal.

Drinking fluids before and at regular intervals during exercise is essential for maintaining health and performance. Although the type of activity will dictate the specific characteristics of the fluid replacement beverage, the beverage should (*a*) be palatable to promote adequate intake, (*b*) cause no gastrointestinal discomfort, (*c*) be rapidly absorbed; and, preferably, (*d*) have an osmolality of less than

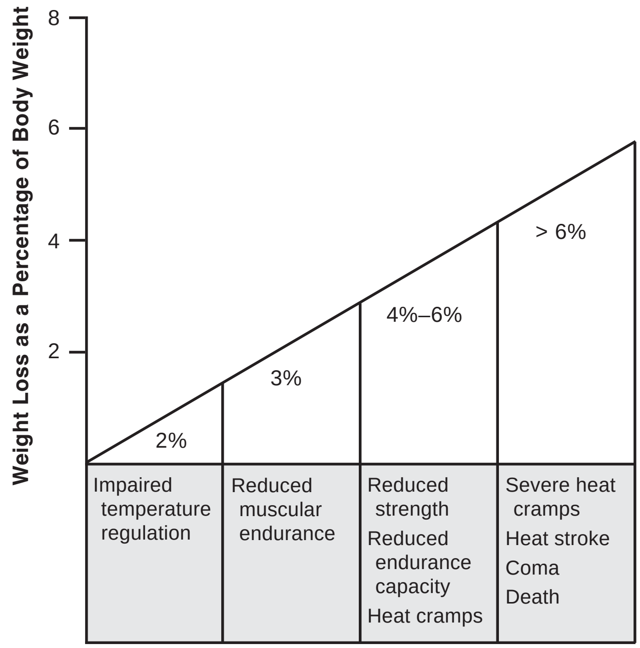

Fig. 17-1. Effects of Dehydration on Body Functions
Source: Original to authors

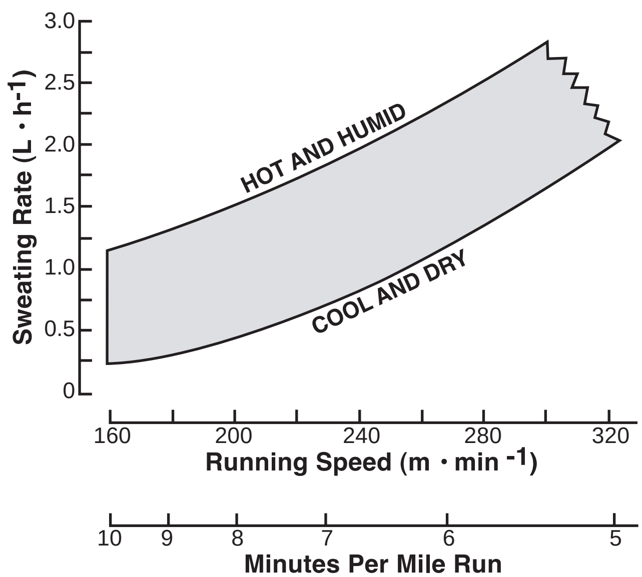

Fig. 17-2. Approximate hourly sweating rates and water requirements for runners based upon metabolic rate data. Reproduced with permission from Sawka MN, Pandolf KB. Effects of body water loss on physiological function and exercise performance. In: CV Gisolfi, DR Lamb, eds. *Fluid Homeostasis During Exercise*. Vol 3. *Perspectives in Exercise Science and Sports Medicine*. Indianapolis: Benchmark Press; 1990.

350 mOsm/L. If the exercise is to be continued for an extended period of time, the fluid replacement beverage should provide CHO and electrolytes, primarily sodium and potassium; extensive amounts of electrolytes can be lost when exercise is performed in the heat for a long time period or over extended days.[8–10] Water, CHO-containing beverages, and diluted fruit juices have all been recommended, but the CHO content should not exceed 12%; 6% to 8% solutions are optimal.[8,9] Carbonated beverages should be avoided during exercise as their consumption may cause gastrointestinal distress. In addition, the caffeine content of sodas may make them undesirable under some conditions. Table 17-1 compares the composition of selected fluid replacement beverages. The most commonly

TABLE 17-1

COMPARISON OF SELECTED FLUID REPLACEMENT BEVERAGES

Beverage (8 oz)	CHO Source* and Concentration	Sodium (mg)	Potassium (mg)	Other Nutrients	Osmolality (mOsm/L)
Gatorade	6% sucrose/glucose	110	25	Chloride, phosphorus	280–360
Exceed	7.2% glucose polymers/fructose	50	45	Chloride, calcium, magnesium, phosphorus	250
All Sport	8.0% high-fructose corn syrup	55	50	Thiamin, niacin, chloride, phosphorus, vitamins B_6 & B_{12}, pantothenic acid	525
10-K	6.3% sucrose/glucose/fructose	52	26	Phosphorus, vitamin C, chloride	350
POWERade	7.9% high-fructose corn syrup/glucose polymers	55	30	Phosphorus	388
Coca Cola	11% high-fructose corn syrup/sucrose	9.2	Trace	Phosphorus	600–715
Sprite	10.2% high-fructose corn syrup/sucrose	28	Trace	——	695
Cranberry Juice Cocktail	15% high-fructose corn syrup/sucrose	10	61	Vitamin C, phosphorus	890
Orange Juice	11.8%fructose/sucrose/glucose	2.7	510	Calcium, niacin, iron, vitamins A & C, thiamin, phosphorus, riboflavin	690
Water	——	Low	Low	——	10–20

*Sucrose = fructose and glucose
high-fructose corn syrup = a 54%:46% mixture of fructose and glucose derived from processed and converted corn starch
glucose polymers = long chains (> 3 molecules linked) of glucose

studied fluid replacement beverages contain electrolytes and either simple or complex CHO (maltodextrin or glucose polymers); these beverages usually taste good, promote rapid absorption of water, and provide substrate for the working muscles.[8–10] CHO-electrolyte (CHO-E) beverages have been studied in military populations and have shown positive results.[13–17] Importantly, CHO-E beverages can be ingested at any time—with meals, as a snack, or before, during, and after physical training sessions—to compensate for sweat losses and to maintain plasma volume.

Recommendations include drinking 0.30 to 0.50 L (0.25 to 0.5 qt) of cool, plain water 1 hour before starting a physical training exercise or any intense physical exertion[9,10] to minimize strain on the thermoregulatory system. However, excessive water intake during exercise may lead to electrolyte imbalances in hot weather.[18,19] Ideally, 0.25 to 0.75 L (0.26 to 0.8 qt) of a beverage supplemented with CHO-E (5% to 8% CHO) should be drunk every 30 minutes throughout strenuous exercises lasting more than 60 minutes, depending on the environmental conditions, to prevent hypoglycemia and extend performance[8–10] (Figure 17-3). In most studies that show benefits of CHO-E supplementation, subjects were provided 25 to 60 g of CHO per hour of exercise.[8,10] Providing CHOs 15 to 30 minutes before the anticipated onset of fatigue may extend performance for a short time.[20] If exhaustion has been reached before provision of the CHO-E, though, work capacity will not be extended because the rate of glucose absorption is slower than the rate at which blood glucose can be taken up and used by exercising muscles. Evidence also indicates that ingesting CHO-E (1.0 g/kg body weight) immediately after prolonged exercise and again 2 hours later will enhance endurance capacity 4 hours later.[21]

Energy Balance

One of the biggest nutritional problems in the field is the failure to maintain energy balance. Monotony of the diet, decreased appetite, and lack of time to eat contribute to decreased energy intake, whereas sustained activity with heavy loads increases expenditure.[22] In combination, these factors contribute to weight loss. Weight loss in the field is common, regardless of the thermal strain,[23] and may compromise mental and physical performance. Service members should be made aware of the importance of consuming their daily field rations for maintaining readiness.

