Wildland Firefighter
Health & Safety Report
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Background

This report, the ninth in a series, reviews activities related to the Missoula Technology and Development Center (MTDC) project on wildland firefighter health and safety. The project focuses on three main areas:

Work, rest, and fatigue: Determine work/rest guidelines, assignment length, and fatigue countermeasures for crews and overhead.

Energy and nutrition: Improve energy intake, nutrition, immune function, and the health of wildland firefighters.

Fitness and work capacity: Use work capacity and medical standards to ensure the health, safety, and productivity of wildland firefighters.

Micronutrients

Previous editions of this report have considered the macronutrient needs of wildland firefighters—the energy supplied by carbohydrates, fats, and proteins. This edition focuses on micronutrients, the vitamins and minerals required to sustain health and perform prolonged arduous work. The featured topic summarizes the recommendations of authoritative organizations on vitamin and mineral supplements, reviews studies of individuals involved in prolonged work (such as soldiers and ultraendurance athletes), and discusses gaps in current knowledge. The research section summarizes field studies conducted during the 2004 fire season on cognitive function, hydration, core temperature, and electrolytes. An overview of vitamin and mineral needs is provided in the Risk Management section, and the Field Notes section illustrates how to meet vitamin and mineral requirements during the fire season.

See the new Pyramid at *www.mypyramid.gov* and the *Dietary Guidelines for Americans* 2005 (page 6).

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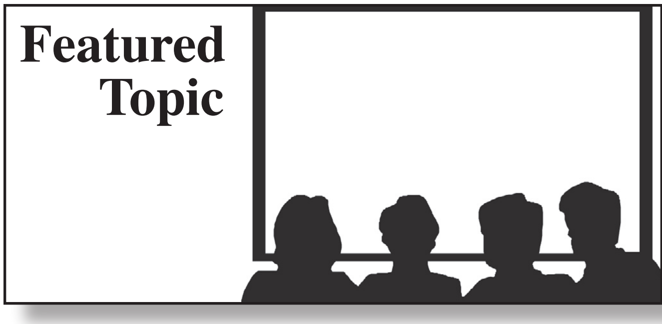

Vitamin and Mineral Supplements

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Since the 1960s, MTDC and the University of Montana Human Performance Laboratory have evaluated the energy and nutrition needs of wildland firefighters. Field studies consistently show a high level of energy expenditure. Energy needs average about 7.5 kilocalories per minute, more than 400 kilocalories per hour. In 1998, Drs. Brent Ruby and Brian Sharkey studied firefighter total energy expenditure during 5 days of wildland fire suppression.

Using sophisticated doubly labeled water techniques, they found that the energy expenditures ranged up to and beyond 6,000 kilocalories per day. The data showed that firefighters lost total and fat-free weight during the work period, despite the availability of sufficient food in fire camp meals.

Because of those findings, liquid and solid energy supplements have been incorporated into firefighter nutrition. The supplements improve performance, decisionmaking, hydration, and immune function.

High metabolic rates increase the need for micronutrients. Firefighters work in a harsh environment, and are exposed to smoke, heat, cold, sunshine, stress, and exhaustion—conditions that increase oxidative stress and the need for vitamins and minerals.

Nutritional analysis of the food provided to firefighters suggests that energy and micronutrient needs will be met, so long as the firefighter eats enough of the right types of food, including carbohydrate and protein-rich foods, nine or more servings of fruits and vegetables, and several servings of whole grains daily. Some firefighters do not follow this recommendation. This article reviews studies of individuals involved in prolonged work, summarizes recommendations of authoritative organizations, and discusses gaps in current knowledge.

Recommendations

The following organizations have made recommendations for vitamin and mineral supplements based on extensive review of the scientific literature. The summaries below include specific recommendations for those involved in high levels of exertion.

American Dietetic Association: The best nutritional strategy for promoting optimal health and reducing the risk of contracting chronic diseases is to obtain adequate nutrients from a wide variety of foods. Vitamin and mineral supplements are appropriate when well-accepted, peer-reviewed, scientific evidence shows that they are safe and effective.

American Heart Association (AHA): The *AHA Dietary Guidelines Revision* (2000) says that vitamin and mineral supplements are not a substitute for a balanced and nutritious diet based on fruits, vegetables, and grains. A science advisory published in *Circulation* (2004) showed that antioxidants (vitamins C, E, and beta carotene) have no effect on preventing or treating cardiovascular diseases.

A recent review of 19 clinical trials, reported at the 2004 meeting of the AHA, indicated that individuals who supplemented their diets with an average of 400 IU (international units) of vitamin E daily had a small but statistically greater risk (10 percent) of dying from any cause, compared to those who did not take the supplement.