Depending on the type and duration of the maneuver, soldiers have been known to expend 3,000 to 6,000 kcal/d during cold weather operations.[23,24] The primary energy substrates used during military operations are CHO and fatty acids; less than 10% of the energy expended is derived from the oxidation of protein. An 80-kg man stores approximately 1,800 kcal of CHO as glycogen in liver and muscle and 75,000 to 150,000 kcal as fat. In spite of

	Carbohydrate (CHO) Delivered by Beverage of Given Concentration				
	25 g/h	30 g/h	40 g/h	50 g/h	60 g/h
Concentration of Beverage (%)	Approximate Volume (mL) of Beverage Required to Deliver Desired Amount of CHO per Hour				
3	825	1,000	1,325	1,675	2,000
5	500	600	800	1,000	1,200
6	425	500	675	825	1,000
7	350	425	575	725	850
8	300	375	500	625	750
10	250	300	400	500	600
12	200	250	325	425	500

Fig. 17-3. The volume of fluid required to provide varying amounts of carbohydrate (CHO) each hour for a given concentration of CHO in the beverage. Beverage concentrations are on the left (3% to 12%) and amount of CHO is across the top (25 to 60 g/h). The shaded section represents the volumes of beverage that are adequate for fluid replacement (500 to 1500 mL/h). The unshaded sections are volumes that are either too low (< 500 mL/hr) or too high (> 1500 mL/hr) to be beneficial.
Adapted with permission from Coyle EF, Montain SJ. Carbohydrate and fluid ingestion during exercise: Are there trade-offs? *Med Sci Sports Exerc*. 1992;24:671–678.3.

the large stores of fat, overall performance is most affected by CHO stores. Once glycogen stores are exhausted, physical and mental performance will deteriorate and exhaustion will ensue. Overall, the relative contribution of CHO and fatty acids is determined by the intensity and duration of the physical activity, prior nutritional status, conditioning level of the service member, and ambient environmental conditions.[25]

Regulation of energy balance depends on the balance of CHOs, proteins, and fats in the diet. However, evidence indicates that only CHO and protein balances are precisely regulated.[26] Because CHO (glycogen) stores are limited, CHO oxidation is adjusted to the intake of CHO over a period of 24 hours. It has been shown that depletion of glycogen will induce an increase in CHO intake.[27] Given that glycogen is an important energy substrate for the active muscle, liver and muscle glycogen stores should be replaced after an intense military operation to maintain CHO balance.

Similarly, protein balance is a function of energy intake and expenditure. When energy intake matches energy expenditure, protein intakes above requirements induce an increase in protein oxidation and only a transient increase in positive nitrogen balance. Furthermore, an increase in protein intake results in a marked postprandial thermic effect.[27] Unlike CHO, protein is a minor energy substrate for working muscle. Thus, protein balance is only minimally disturbed by physical exertion.

In contrast to CHO and protein, fat (fatty acids or lipids) balance does not appear to be intrinsically regulated: ingestion of fat does not promote oxidation of fatty acids but rather energy needs determine the degree of dependence on fatty acids as substrate.[27] Physical exertion is one physiological stress that induces an increase in fatty acid oxidation, an indication that exercise may be one mechanism to minimize a surplus of fat. Maintaining energy balance when the energy demands are high requires a basic knowledge of the appropriate amount of each of the three energy-providing nutrients.

Carbohydrate Requirements

It is generally acknowledged that a diet high in CHO is required to replenish glycogen stores between consecutive days of training; when CHO intake is low, rigorous training over several days will result in a gradual depletion of muscle glycogen stores.[7,28,29] Costill and colleagues[7] demonstrated that when subjects who trained 2 hours each day consumed a diet providing only 40% (as compared to 70%) of the energy from CHO, glycogen depletion was evident after only 3 days. Others[30] observed a decline in muscle glycogen over a 7-day period in runners and cyclists who exercised for 1 hour daily and ate a diet that provided only 42% (5.0 g CHO/kg of body weight per day) of their energy from CHO. Despite the decline in muscle glycogen stores, daily training capacity remained similar over the 7-day period, so a short-term decrease in muscle glycogen stores may not impair performance. However, another study[31] reports that CHO intake during strenuous exercise can delay fatigue by decreasing the rate of muscle glycogen depletion.

A diet high in CHO for several days before a sustained training operation has the potential to increase liver and muscle glycogen stores and thereby extend the time to exhaustion. This may be accomplished by frequent snacking, or "grazing," on foods high in CHO to achieve an intake of 6 to 10 g of CHO per kilogram of body weight; approximately 60% to 70% of the total energy intake from CHO may be required each day to maintain glycogen stores.[32–34] A good premission meal can increase glycogen stores in muscles and liver and delay the onset of hypoglycemia. Goforth and colleagues[35] have shown glycogen supercompensation achieved by ingestion of a high-CHO diet (720 g/d) for 3 days was sustained for an additional 3 days when the subjects were inactive but maintained a moderate intake of CHO (332 g/d).

If a high-CHO diet cannot be eaten before an operation, ingestion of up to 4.5 g of CHO per kilogram of body weight 4 hours before a prolonged, physically demanding march or other field maneuver may maintain or extend performance by augmenting glycogen stores or maintaining blood glucose levels.[36,37] A premission meal should have limited amounts of fat and protein, since these nutrients take longer to digest and, if consumed less than 1 hour before a physical training or activity session, may cause gastrointestinal distress. A high-protein meal should be avoided because excessive protein can increase fluid requirements and may cause dehydration. CHO and CHO-E beverages are excellent choices in this situation. A smaller (400-500 kcal) high-CHO meal could be eaten 2 to 3 hours before the exercise.[36] Again, a CHO-E beverage 1 to 2 hours before a mission will leave the stomach faster than a solid meal.

Service members should know their individual tolerances for timings of meals and their ability to perform endurance activities. In general, they should allow more time for digestion before events that require intense physical activity. During extended field maneuvers, they should be encouraged to drink CHO-E beverages; however, some individuals may prefer to eat solid foods, primarily various energy bars or dried fruits. These foods will serve as a source of CHO to maintain blood glucose during prolonged events.[38] A study[13] that examined the effects of drinking a CHO-E beverage during several days of military training concludes that:

- CHO-E beverages can increase energy intake during field exercises,
- service members drinking CHO-E and eating their food were more likely to sustain physical performance than those eating only part of their food, and
- CHO-E beverages provide a readily accessible source of energy, which can be advantageous when inadequate food consumption is likely.

Food selections are personal choices, but dietary manipulations should always be tested in training sessions to ensure the foods selected will not cause gastrointestinal distress,[33] a common problem among endurance athletes.[38–40] Fasting, as an effort to reduce gastrointestinal distress and enhance fatty acid oxidation during physical exertion, is discouraged because it may impair physical performance by depleting liver glycogen stores and compromising blood glucose levels.[41]

Use of non-issue food items as substitutes for meals or rations should be limited since non-issued items may be lacking in several important nutrients, be high in fat, or be both. Such items, however, can be used as snacks to supplement total daily intakes. Also, high-CHO items, such as crackers, dried fruits, trail mixes, and sports bars, can be used. It is important to check the fat content of snack items, such as sports bars, because if it is greater than 3.0 g/100 kcal (27% or 27 kcal/100 kcal), absorption may be delayed and stomach cramping may occur. To maintain energy intake and blood glucose levels during sustained physical exercises, when possible service members should be encouraged to drink 25 to 50 g of CHO an hour.

Protein Needs

There is no consensus as to whether protein requirements are influenced by physical activity.[42] Amino acids can be oxidized during exercise, but the extent of oxidation depends on the exercise intensity, the availability of glucose and free fatty acids, and prior nutritional state. In particular, oxidation of the amino acid leucine appears to be enhanced when exercise is enforced in a fasted state as compared to a postabsorptive state. Moreover, increased nitrogen excretion in response to exercise has been demonstrated.[42] Interestingly, it has been shown that women exhibit a lower nitrogen excretion than men during exercise.[43] Whether this reflects their lower muscle mass or a decreased protein use during exercise has not been determined. Despite these exercise effects on amino acid and protein metabolism, the extent of the obligatory protein losses with exercise remains unresolved. As of 1999, protein's recommendations are still derived from a study by Tarnopolsky and colleagues[44] comparing the protein needs of body builders and endurance athletes. The highest values were found for the endurance athletes, and it was concluded that protein needs may depend on the intensity and volume of training.[32,33,44] A protein intake of 1.6 g/kg body weight was deemed adequate to maintain nitrogen balance in endurance athletes,[44] but strength athletes need less. In general, these protein needs can be met when 12% to 15% of daily energy intake is derived from protein and when energy balance is maintained.[32] When energy intakes approach 4,500 kcal/d, protein needs can be met when protein constitutes only 8% of the total energy intake.

Micronutrient Needs

Requirements for vitamins and minerals are typically met when service members eat a balanced diet. During deployment this may not be the case. In particular, when energy needs are not met through the diet, inadequate amounts of essential micronutrients will be consumed. A shortage of vitamins decreases the work capacity of personnel, and it has been shown that strenuous military missions are accompanied by an increased utilization of vitamins and minerals.[45] When military rations are the major source of energy, it is important for unit leaders to encourage consumption of those items that have been fortified to optimize nutrient intake.

In addition to inadequate energy intakes contributing to a potential deficit in vitamins and minerals, most deployment environments pose specific problems. By being outdoors and being physically active, service members are exposed to intense sunlight and high metabolic rates, and these exposures may result in significant oxidative stress.[2] Individuals may benefit from taking additional amounts of the antioxidant nutrients, such as vitamins E and C, but the amounts of particular nutrients that should be taken to offset environmental stressors are controversial. Recommendations to meet the increased micronutrient requirements at altitude can be found below in the section on altitude and may be used as a guide for both hot and cold environments in the absence of definitive data.

NUTRITIONAL CONSIDERATIONS BETWEEN MISSIONS

Recovery from prolonged operations may be critical, especially if only short rest periods are possible. Research has shown that if adequate nutritional strategies are implemented, additional physical work can in fact be achieved despite fatigue.[21] The three primary nutritional interventions that can influence recovery are glycogen restoration, rehydration, and electrolyte (particularly sodium) replacement.

Replacement of glycogen stores should start immediately or soon after completing a sustained effort. Providing 1.5 g of glucose per kilogram of body weight immediately after and again 2 hours after exercising for 2 hours significantly enhances replenishment of muscle glycogen stores.[46] Ingestion of CHO should continue even after the first 2 hours, though. Blom and colleagues[47] presented a schedule to maximize glycogen stores wherein subjects ingested 50 g of CHO every 2 hours after exercise for 6 hours. Glycogen resynthesis proceeded at a relatively constant rate as long as blood glucose remained elevated; ingestion of greater amounts of CHO does not further accelerate glycogen resynthesis.[46] Importantly, CHO foods with a low glycemic index (ability to raise blood glucose concentration) were not as effective as foods with a moderate-to-high glycemic index.[47,48] The importance of consuming foods with a high glycemic index has been confirmed.[49]

In addition to sustained, low-intensity aerobic exercise, high-intensity resistance exercise is associated with a rapid utilization of glycogen; only 30 minutes of intense exercise resulted in a 25% decline in muscle glycogen.[50] Ingestion of 1.5 g of CHO per kilogram of body weight immediately and again 1 hour after resistive exercise is effective in repleting glycogen stores.[6] It is reasonable to assume that foods with a high glycemic index would be restorative after heavy anaerobic activities as well. The glycemic index of selected foods is presented in Table 17-2.

For rehydration after strenuous exercise, forced fluid ingestion may be essential because the sensation of thirst can be blunted. Typically, voluntary consumption of fluids will restore only half of the fluid lost.[51] Body weight should be monitored to estimate fluid losses, so that over a period of several hours, a liter of fluid is ingested for every kilogram of body weight lost. Most commercially available fluid replacement beverages are appropriate for rehydration and appear to be as effective, if not more so, than water.[52]

TABLE 17-2

A SELECTION OF FOODS AND THEIR GLYCEMIC INDEXES*

Foods	Amount of Food That Provides 50 g of Carbohydrate
Highly Glycemic Foods (GI > 85)	
Bagel	1.3 bagel
Bread (white or whole wheat)	4.2 slices
Cornflakes	2.5 cups
Honey	2.9 tbsp
Maple syrup	3.1 tbsp
Potato, baked w/ skin	1 medium
Raisins	0.4 cup
Shredded wheat cereal	1.4 cups
Sweet corn, cooked	1.5 cups
Watermelon	4.5 cups
Moderately Glycemic Foods (GI between 60 and 85)	
Baked beans	1.0 cup
Banana	1.8 medium
Grapes	55 grapes
Oatmeal, cooked	2.0 cups
Orange juice	2.0 cups
Rice, cooked	1.0 cup
Sweet potato, boiled	0.8 cup
Low Glycemic Foods (GI < 60)	
Apple	2.5 medium
Peaches	5 medium
Pear	2 medium
Green peas, cooked	2.2 cups
Ice cream	1.6 cups
Spaghetti and other pasta, cooked	1.4 cups
Yogurt, nonfat plain	2.9 cups

*The glycemic indexes (GI) in this table are based on a relative GI of 100 for white bread.

Reproduced from Coyle. Timing and method of increased carbohydrate intake to cope with heavy training, competition and recovery. *Sport Sci*. 1991;9:2–-51.

NUTRITIONAL CONSIDERATIONS FOR SPECIFIC ENVIRONMENTS

Exposure to extreme environments always poses unique nutritional problems that must be considered, before deployment if possible. The three environments most often encountered during military operations are heat, cold, and high altitude (see chapter 19, Environmental Medicine: Heat, Cold, and Altitude). Service members may be deployed to environments that are hot and humid, hot and dry, cold and wet, or cold and dry. The environments may be even more varied, depending on the geographical location and time of year. Acclimation is desirable for maintaining performance, but nutritional interventions may also be of benefit.

Hot Environments

Any type of activity in the heat presents a challenge to maintenance of temperature homeostasis and plasma volume. As the intensity of activity increases, the generation of metabolic heat increases, and this heat must be dissipated to achieve thermal balance. The effectiveness of heat loss mechanisms depends on the ambient temperature and the humidity. The circulatory system adapts to the strain by invoking two primary events: an increase in blood flow to the skin and the onset of sweating, both of which facilitate heat transfer to the skin surface, where it can be dissipated into the environment.[53] Major concerns in a warm or hot environment are fluid and electrolyte balance, since water and electrolytes are lost through sweating. Working at a high intensity in hot, humid surroundings can result in significant fluid and electrolyte losses. One to two liters can be lost each hour and even more when special protective clothing is worn. The highest sweating rate ever reported was approximately 4 L/h.[12] Therefore, maintaining fluid status is the primary nutritional consideration for adapting to a hot environment. Electrolyte balance and energy needs are other nutritional concerns in hot environments.