American Cancer Society: The society recommends a well-balanced diet and does not recommend the use of vitamin and mineral supplements as a preventive or therapeutic intervention.

American Academy of Family Physicians: The academy states that the decision to provide special dietary intervention or nutrient supplements must be on an individual basis, using the family physician's best judgment based on evidence of benefit as well as lack of harmful effects. Megadoses of certain vitamins and minerals have proven harmful.

U.S. Preventive Services Task Force: The task force published recommendations concerning vitamin supplementation to prevent cancer and cardiovascular disease. Task force members conclude that the evidence is insufficient to recommend for or against the use of supplements of vitamins A, C, or E; multivitamins with folic acid; or antioxidant combinations for the prevention of cancer or cardiovascular disease (2003). They recommend that individuals avoid taking take beta carotene to lower the incidence of disease.

Heart Outcomes Prevention Evaluation: In patients at high risk for cardiovascular events, treatment with vitamin E (400 IU daily) for an average of 4.5 years had no apparent effect on their cardiovascular outcomes (*New England Journal of Medicine* 2000).

Mayo Clinic: Whole foods are the best sources of vitamins and minerals. They offer three main benefits over supplements:

- Whole foods are complex; they contain a variety of micronutrients.
- Whole foods provide dietary fiber that reduces the risk of cancer, diabetes, and heart disease.
- Whole foods contain other substances that appear to be important for good health. Fruits contain chemicals that may help protect against cancer, diabetes, heart disease, and hypertension. For more information, visit the Mayo Clinic's Web site, *http://mayoclinic.com*.

Summary: These recommendations reflect current scientific data that do not support the use of vitamin and mineral supplements. While studies indicate the value of a diet that includes specific vitamins and minerals, supplementation with specific nutrients does not provide the expected benefit. Supplements are not a substitute for a balanced and nutritious diet. Foods include numerous micronutrients and their benefits may depend on the mixture, not on the individual nutrient used as a supplement.

Vitamins in food have proven more effective than vitamin supplements.

Nutrition and Performance

The increased energy and nutrient demands of performance in work and sport call for more specific micronutrient recommendations. In 2000, the American College of Sports Medicine, the American Dietetic Association, and the Dietitians of Canada published recommendations for nutrition and athletic performance. They recommend appropriate selection of food and fluids, timing of their intake, and supplemental choices for optimal health and performance. They state:

Athletes will not need vitamin and mineral supplements if adequate energy to maintain body weight is consumed from a variety of foods.

However, supplements may be required by athletes who:

- Restrict energy intake
- Use severe weight-loss practices
- Eliminate one or more food groups from their diet
- Consume high-carbohydrate diets with low micronutrient density

Nutritional performance-enhancing aids should be used with caution, and only after carefully evaluating the product for safety, efficacy, and potency.

American College of Sports Medicine (ACSM): A current comment by the ACSM on vitamin and mineral supplements notes that athletes may be using dietary supplements to gain a competitive advantage. However, athletes should be aware that:

- They should consume a variety of foods rather than nutritional supplements to optimize the vitamins and minerals in their diet.
- Performance will not be improved if individuals already are consuming nutritionally adequate diets.
- Only athletes with a defined nutritional deficiency will benefit from supplementation of the limiting nutrient(s).
- The nutritional adequacy of an individual's diet should be evaluated by a registered dietician experienced in counseling athletes.
- Megadoses of vitamins and minerals are not recommended because of the possibility of toxicity and adverse interactions among nutrients.
- Physically active people who intermittently use vitamin and mineral supplements should use a product that does not exceed the DRI (Dietary Reference Intake) for essential nutrients.

Military Nutrition: The Committee on Military Nutrition Research of the Institute of Medicine's Food and Nutrition Board has reviewed strategies for sustaining nutrition and immune function in the field (1999). The committee does not recommend vitamin and mineral supplementation of military rations above recommended daily allowance levels. It recommends that, when needed, the preferred method of providing supplemental nutrients is through a ration component. It also recommends that the military gain a better understanding of the prevalence of supplement use and abuse by personnel and make strong recommendations for the use or nonuse of supplements.

Summary

Reputable organizations and scientific studies do not support the use of vitamin and mineral supplements to prevent or reduce the risk of disease. They do recommend a balanced diet using a variety of foods, with emphasis on fruits, vegetables, and whole-grain products.

Athletes will not need vitamin and mineral supplements if their diets provide enough energy to maintain their body weight and come from a variety of sources. Supplements may be required in specific cases. The Committee on Military Nutrition Research does not recommend vitamin and mineral supplements for military personnel whose workloads are similar to those experienced by wildland firefighters.

Vitamins and Minerals

Vitamins: Scientific evidence does not support a performance-enhancing benefit of vitamin supplements in individuals who consume a well-balanced diet. Any improvement in physical performance attributed to the use of vitamin supplements in an adequately nourished individual could be the result of a placebo effect. Vitamins are organic compounds that function as regulators of protein, carbohydrate, and fat metabolism. They are needed to transform the potential energy in food to chemical energy for work. Vitamins are not direct sources of energy.

Vitamins are classified according to their solubility. B-complex vitamins and vitamin C are water soluble. Excess quantities of these vitamins are flushed away in the urine. Large doses of vitamin C can cause adverse effects, such as gastrointestinal disturbances and the formation of kidney stones. Fat-soluble vitamins (A, D, E, and K) are ingested with fats in the diet. Amounts in excess of daily needs are stored in body tissues; megadoses can have adverse effects or become toxic (for example, megadoses of vitamins A and E).

Intense exertion produces compounds called free radicals. These highly reactive compounds can damage muscle tissue and have been associated with heart, cancer, and vision problems. The so-called antioxidants—vitamins C, E, and beta carotene, along with the minerals selenium and zinc—may protect against some effects of reactive oxidative radicals.

Related Studies: Recently, the use of antioxidant vitamins has been suggested to promote health and enhance performance. Long- or short-term supplementation with these vitamins has no effect on submaximal performance, aerobic capacity, or muscle strength. Evans (*American Journal of Clinical Nutrition*, 2000) recommended vitamins E and C for endurance athletes to protect them from oxidative stress and reduce the rate of lipid oxidation, that could be associated with the risk of heart disease.

The results of studies of vitamin C and E in endurance athletes have been inconclusive or negative. Vitamin C supplements failed to reduce exercise-induced oxidative stress and decreases in immune function during an ultramarathon (Nieman and others, *Journal of Applied Physiology*, 2002). Two months of vitamin C (1,000 milligrams daily) did not decrease the incidence of upper respiratory tract infections in marathon runners (Himmelstein and others, *Journal of Exercise Physiology*, 1998). Two months of vitamin E (800 IU daily) were associated with an increase—not a decrease—in lipid oxidation and inflammation during a triathlon. The vitamin E dosage may have been so high it reversed the antioxidant effects (Nieman and others, *Medicine and Science in Sports and Exercise*, 2004). Additional research is needed to justify vitamin supplementation in endurance athletes.

Minerals: Minerals (such as calcium, iron, zinc, selenium, sodium, potassium, and magnesium) are inorganic elements that act as cofactors for the enzymes that influence all aspects of energy metabolism. They also act as electrolytes in cellular processes. Minerals are not sources of energy. Mineral status may be impaired in individuals who restrict their energy intake during training and performance, or who exclude important food groups.

Performance improves when mineral deficits are reduced. High sweat rates lead to the loss of some minerals. Mineral supplements, especially in those with adequate nutrition, can have detrimental effects, ranging from gastric upset to a copper deficiency and reduced levels of HDL (good) cholesterol (caused by zinc supplements). High doses of some vitamins and minerals can lead to neurological damage and may interfere with the absorption of other nutrients.

Zinc may subtly reduce cold symptoms. Iron is prescribed for those with verified iron deficiency, and calcium is used by those at risk for osteoporosis (loss of bone density). High consumption of cola drinks increases the risk of osteoporosis. The sodium and potassium lost in sweat during work in the heat can be replaced during meals, when snacking, and when drinking carbohydrate/electrolyte beverages. Salt tablets that are sometimes used to replace sodium can cause gastrointestinal distress and elevate blood pressure.

Gaps in Knowledge

Recommendations on vitamin and mineral supplements that are appropriate for the general population do not address the concerns of wildland firefighters. Recommendations for endurance athletes are more specific in regard to high energy expenditures during training and performance. Military nutrition recommendations are most specific in regard to energy requirements, environmental conditions, and stress. However, there is limited information on which to base a recommendation for vitamin and mineral supplements for wildland firefighters.

While we know the energy and nutrient content of fire camp meals, we do not know the extent to which firefighters select and eat foods that meet nutritional guidelines. Failure to meet guidelines may be tolerable during short deployments, but over a full season of work, nutritional deficits could lead to decreases in work performance, reduced immune function, and possible illness. Field studies could provide information concerning nutrient intake and the need for wildland firefighters to receive vitamin and mineral supplements.

Conclusions

The increased energy and nutrient demands of wildland firefighting should be met by a balanced diet based on a variety of foods, including carbohydrate and protein-rich foods, nine or more servings of fruits and vegetables, and several servings of whole grains daily.