Fluid Requirements

The detrimental effects of dehydration on physical performance are well known and have been described earlier (see Figure 17-1). Failure to replace fluids lost through sweating will result in dehydration and eventually in heat injury.[8–10] Because thirst is not a sufficient stimulus for maintaining body water during physical exertion, forced drinking of fluids is often necessary in warm environments.[51,54] The level of dehydration was 4% in men and women who drank approximately 10 mL of fluid per kilogram of body weight each hour (0.50 to 0.80 L/h) while running in a hot, humid environment.[55] Thus, 0.50 to 0.80 L of fluid each hour was not sufficient for strenuous activities under hot and humid conditions.

Approximately 0.5 to 0.75 L (0.5 to 0.8 qts) of fluid should be drunk every 30 minutes, depending on whether service members are working continuously or are using work-rest cycles. Regardless of the temperature and work conditions, service members cannot absorb more than 0.80 L (0.85 qt) every 30 minutes. The upper limits for fluid replacement in a warm environment are set by the maximal gastric emptying rates, which approximate 1.2 to 1.6 L/h for an average adult male.[54,56] In hot weather when the physical demands require efforts greater than 70% of $\dot{V}O_2max$, fluid losses can be as high as 2.0 L/h (2.1 qt).[51] Thus, fluid intakes of up to 1.6 L/h (1.7 qt) may be necessary when military personnel are required to perform in the heat for 3 or more hours;[9] ingestion of more than 1.6 L/h may cause gastric distress. US Army recommendations for 1999 have 1.5 qt/h and no more than 12 qt/d as the upper limit for water requirements during hard, continuous work in the heat. This volume of water is needed to replace fluid lost during heavy work, but service members should also drink this additional fluid (0.25 to 1.0 qt/h) during periods of rest when water requirements are lower.[57] Ideally, the fluid replacement beverage should contain electrolytes and a 5%- to 7%-concentration of CHO to promote fluid absorption and provide exogenous glucose, respectively, when the activities exceed 1 hour.[58]

Once the activity is over, weight loss can be used to estimate the degree of dehydration and amount of fluid to be replaced. The rehydration beverage should contain 2.32 g of sodium chloride or 40 mEq of sodium per liter of fluid to accelerate rehydration, maintain the osmotic drive for drinking, and minimize the water clearance associated with a reduction in serum electrolytes.[9,59] Conversely, unusual weight gains can and should be used as a sign of overhydration.

Electrolyte Concerns

Electrolytes are lost in the sweat, and excessive losses of electrolytes can lead to cramping of muscles or severe medical problems. Losses of sodium, in particular during prolonged physical exertion, can be significant, and these losses will initially result in a proportional contraction of the extracellular volume to maintain normal serum sodium levels. Further losses can lead to hyponatremia. Hyponatremia has been observed in athletes who exercise for extended periods of time in the heat. Although drinking too much water or fluid with a low sodium content during prolonged exercise may result in hyponatremia,[19] excessive sodium loss through sweating is also a likely cause.[19,60] Hyponatremia is rare [19] but can be life-threatening.[61]

The best way to maintain electrolyte balance over prolonged exposure to heat is to drink CHO-E replacement beverages. Gisolfi and colleagues[9] concluded that 20 to 30 mEq/L of sodium in a sports drink should be protective; most commercial fluid replacement beverages provide sufficient sodium so that hyponatremia should not be a significant concern. The beverage selected should provide no more ions than indicated in Table 17-3.[62,63] The National Academy of Sciences recommends that chloride be the only "anion" (negatively charged electrolytes) accompanying sodium and potassium; no other electrolytes are recommended.[63] Typically, magnesium and calcium are present in most sport beverages but in amounts well below the recommended upper limits. If a rehydration solution containing 40 mEq of sodium per liter is consumed during the first 2 hours after prolonged exercise, sodium replacement will help restore fluid volume. In addition, foods that are high in water and rich in potassium should be eaten.

Energy Balance and Carbohydrate Needs

Although minimal information on the metabolic cost of military maneuvers in hot environments is available, several studies indicate expenditure values of over 4,000 kcal per day in a hot, humid jungle[64], hot-dry environments,[23] and hot-wet swamps.[65] In all cases, energy intakes were well below expenditures.[23,64,65] Others have reported an increased metabolic rate with acute heat exposure[66] and a 5% increase in oxygen uptake to perform a given task in the heat as compared with more comfortable conditions.[23] Thus, energy balance may be compromised when service members reside and work in a hot environment, and appetite may be suppressed in the hot weather, especially the first few days after arrival. This means that when living and working in temperatures ranging from 30ºC to 40ºC (86ºF to 104ºF), energy intakes should be increased somewhat, unless activity level decreases accordingly. One measure to offset any potential energy deficit is to enforce regular ingestion of CHO-E beverages, but the concentration of CHO should be lower under conditions of heat stress (5% to 7%) than in thermoneutral conditions so that the fluid is rapidly absorbed.

TABLE 17-3

UPPER LIMITS FOR SODIUM AND POTASSIUM IN FLUID REPLACEMENT BEVERAGES DURING HEAT STRESS

Units	Sodium	Potassium
mg/8 oz	165	46
mg/L	690	195
mEq/8 oz	7.2	1.2

Source: Commentary and summary. In: Marriott GM, ed. *Nutritional Needs in Hot Environments: Applications for Military Personnel in Field Operations*. Washington, DC: National Academy Press; 1993.

Cold Environments

Exposure to a cold environment, be it air or water, disrupts homeostasis and imposes a significant physiological strain. The consequences of cold stress are related to the severity of the cold stimulus. Performing daily activities and, ultimately, survival in such environments require that a new balance between heat production and heat loss be achieved. Under conditions of rest, the body's adaptive response to cold exposure is cutaneous vasoconstriction to minimize heat loss, followed by the onset of shivering, or cold-induced thermogenesis, to enhance heat production. When living or performing military training operations in the cold, the physiological strain may be mitigated by selected nutritional measures. These interventions strive to compensate for the adaptive responses to cold of increased urine output and energy expenditure. Therefore, the most important aspects of nutrition in a cold environment are hydration status, energy balance, and CHO intake.