Firefighters who are unable or unwilling to include a wide variety of foods from all the food groups could consider a multiple vitamin and mineral supplement, not to exceed the DRI. Doses that exceed the DRI should be reviewed by a registered dietician familiar with the individual and the energy demands of the job. High doses of some vitamins and minerals could lead to toxicity and interfere with the absorption of other nutrients. No scientific data or authoritative organizations support nutritional supplements for wildland firefighters.

Recommendations

To assess micronutrient needs of wildland firefighters, the authors recommend:

- Short-term (14-day) and season-long evaluation of firefighter nutritional status. Field studies will provide information concerning energy and nutrient intake and the need for vitamin and mineral supplements. Type I and II firefighters should be included in the analysis.
- Development of a nutritional guidance program that can be introduced in training and emphasized in fire camps. The program would use printed materials (brochures and posters), Web sites, PowerPoint presentations, and counseling on diets and other information to reach a broad audience.
- If field data support the need for supplements, they should be incorporated in a ration component (such as an energy bar with antioxidant supplements).

For more information on vitamins and minerals, see the Risk Management and Field Notes sections.

Dietary Guidelines for Americans 2005

The Dietary Guidelines for Americans 2005 (*http://www.health.gov/dietaryguidelines/dga2005*) provide science-based advice to promote health and to reduce the risk for major chronic diseases through diet and physical activity. The guidelines state that nutrient needs should be met primarily by consuming food. Key recommendations include:

- Consume a variety of nutrient-dense foods and beverages from the basic food groups while choosing foods that limit the intake of saturated and trans fats, cholesterol, added sugars, salt, and alcohol.
- Two cups of fruit and 2½ cups of vegetables per day are recommended for a 2,000-calorie daily diet. The amount of fruits and vegetables recommended will vary according to the amount of calories in the diet.
- Consume three or more ounce-equivalents of whole-grain products per day, with the remaining three ounce-equivalents coming from enriched or whole-grain products.
- Consume 3 cups per day of fat-free or low-fat milk (or equivalent milk products).

For weight management, the guidelines recommend:

- To maintain body weight in a healthy range, balance calories consumed from foods and beverages with the calories expended.
- To prevent gradual weight gain over time, make small decreases in the calories consumed in food and beverages and increase physical activity.

For physical activity, the guidelines recommend:

- Engage in regular physical activity and reduce sedentary activities to promote health, psychological well-being, and a healthy body weight.
  - Engage in at least 30 minutes of moderate-intensity physical activity most days of the week.
  - Greater health benefits can be obtained by engaging in more vigorous physical activity or by exercising longer.
  - To help manage body weight and prevent gradual, unhealthy body weight gain, engage in about 60 minutes of moderate to vigorous physical activity most days of the week.
  - To sustain weight loss, participate in at least 60 to 90 minutes of moderate physical activity daily.

Achieve physical fitness by including cardiovascular conditioning, stretching exercises for flexibility, and resistance exercises or calisthenics for muscular strength and endurance.

Research

This section reviews project-related field studies conducted on wildland firefighters during the 2004 fire season. The studies were conducted by researchers from the University of Montana Human Performance Laboratory in cooperation with MTDC and with support from the National Wildfire Coordinating Group.

Supplemental Feeding and Cognitive Function

Field studies have shown that wildland firefighters can maintain their blood glucose levels by ingesting supplemental carbohydrate, either as a liquid or solid. Supplemental carbohydrate allows firefighters to increase their total daily work without affecting their perception of how hard they have worked. This study examined the effect of supplemental carbohydrate on cognitive performance and decisionmaking.

Hotshot crews performed reaction and mathematical processing (cognitive) tests on a hand-held microprocessor. The cognitive test was completed and a blood glucose sample was taken before breakfast, immediately before the work shift, and immediately after the work shift. Subjects recorded hourly estimates of work intensity and wore an activity monitor that measured energy expenditure throughout the shift. Data were collected on each subject during two 12-hour days of wildland fire suppression, once with subjects drinking supplemental carbohydrate every hour, and once with subjects drinking a flavored placebo.

When subjects ingested 200 milliliters of a 20-percent carbohydrate liquid every hour (160 kilocalories), they maintained blood glucose and sustained a significantly higher level of work output (figure 1).

The increase in total activity during the 12-hour shift was significant when compared to the activity of subjects who received a placebo. In this study, the difference, which occurred after lunch, represented an increase of 16.6 percent for the carbohydrate group, the equivalent of 2 hours of additional work.

There was no significant difference in the sleep score, perceived exertion, and cognitive test scores for the two groups. The mean reaction time for correct responses was faster after the shift for the group receiving supplemental carbohydrate, while the reaction time was significantly slower for the group that did not receive supplemental carbohydrates. Eating carbohydrates at regular intervals may benefit wildland firefighters, based on:

- Maintenance of blood glucose
- High work output without a perception of working harder
- The slight improvements in decisionmaking and reaction time
- Anecdotal reports that the firefighters felt better, and were not as hungry when they had supplemental carbohydrates.

The results suggest that wildland firefighters are not becoming mentally fatigued at the end of a 12-hour shift. In addition, they show that firefighters are more alert at the end of the shift than earlier in the day. Whether firefighters can stay mentally alert for longer periods has yet to be determined, but research by our laboratory and the military would suggest that cognitive and physical performance can be maintained for longer periods, especially when blood glucose is maintained.

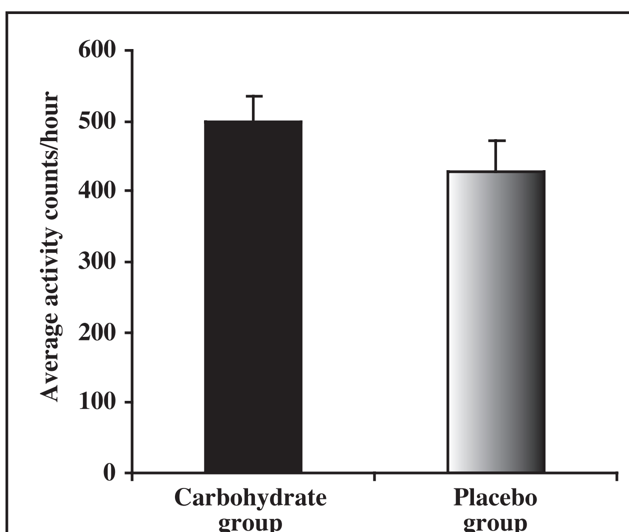


Figure 1— Firefighters worked harder when they received supplemental carbohydrate. The hourly average activity counts are measured over a 12-hour shift.

Source: *Effect of Supplemental Feeding on Cognitive Function in Wildland Firefighters During Arduous Fire Suppression.* S. Gaskill, B. Ruby, A. Goodson, A. McClaughry, and J. Cuddy. Paper delivered at the annual meeting of the American College of Sports Medicine, 2005.
(Cognitive function test equipment provided by the U.S. Army Research Institute for Environmental Medicine).

Core Temperature and Hydration

Wildland firefighters work long shifts in extreme environmental conditions. Temperature regulation and hydration status are among the factors that affect cognitive and physical performance. This investigation determined the effects of the work performed during wildland fire suppression on temperature regulation and drinking behavior during an arduous day on the fireline.

Subjects included male (n = 16) and female (n = 4) firefighters from various hotshot and district crews. Core, skin, and ambient temperature and self-selected work rate (recorded by activity monitors) were measured using a wireless physiological monitoring system.

Core temperature was measured using an ingested temperature sensor. Drinking characteristics were recorded with a previously validated digital flow meter (*Medicine and Science in Sports and Exercise* 33(5): S257, 2001), which allowed researchers to measure drink volume (milliliters per hour), drink frequency (drinks per hour), and total volume consumed (liters per workshift).

Urine specific gravity was measured at the second morning urination, late morning, late afternoon, and 1 hour after the shift. Data were analyzed throughout the day by comparing average morning and afternoon workshift values using repeated measures analysis of variance.

Ambient temperature increased from 24.8 °C in the morning to 34.0 °C in the afternoon (figure 2). Core temperatures increased significantly throughout the day (from 37.2 °C in the morning to 37.8 °C in the afternoon), as did skin temperatures (from 32.7 °C in the morning to 34.67 °C in the afternoon).

Statistical significance means that the possibility that these results were solely due to chance is less than 5 percent, or $p < 0.05$. Drinking volume was significantly higher during work hours 8 to 15 (275 milliliters per hour in the morning and 583 milliliters per hour in the afternoon). However, drinking frequency (drinks per hour) was similar from hours 1 to 7 and 8 to 15 (5.3 drinks per hour in the morning and 7.4 drinks per hour in the afternoon).

Nude body weight decreased significantly after the shift (0.7 kilograms or 1.54 pounds). Urine specific gravity increased significantly throughout the workshift (from 1.019 in the morning to 1.023 in the afternoon, values higher than 1.020 indicate dehydration)

Self-selected work rate (mean activity counts per hour) declined between early and later segments of the workshift, but the difference was not statistically significant (502 activity counts per hour in the morning, compared to 450 counts per hour in the afternoon).