Hydration Status

The initial physiological response to a cold environment is diuresis, which contributes to a reduction in plasma volume and ultimately dehydration. In addition, fluid losses in the cold are increased through respiration, reduction in fluid intake, and sweat lost from physical exertion. Urinary excretion of sodium, potassium, and other ions is also increased in the cold, but fluid losses are of greater concern. Plasma volume has been shown to decrease by as much as 17% during prolonged immersion in cold water.[67] Thus, maintenance of hydration status by drinking fluids is absolutely critical. Dann and colleagues[68] demonstrated that exertion in a cold environment is associated with a decrease in voluntary fluid intake, dehydration, and a reduction in glomerular filtration rate. They estimated that 0.15 L (0.16 qt) of fluid should be ingested each hour to avoid compromising kidney function. Given that the cold-induced diuresis results in a loss of sodium, potassium, and other cations in the urine, drinking fluids that provide electrolytes may be preferable,[67] but this intervention has not been carefully examined. In general, body weight and urine color should be monitored to ensure fluid needs are met. As in the heat, forced fluid ingestion of 0.25 to 0.75 L every 30 minutes may be required to achieve fluid balance. A CHO-E beverage, preferably a 5% to 7% solution, has been shown to improve physical performance in cold environments.[69]

Energy Balance

Studies of individuals and groups of civilians and military personnel indicate that exposure to cold environments can increase energy requirements 2- to 5-fold.[53,70] Expenditures as high as 7,500 kcal/d have been reported for Arctic expeditions.[71] Studies of military populations under conditions of moderate activity and extreme cold (–30ºC to –15ºC [–22ºF to 5ºF]) have noted energy expenditures of 4,200 to 4,750 kcal/d.[23,64,72] Coupled with these expenditures were intakes of fewer than 3,000 kcal/d. Thus, one of the major problems in the cold is maintaining energy balance.

Factors that may serve to increase energy needs include the added exertion due to wearing heavy clothing, shivering, the increased activity associated with traveling over snow and icy terrain, and the increased activity to keep warm. In general, energy requirements will increase in proportion to the intensity of shivering, the duration and relative intensity of the physical exertion, and the severity of the cold insult. Under resting conditions, a 3ºC to 4ºC decrease in core temperature invokes shivering and a significant increase in resting oxygen uptake.[73] Physical exertion is one way of promoting thermal balance by increasing metabolic heat production. However, physical exercise will increase energy requirements as well as heat loss due to increased blood flow to the skin and active muscles.[70] Metabolic heat production during exercise in cold air can override cold-induced heat losses when the exercise intensity is sufficiently high, but even intense exercise in cold water may not be adequate to compensate for heat losses.[74] Energy requirements should be unaltered in persons who are adequately clothed and protected from the environment.[70]

Carbohydrate Requirements

Both fats and CHOs are used as metabolic fuels, but CHO may contribute more to total energy metabolism in cold as compared with temperate environments.[70] Theoretically, dependence on CHO as the primary energy substrate might minimize heat loss by increasing metabolic heat production during exposure to cold. However, investigations have not supported the hypothesis that preferential metabolism of CHO will improve thermal balance. Vallerand and colleagues[75] demonstrated that feeding of high-CHO foods (100% and 68%), as compared with water, did not induce any detectable changes in either cold-induced thermogenesis, heat loss, or body temperature under resting conditions, despite a greater reliance on CHO as the energy substrate.

One of the adaptations to cold in the absence of adequate clothing and protection is shivering. As shivering increases, so does oxygen uptake, with the magnitude of increase being greater in cold water than cold air.[70] Because shivering requires a continuous supply of energy substrate to support the contractile process, significant research has focused on what substrate is preferentially used to maintain muscular contraction. Some investigators believe that CHOs are the primary source of energy for shivering thermogenesis, but this is controversial.[53,73,75,76] If CHOs were the only suitable energy substrate, glycogen stores would be rapidly depleted, and exposure time would be severely limited.

Numerous studies have been conducted to determine whether CHO or free fatty acids are preferentially utilized; protein oxidation is minimal. Vallerand and colleagues[73] demonstrated a 7-fold increase in CHO oxidation and a less than 2-fold increase in the oxidation of fatty acids during resting conditions. However, Martineau and Jacobs[77] were unable to demonstrate impaired thermal balance when intramuscular glycogen stores were low and the availability of plasma free fatty acids was reduced. Similarly, Young and colleagues[76] demonstrated that thermal balance was not compromised when initial muscle glycogen levels were low. Thus, it appears that when resting, the body compensates by using metabolic substrates other than muscle glycogen to maintain energy production.

It has been postulated that when exercise is performed in the cold, CHOs serve as the preferred substrate,[78] but utilization and mobilization of free fatty acids is accelerated during exercise in the cold.[79] Numerous studies have shown a relative decrease in the respiratory gas exchange ratio during low-to-moderate intensity exercise, whereas an increase or no change has been noted when the exercise is more vigorous.[78,79] The relative proportion of each substrate appears to depend on a variety of individual factors, such as percent of body fat, physical fitness, prior dietary patterns, and cold acclimation, as well as the type and intensity of the exertion and degree of cold stress.[78,80] When exercise and shivering occur in combination, the rate of muscle glycogen breakdown may be considerably accelerated as compared with an equivalent exercise bout in a warmer temperature.[78] Given that lipid stores are rarely limiting, a high-CHO diet would be preferable when exercising in the cold to ensure maintenance of glycogen stores necessary for maintaining metabolic heat production.[75] In addition, glycogen loading, or supercompensation, achieved by maintaining a diet high in CHO with minimal physical activity, may be effective in enhancing muscle and liver glycogen stores for exercise in the cold.

High-Altitude Environments

Ascent to altitude (> 3,050 m [10,000 ft]) imposes the stress of hypoxia in addition to stresses imposed by cold exposure. Hypoxia-induced adaptations of the oxygen delivery system include increased respiratory drive to increase oxygen delivery and enhanced extraction of oxygen by tissues; an increase in blood hemoglobin is a later adaptation. As with cold exposure, vasomotor adaptations strive to minimize heat loss and metabolic responses serve to generate heat, which is lost to the environment. Failure to invoke these multiple physiological adaptations can have serious consequences, even in the absence of physical activity.

With respect to physical training at altitude, emphasis has focused on substrate utilization, induction of energy pathways within the musculature, and respiratory fluid losses. One notable physiological response to exertion at altitude is an exaggerated blood lactate concentration for a given relative exercise workload;[81] this response may reflect an enhancement in glycolysis and preferential utilization of glycogen.[53] Interestingly, the exaggeration of blood lactate is diminished by acclimation,[81] which has been interpreted as a reduced reliance on glycolysis.[82] Nonetheless, several investigators have shown that there is a dependence on blood glucose for physical exercise at altitude; this reliance is further enhanced with acclimation.[82] These observations suggest that CHO is the preferred substrate and indicate the importance of nutritional interventions for maintaining performance and readiness. The major nutritional concerns at altitude include hydration status, energy balance, intake of CHO, and micronutrient needs.

Hydration Status and Electrolyte Needs

As in all environments where physical training is part of the daily activities, hydration status is a primary concern. At altitude, fluid balance becomes increasingly important because dehydration may be a factor in the development of acute mountain sickness. The rates and routes of fluid loss at altitude will depend on environmental conditions, including barometric pressure and consequent hypoxia, temperature, and humidity. These specific factors will determine the magnitude of the physiological adaptations affecting fluid balance. Adaptations include diuresis and natriuresis, which result in reduced volume of plasma and interstitial and intracellular fluid.[83] Moreover, respiratory fluid losses are increased because of the increased ventilatory drive in a dry and cold environment. Fluid losses are increased at altitude, and these losses must be compensated for to prevent dehydration and preserve personnel performance. Physical exertion may in part override the apparent reductions in total body water at altitude. Withey and colleagues[84] observed a small positive water balance in those who exercised over several days. This was attributed to an exercise-induced increase in plasma aldosterone. Despite a potential compensatory effect of exercise on overall body water, maintenance of hydration status remains essential. Forced fluid ingestion may be needed because a failure to drink enough water at altitude has been noted[85–88] and thirst does not always keep pace with fluid needs.