These data demonstrate that extended arduous work in the heat is associated with a rise in ambient, core, and skin temperatures during the day and with self-selected drinking volume. The similarity in hourly activity counts during the early and later segments of the workshift suggests that drinking behavior may be related more to temperature changes than work rate. The reduction in body weight and the increase in urine specific gravity suggest that although

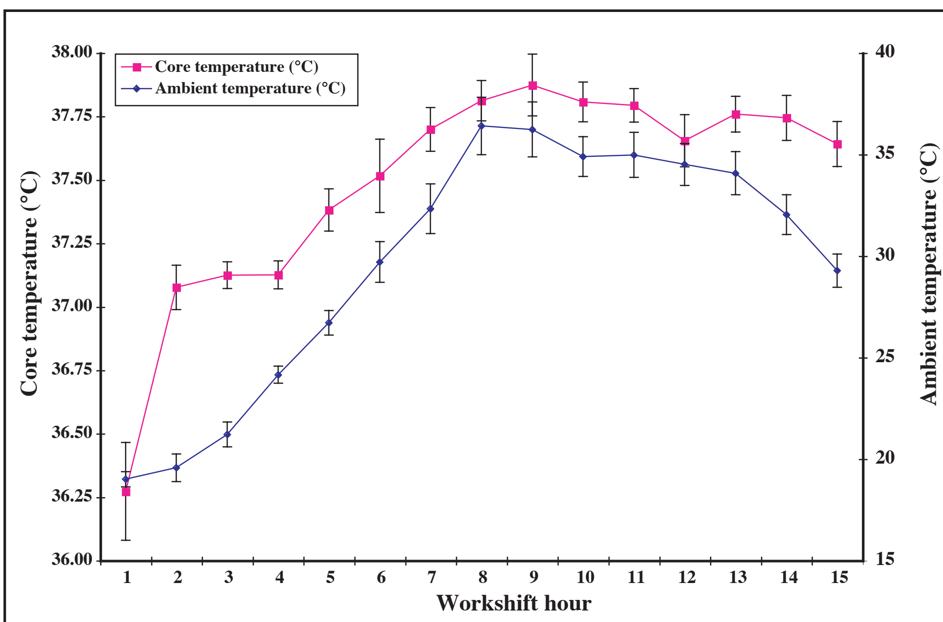


Figure 2—Firefighters' core temperatures and ambient temperatures throughout the workshift.

drinking volume increased throughout the day, it was not sufficient to maintain adequate hydration.

Source: *Factors Affecting Core Temperature and Hydration During Extended Arduous Work*. J. Ham, S. Harger, S. Gaskill, and B. Ruby. University of Montana. Paper delivered at the annual meeting of the American College of Sports Medicine, 2005. (Supported by a grant from the Mini Mitter Co., Bend, OR. Hydration monitoring system provided by the U.S. Army Research Institute for Environmental Medicine.)

Water, Electrolytes, and Hydration

Our laboratory recently demonstrated a mean rate of water turnover of 95 milliliters per kilogram per day in elite wildland firefighters during 5 days of extended work shifts (*Medicine and Science in Sports and Exercise* 35(10): 1760–1765, 2003). For example, a 165-pound (75-kilogram) firefighter would have a mean rate of water turnover of 95 milliliters times 75 kilograms or 7.13 liters per day.

This study evaluated the effects of water or water and supplemental electrolytes on core body temperature, self-selected work, hydration, and drinking behavior during arduous wildland fire suppression. Subjects included male (n = 16) and female (n = 4) wildland firefighters from various hotshot and district crews during the 2004 Fischer Fire in Washington.

Subjects were randomly placed into a group (n = 10), that consumed only water during the entire workshift or a group (n = 10) that consumed water with an electrolyte additive (45 milligrams of magnesium, 125 milligrams of sodium, 390 milligrams of chloride, and 130 milligrams of potassium per liter). Each subject was outfitted with a wireless data recording system for continuous measurement of core, skin, and ambient temperatures and self-selected activity (Mini Mitter activity monitor).

Nude body weight was recorded before and after the workshift. Urine specific gravity was measured at the second morning urination, late morning, late afternoon, and 1 hour after the shift. Drinking behavior was measured with a previously validated drinking reservoir system. Data analysis used a mixed design analysis of variance with repeated measures.

Nude body weight decreased significantly during the workshift (from 79.8 kilograms to 79.1 kilograms, a loss of 0.7 kilograms or 1.54 pounds) for the entire group. While the group that consumed electrolyte additives lost more weight (0.96 kilograms compared to 0.44 kilograms), the difference was not statistically significant. There were no differences between ambient, core, or skin temperatures throughout the day for the two groups. Average hourly self-selected work rate was similar for both groups (439 activity counts per hour without electrolyte additives compared to 487 counts per hour with additives).

Urine specific gravity increased significantly during the workshift in the group that received electrolyte additives (from 1.019 in the morning to 1.025 in the afternoon). However, urine specific gravity was unchanged in the group that did not receive additives (1.019 in the morning compared to 1.021 in the afternoon).

Total drinking volume was significantly higher for the group that did not receive electrolyte additives (7.5 liters compared to 4.3 liters, figure 3). Based on the disparity in drinking volume and the similarity in weight loss, these data indicate that consuming electrolyte additives in water may act to preserve total body water during arduous work in extreme environments, when access to water may otherwise be limited.

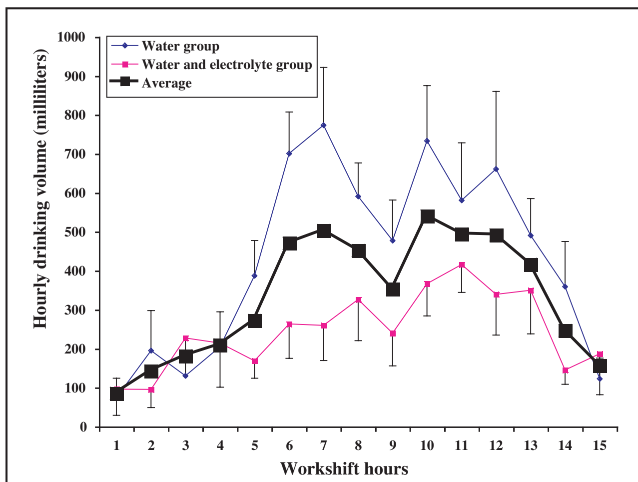
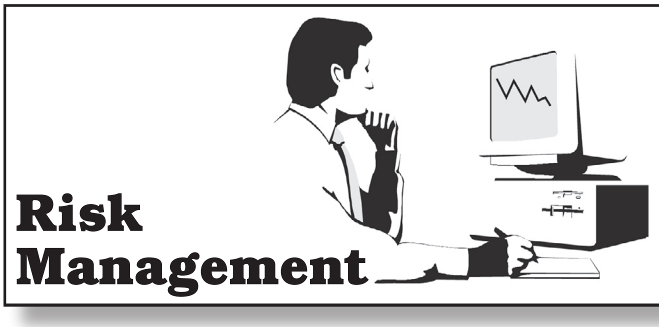


Figure 3—Hourly drinking volume for the groups of firefighters that just received water, compared to the group that received electrolyte additives in water.

Source: *Effects of Water and Water + Electrolytes on Changes in Body Temperature, Hydration Status, and Drinking Behaviors During Arduous Work*. B. Ruby, S. Montain, S. Harger, J. Ham, and S. Gaskill. University of Montana and U.S. Army Research Institute for Environmental Medicine. Paper presented at the annual meeting of the American College of Sports Medicine, 2005. (Supported by a grant from the Mini Mitter Co., Bend, OR. Hydration monitoring system provided by the U.S. Army Research Institute for Environmental Medicine.)



Vitamin and Mineral Requirements

Vitamin and mineral needs depend on the level of energy expenditure. The energy expenditure of wildland firefighting is two to three times higher than the expenditure of the typical individual (up to 6,000 kilocalories per day for firefighters compared to 2,000 kilocalories per day for the typical individual).

Vitamins, minerals, antioxidants, and immune-friendly foods can be obtained by increasing caloric intake to match energy expenditure, by eating a variety of foods, and by eating enough servings of fruits, vegetables, and whole-grain products. Under the old U.S. Department of Health and Human Services and U.S. Department of Agriculture dietary guidelines less active individuals were encouraged to eat two servings of fruits and three servings of vegetables daily. New (2005) guidelines call for everyone to eat four servings of fruit and five servings of vegetables daily. Firefighters should eat even more (see the Field Notes section).

Firefighters should begin deployment with a sound nutritional base.

Military studies demonstrate the need to begin an arduous deployment with a sound nutritional base. The Committee on Military Nutrition Research recommends that, whenever possible, individuals who have lost significant lean body mass should not be deployed until they regain the lean mass. Maintenance of body weight is a simple indicator of nutritional status. Loss of weight and lean tissue are signs of an energy imbalance. Failure to restore energy balance will harm physical performance and immune function, and could open the door to upper respiratory infections and other illnesses.