There are no recommendations for the exact amount of fluid required to maintain fluid balance at altitude. Reports[89] of water losses approximating 7.0 L/d have been challenged; these losses were based on the assumption that expired air is fully saturated with water vapor, and others have since shown this assumption to be incorrect.[90] Studies on Mount Everest and other locations have estimated fluid losses to be between 2.6 and 4.0 L/d; water balance has been achieved with intakes of 1.8 to 4.0 L/d.[85,87,88] Water losses of 2.5 to 5.1 L/d have been noted in subjects exposed to altitudes between 5,900 and 8,046 m over a 7-day period.[86] The losses were not met by water input, which ranged from 2.1 to 3.9 L/d. Worme and colleagues[91] demonstrated that fluid balance was maintained in men who ate a dehydrated ration and exercised vigorously for 31 days at moderate altitude (2,400 to 3,500 m) and drank approximately 5 L of fluid a day. They were, however, extremely conscientious about regular fluid ingestion. In general, the magnitude of sweat lost, CHO in the diet, activity level, range of daytime temperatures, absolute altitude reached, and duration of acclimation will determine the amount of water required to maintain hydration status. At a minimum, 1 L should be ingested for every 1,200 to 1,500 kcal consumed, and body weight should be monitored to ascertain needs. Future research should address this issue so that definitive recommendations can be provided.

Energy Balance

Virtually all persons who go to moderate or high altitudes experience some weight loss and loss of lean body mass. Many investigators have concluded that weight loss can be prevented by increasing energy intake at altitudes below 5,000 m, but a 5% to 10% weight loss may be inevitable at altitudes above 5,000 m due to decreased food intake.[86,92,93] Reasons for weight loss at high altitude include greater energy requirements, a reduction in food intake, loss of body water from increased ventilation and dry air, decreased fluid intake, malabsorption of nutrients, and acute mountain sickness, which can cause nausea, vomiting, headache, and decreased appetite.

Several studies have indicated a 6% to 50% increase in basal metabolic rate and the energy cost of physical exertion with altitude exposure[85,87,91,94]; these responses may be early adaptations to altitude. One report[94] noted increased oxygen uptake requirements of 3% to 35% at various exercise workloads at altitude as compared with sea-level requirements. Others[85] noted an initial 28% increase in basal metabolic rate when men were acutely exposed to altitudes of 4,300 m; after 10 days the increase was only 17%. Comparable increases have previously been estimated for women at similar altitudes.[95] Doubly labeled water has been used to determine the energy expenditure of climbers during ascent of Mount Everest,[88,92] with reported values ranging from 3,000 to 5,000 kcal/d. The high-energy expenditures have been attributed to an enhanced sympathetic drive in response to the initial stress of exposure, but an understanding of the mechanisms will require further study.

Another issue to address is the purported decline in energy intake. Subjects maintained in a hypobaric chamber for 40 days and who reached a final altitude of 8,884 m decreased their energy intake 43% and lost an average of 7.4 kg.[96] These results reinforce the notion of a declining food intake with altitude exposure, but not all studies support this finding. Subjects who remained at 5,050 m for 1 month increased their daily energy intake 45% (from sea-level intakes of 2,100 kcal to 3,200 kcal); weight loss averaged approximately 2.6 kg, or 3.8% of preexposure weight.[97] Similarly, others[91] have reported a 45% increase in daily energy intake (from about 2,350 kcal to about 3,500 kcal) in subjects who spent 1-month at 3,000 m, with a 1.9 kg loss (2.5% of initial body weight). Another study[85] reported increased intakes from 3,000 to 3,400 kcal/d; the subjects lost only 1% to 2% of their initial body weight. In contrast, energy intake averaged only 2,200 kcal/d during the Mount Everest expedition of Westerterp and colleagues[88] and only 1,900 kcal/d for the Mount Everest expedition of Reynolds and colleagues.[92] Part of the differences may reflect the altitude attained, the amount of activity, and the overall conditioning level of the participants, but it is also reasonable to conclude that weight loss can be minimized when palatable foods are provided and leaders emphasize the importance of food intake to maintain weight for strength and performance.

Intake of Carbohydrate

Given that glycogen stores may be a limiting factor for physical exertion at altitude, high-CHO foods have been considered the preferred energy substrate. In addition to repleting glycogen stores depleted by strenuous physical activity and shivering, CHO may improve metabolic efficiency by requiring less oxygen than fatty acids for complete oxidation. Moreover, a preferential reliance on CHO may be advantageous for the pulmonary system because it effectively decreases the physiological altitude by 305 to 610 m.[83] The higher respiratory quotient with CHO results in an increased alveolar oxygen partial pressure for a given alveolar carbon dioxide pressure.[98] A high-CHO diet has also been shown to increase physical performance after a rapid ascent to altitude.[99] Other studies indicate that consumption of CHO can blunt or delay the progression or severity of symptoms of acute mountain sickness. It has been suggested that individuals develop a preference for CHO-rich foods after ascending to altitude,[97] but this is not always the case.[92,93,96]

Investigations that have monitored CHO intake at altitude reveal inconsistent outcomes. Worme and colleagues[91] provided subjects a high-CHO diet (65% or approximately 575 g/d) and were careful to ensure that weight loss was minimal, even if complaints of bloating, flatulence, and abdominal distress were frequent. Kayser and colleagues[97] provided subjects a wide variety of palatable foods and found that CHO increased from 62% of energy intake at sea level to 77.3% after three weeks at 5,050 m; this finding supports a preference for CHO foods. In contrast, when subjects had free access to palatable food in a hypobaric chamber for 40 days, the percent of CHO in the diet declined from 62% before the exposure to 53%. Rose and colleagues[96] concluded that prolonged altitude exposure was associated with a reduction in their selection of foods high in CHO. However, their findings in a hypobaric environment may reflect a response quite different from what might be encountered on a mountain, so a diet that derives a major proportion of energy from CHO is still recommended.

Energy expenditure estimates should be used to determine the absolute amount of CHO. In general, the breakdown of energy should be 60% to 65% from CHO, 10% to 15% from protein, and 20% to 30% from fat. When energy requirements are above 4,000 kcal, however, more fat may be required because it is difficult to obtain sufficient calories from CHO alone. Recommendations for the approximate gram amounts of CHO, protein, and fat for various energy levels are shown in Table 17-4. At a minimum, 400 g of CHO should be consumed; this can be accomplished by eating high-CHO snacks between meals and drinking warm CHO-E beverages during activity and recovery periods.

TABLE 17-4

APPROXIMATE NUMBER OF GRAMS OF CARBOHYDRATE, PROTEIN, AND FAT RECOMMENDED FOR VARIOUS ENERGY INTAKE LEVELS DURING SUSTAINED AND HIGH-TEMPO OPERATIONS

Energy Level (kcal)	Carbohydrate (g)	Protein (g)	Fat (g)
3,000	450	110	85
3,500	525	115	100
4,000	600	125	120
4,500	675	135	140
5,000	700	160	170

Micronutrient Needs

Increased intakes of selected vitamins and minerals may be needed for maintaining performance at altitude where hypoxia and thermal challenges prevail. For example, the classic response to hypoxia is blood volume expansion, increased erythropoiesis, and increased hemoglobin concentration 1 to 3 weeks after ascent. The primary nutrient required for hemoglobin synthesis is iron.[100] For this reason,

TABLE 17-5

SUGGESTED ADDITIONAL AMOUNTS OF VITAMINS AND MINERALS FOR SOJOURNS TO ALTITUDE

Nutrient	Suggested Amount	% of RDA
Vitamin E	400 IU	4,000
Vitamin B_1 (thiamin)	3 mg	200
Vitamin B_2 (riboflavin)	2 mg	118
Vitamin B_3 (niacin)	5 mg	26
Pantothenic acid	5 mg	100
Folic acid	200 µg	100
Vitamin B_{12}	1 µg	50
Iron	5 mg	33
Magnesium	200 mg	57
Zinc	5 mg	33

Sources: Reynolds R. Nutritional needs in cold and in high-altitude environments. In: Marriot BM, Carlson-Newberry SJ, Institute of Medicine Committee on Military Nutrition Research. *Nutritional Needs in Cold and in High-altitude Environments: Applications for Military Personnel in Field Operations*. Washington, DC: National Academy Press; 1996; Committee on Dietary Allowances, Food and Nutrition Board, National Research Council. *Recommended Dietary Allowances*. 10th ed. Washington, DC: National Academy Press; 1989.

many investigators have examined changes in iron stores, hematocrit, hemoglobin, and serum iron with altitude exposure.[91] Adequate iron stores are necessary for hematological adaptations to the hypoxia of altitude[101] but supplementation with iron is beneficial only when iron stores are inadequate.

Requirements of vitamins used for energy metabolism, including thiamin, riboflavin, and niacin, may also increase. When energy intake is sufficient to meet energy needs, the intake of these nutrients is also sufficient. Given that energy intake is typically compromised at altitude, however, supplemental intake of specific nutrients may be necessary to meet the increased requirements.[102] In addition, higher intakes of certain vitamins and minerals may be protective against some of the pathological changes that occur at altitude.[103] The increased metabolic rate and hypoxic conditions at altitude can increase the production of harmful free radicals, which may compromise the circulatory system and impair physical performance. Taking greater amounts of the antioxidant vitamin E may be protective against oxidative injury. Preliminary findings indicate that taking 400 mg of vitamin E daily at high altitude reduced free radical production and maintained anaerobic performance in men.[104] Vitamin E supplementation also appears to prevent some of the rheological disturbances induced by high altitude.[102] Vitamin and mineral recommendations were proposed in 1995 to account for possible increased requirements of specific nutrients at altitude.[105] The recommendations were derived from intake data from field studies, urinary excretion of nutrients, other measures of "nutrient status," and the well-documented reduction in food intake. Table 17-5 presents the suggested additional amounts of nutrients that may be necessary when working in the cold at altitude.

OPERATIONAL RATIONS

When the tactical situation and unit missions preclude the use of kitchen equipment for preparing warm meals for the group, individually packaged rations are the next line of field feeding. Individually packaged operational rations may be wet-pack (sealed in a pouch without any of the food's moisture being removed) or dehydrated and can be consumed hot or cold. The dehydrated rations can usually be reconstituted with hot or cold water or consumed dry. All of the individual field rations are specifically designed to supply adequate energy and nutrients for particular types of missions. Since the duration and environmental conditions of missions vary, different types of operational rations have been developed. These rations provide different amounts of energy, with varying proportions of CHO, protein, and fat, to meet the nutritional demands of various operational scenarios. Although many people think that military rations are suboptimal, they have been carefully designed and will sustain service members during deployment. A number of rations are available, and these rations are discontinued, improved, or modified based on an annual ration review. Some of the rations introduced after 1995 include the Unitized Group Ration and the Go-To-War Ration. The Unitized Group Ration is for sustaining groups of service members during deployments where organized food service facilities can be set up. In contrast, the Go-To-War ration is for sustaining an individual during the early states of mobilization when other options are not available. This ration augments other rations and does not replace them. In addition, Food Packet, Survival rations have been reformulated and have several types, such as General Purpose, Improved; Abandon Ship; and Aircraft, Life Raft. Detailed information about these operational rations can be obtained elsewhere.[106] Commonly used operational rations are described below.

Meal, Ready-to-Eat, Individual

The ration known as the MRE (Meal, Ready-to-Eat) is used to sustain the individual service member during operations when organized food service is unavailable. The MRE menus are revised periodically, and the number of menus doubled to 24 between 1995 and 1998, with the production of MRE XVIII. The ration for 1 day comprises three meals and provides about 3,900 kcal (51% CHO, 13% protein, and 36% fat; sodium content: 5.5 g). Each MRE contains an entree, crackers, a spread (cheese, peanut butter, or jelly), a dessert or snack, beverages, an accessory packet, a plastic spoon, and a flameless ration heater (Table 17-6). When included, the supplemental pouch bread will provide an additional 200 kcal (55% CHO, 12% protein, and 33% fat). About 23 oz of water is required to rehydrate the beverages.

MREs provide the essential nutrients and maintain readiness if they are consumed by the service members. Three MREs may need to be eaten each day when MREs are the sole source of nutrition. Some components of the MRE have been supple-

TABLE 17-6

12 MENUS FOR MEAL, READY-TO-EAT, INDIVIDUAL (MRE XVIII)

Menu 3	Menu 4	Menu 6	Menu 7	Menu 8	Menu 9
Chicken stew	Ham slice	Grilled chicken	Pork chow mein	Chicken w/ rice	Beef stew
Pretzels	Buttered noodles	Mexican rice	Chow mein noodles	Fudge brownie	Tavern nuts
Pound cake	Pound cake	Pound cake	Cookie, choc-covered	Jalapeno cheese spread	Jalapeno cheese spread
Jelly	Cheese spread	Jelly	Peanut butter	Beverage base	Cocoa
Cocoa	Cocoa	Cocoa	Beverage base	Packet A	Packet B
Packet C	Packet C	Packet D	Packet A		
Menu 10	**Menu 12**	**Menu 15**	**Menu 16**	**Menu 18**	**Menu 20**
Chili w/mac	Cheese tortellini (vegetarian)	Beef franks	Bean & rice burrito (vegetarian)	Turkey breast w/ potatoes	Spaghetti w/ meat sauce
Fig bar	Applesauce	Potato sticks	Fruit	Pound cake	Cheese curls
Peanut butter	Granola bar	Peanut butter	Fruit-filled bar	Cheese spread	Peanut butter
Cocoa	Peanut butter	Candy*	Peanut butter	Chewy choc bar	Candy*
Packet D	Candy*	Beverage base	Peanut brittle	Beverage Base	Cocoa
	Packet D	Packet A	Packet D	Packet D	Packet C

Each menu contains crackers, hot sauce, flameless ration heater, and spoon.
Packet A: coffee, cream substitute, sugar, salt, chewing gum, matches, toilet tissue, towelette
Packet B: coffee, cream substitute, sugar, salt, chewing gum, matches, toilet tissue, towelette, candy (vanilla caramels or Tootsie Rolls)
Packet C: lemon tea w/sugar, salt, chewing gum, matches, toilet tissue, towelette
Packet D: lemon tea w/sugar, apple cider, salt, chewing gum, matches, toilet tissue, towelette
*Jolly Rancher candy, heat stable M&Ms, Peanut Munch bar, or Skittles.
Menus listed in this table are reviewed annually and may change over time.

mented with selected vitamins (ie, A, B_1, B_2, niacin, B_6, and C) and minerals (ie, calcium), and so these items must be eaten to meet nutrient requirements. Fortified items include cocoa beverage powder, cheese spread, peanut butter, crackers, and the coatings of the oatmeal cookies and brownies.

Ration, Cold Weather

The Ration, Cold Weather (RCW) was designed to sustain individuals during operations in cold conditions, and each menu provides 4,500 kcal (60% CHO, 8% protein, and 32% fat; sodium content: 5 g). The six menus, which come as two meal bags (Bag A and Bag B), should provide sufficient energy to meet requirements during strenuous activities in the extreme cold. The various menus are shown in Table 17-7. The RCW is high in CHO since this macronutrient is believed to generate more metabolic heat. Each menu should be sufficient for a 24-hour period, but more can be eaten when energy demands are higher. The RCW is also lower in salt and protein than the MREs to reduce daily water requirements and lessen the possibility of dehydration. A 1-day ration requires 90 oz (about 9 cups or 3 canteens) of water for rehydration.

Food Packet, Long Range Patrol II

The Food Packet, Long Range Patrol II (LRP II) ration was designed for initial assaults, special operations, and long-range reconnaissance missions. The LRP II is a restricted calorie ration, and one packet is issued to an individual per day for up to 10 days. Eight of the twelve menus, consisting of dehydrated entrees, cereal bars, cookies and candy, instant beverages, accessory packets, and plastic spoons, are shown in Table 17-8. Each menu provides 1,560 kcal (50% CHO, 15% protein, 35% fat; sodium content: 2.6 g) and requires approximately 28 oz of water to prepare, although some of the foods may be eaten dry. It is lightweight, has been

TABLE 17-7

12 MENUS FOR RATION, COLD WEATHER

BAG A					
Menu 1	**Menu 2**	**Menu 3**	**Menu 4**	**Menu 5**	**Menu 6**
Oatmeal, strawberry & cream	Oatmeal, apple & cinnamon	Oatmeal, apple & cinnamon	Oatmeal, maple & brown sugar	Oatmeal, apple & cinnamon	Oatmeal, apple & cinnamon
Nut raisin mix	Nut raisin mix	Nut raisin mix	Nut raisin mix	Nut raisin mix	Nut raisin mix
Cocoa beverage powder (2)	Cocoa beverage powder (2)	Cocoa beverage powder (2)	Cocoa beverage powder (2)	Cocoa beverage powder (2)	Cocoa beverage powder (2)
Apple cider mix	Apple cider mix	Apple cider mix	Apple cider mix	Apple cider mix	Apple cider mix
Chicken noodle soup	Chicken noodle soup	Chicken noodle soup	Chicken noodle soup	Chicken noodle soup	Chicken noodle soup
Fruit bars (fig or	Fruit bars (fig or blueberry)	Fruit bars (fig or blueberry)	Fruit bars (fig or blueberry)	Fruit bars (fig or blueberry)	Fruit bars (fig or blueberry)
Crackers (2)	Crackers (2)	Crackers (2)	Crackers (2)	Crackers (2)	Crackers (2)
Spoon	Spoon	Spoon	Spoon	Spoon	Spoon
Accessory packet	Accessory packet	Accessory packet	Accessory packet	Accessory packet	Accessory packet
BAG B					
Menu 7	**Menu 8**	**Menu 9**	**Menu 10**	**Menu 11**	**Menu 12**
Chicken stew	Chicken stew	Chili con carne	Chicken a la king	Chicken & rice	Spaghetti w/ meat sauce
Granola bars (2)	Granola bars (2)	Granola bars (2)	Granola bars (2)	Granola bars (2)	Granola bars (2)
Oatmeal cookie bars (2)	Oatmeal cookie bars (2)	Oatmeal cookie bars (2)	Oatmeal cookie bars (2)	Oatmeal cookie bars (2)	Oatmeal cookie bars (2)
Chocolate-covered cookie or brownie	Chocolate-covered cookie or brownie	Chocolate-covered cookie or brownie	Chocolate-covered cookie or brownie	Chocolate-covered cookie or brownie	Chocolate-covered cookie or brownie
Orange beverage powder	Orange beverage powder	Orange beverage powder	Orange beverage powder	Orange beverage powder	Orange beverage powder
Tootsie Rolls	Tootsie Rolls	Tootsie Rolls	Tootsie Rolls	Tootsie Rolls	Tootsie Rolls
M&Ms	M&Ms	M&Ms	M&Ms	M&Ms	M&Ms
Lemon tea (2)	Lemon tea (2)	Lemon tea (2)	Lemon tea (2)	Lemon tea (2)	Lemon tea (2)
Spoon	Spoon	Spoon	Spoon	Spoon	Spoon

Accessory packet: coffee, cream, sugar, chewing gum, toilet paper (2), matches, closure device (2)

accepted by military personnel, and is relatively inexpensive. To obtain adequate CHO and calories during extended operations, at least two menus would need to be eaten; only 195 g of CHO are provided. Alternatively, the LRP II and the MRE can be combined to meet additional calorie requirements; the two rations are nutritionally compatible.

Other Information

The best way to select a ration is to estimate the anticipated energy expenditure during the deployment. The ration for any mission that involves strenuous physical activity should provide at least 400 g of CHO. One distinct advantage of the military ration is that the nutritional content is known; there is no need to count calories on labels to get the desired energy distribution. For example, if the mission is in a cold environment, the RCW is an excellent ration to choose because it provides 4,500 kcal/d with an appropriate distribution of CHO, protein, and fat. If the rations are prepared as instructed, freeze-dried rations will not increase the need for water unless greater amounts of sodium

TABLE 17-8

EIGHT OF THE TWELVE MENUS FOR THE FOOD PACKET, LONG RANGE PATROL II (LRP) FOR FISCAL YEAR 1996

Menu 1	Menu 2	Menu 3	Menu 4
Chicken Stew	Beef Stew	Sweet & sour pork w/rice	Turkey tetrazini
Fruit-filled cereal bar	Granola bar	Chocolate sports bar	Granola bar
Oatmeal cookie bar	Chocolate-covered cookie	Jelly	Chocolate-covered cookie
Peanut Munch bar	Tootsie Roll (4pk)	Crackers	Caramels
Apple cider drink	Cocoa beverage	Apple cider drink	Cocoa beverage
Accessory packet	Accessory Packet	Accessory packet	Accessory packet
Spoon	Spoon	Spoon	Spoon
Menu 5	**Menu 6**	**Menu 7**	**Menu 8**
Chicken & rice	Spaghetti w/meat sauce	Chili con carne	Beef w/rice
Apple cinnamon pastry	Chocolate sports bar	Fruit-filled bar	Cornflake bar
Peanut butter	Fig bar	Crackers	Fig bar
Crackers	Crackers	Starch jellies (Chuckles)	M&Ms
Lemon tea (2 pkts)	Cocoa beverage	Orange beverage	Beverage base (MRE)
Accessory packet	Accessory packet	Accessory packet	Accessory packet
Spoon	Spoon	Spoon	Spoon

Accessory packet: coffee, creamer, sugar, chewing gum, toilet paper (2), matches, salt

or protein are added to them.

As long as the package is left unopened, stored properly (low humidity and at less than 27°C [80°F]), and not handled excessively, most military rations will be usable for at least 3 years; the MRE and RCW have shelf lives of 3 years. The ration with the longest shelf life is the LRP II, which has an estimated life of 10 years at 27°C.

SUMMARY

During deployment, military personnel typically undergo sustained operations under a variety of environmental extremes. Exposure to these multiple physiological challenges can result in performance decrements, often due to dehydration and weight loss. Nutritional interventions that minimize such physical changes will mitigate physiological strain, facilitate adaptation, and promote readiness. The primary nutritional considerations for deployment are maintaining fluid, electrolyte, and energy balance and obtaining the right proportion of energy from CHO, protein, and fat.

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