Vitamins

Why are vitamins, which do not supply energy and are needed in the tiniest quantities, essential for life? In many cases, the answer lies in vitamins' role as enzymes needed for cellular metabolism. For example, vitamin B_1 (thiamin) is a coenzyme that removes carbon dioxide in a metabolic pathway. Without the vitamin, the metabolic pathway grinds to a halt, and intermediary compounds build up. Chronic lack of vitamin B_1 leads to a vitamin deficiency characterized by weakness, wasting, and nerve damage (beriberi). Fortunately, the small amounts of vitamins needed are readily available from a variety of foods in a well-balanced diet. Doses that exceed the DRI (megadoses) do not improve function or performance, and they may be toxic.

Vitamins in food have proven more effective than vitamin supplements.

Vitamins are classified according to their solubility. Fat-soluble vitamins are ingested with fats in the diet. Water-soluble vitamins are found in a wide variety of foods. While excess water-soluble vitamins can be eliminated in the urine, excess fat-soluble vitamins may accumulate, sometimes to toxic levels. High doses of some water-soluble vitamins (B_6 and C) also have been shown to be toxic. Table 1 lists the vitamins, their daily reference intakes for adults, important functions, and foods that are sources of these vitamins.

Table 1—The recommended dietary reference intake of vitamins for adults, their functions, and their sources in the diet. References to greens mean dark leafy greens. Grains mean whole grains. The abbreviation *mg* means milligrams per day, and the abbreviation *µg* means micrograms per day.

Vitamins	Dietary reference intake (female/male)	Functions	Sources
Fat Soluble			
A (retinal)	700/900 µg	Vision, immune function	Milk products, liver, eggs
D	5 µg	Bones, teeth	Sunlight, eggs, fish, milk
E	15 mg	Antioxidant	Vegetable oils, nuts, greens
K	90/120 µg	Blood clotting	Greens, milk, meats
Water Soluble			
Beta carotene	3 mg	Cell growth, antioxidant	Fruits, vegetables
B_1 (thiamin)	1.1/1.2 mg	Energy production	Pork, grains, legumes, nuts
B_2 (riboflavin)	1.1/1.3 mg	Energy production	Milk, shellfish, meat, greens, grains
Niacin	14/16 mg	Energy production	Nuts, fish, poultry, grains, milk, eggs
B_6 (pyridoxine)	1.3 mg	Energy and protein metabolism	Meats, grains, vegetables, fruits, fish, poultry
Folate	400 µg	Red/white blood cells, RNA, DNA, amino acids	Vegetables, grains, legumes
B_{12}	2.4 µg	Blood cells, RNA, DNA, energy	Meat, fish, poultry, milk, eggs
Biotin	30 µg	Fat and amino acid metabolism, glycogen synthesis	Eggs, soybeans, fish, grains
C (ascorbic acid)	75/90 mg	Healing, immune function, antioxidant, connective tissue	Citrus fruits, strawberries, cantaloup, greens

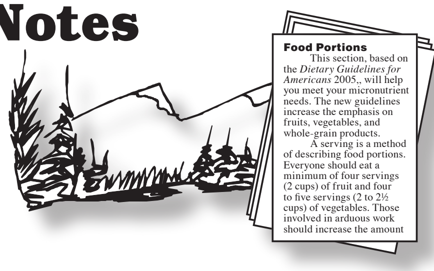
Minerals

Minerals are important for enzymes and cellular activity, for some hormones, for bones, for muscle and nerve activity, and for acid-base balance. Minerals are available in many food sources, but concentrations are higher in animal tissues. Excess intake of mineral supplements can pose problems, including diarrhea (magnesium, zinc), high blood pressure (sodium), or liver damage (iron). Mineral and vitamin supplements should not exceed the DRI (table 2).

Table 2—The recommended dietary reference intake of minerals for adults, their functions, and their sources in the diet. References to greens mean dark leafy greens. Grains mean whole grains. The abbreviation *mg* means milligrams per day, and the abbreviation *μg* means micrograms per day.

Minerals	Dietary Reference Intakes (female/males)	Functions	Sources
Calcium	1,000 mg	Bones, teeth, blood clotting, muscle and nerve function	Milk, tofu, broccoli, legumes
Chloride	2,300 mg	Digestion, fluid balance	Salt (in foods)
Chromium	25/35 μg	Energy metabolism	Grains, meats, vegetable oils
Copper	900 μg	Iron metabolism	Seafood, nuts, grains
Fluorine	3/4 mg	Bones, teeth	Water, seafood, tea
Iodine	150 μg	Thyroid hormone	Seafood, milk, iodized salt
Iron	18/8 mg	Oxygen transport	Meats, legumes, dried fruit
Magnesium	320/420 mg	Protein synthesis, muscle and nerve function	Grains, nuts, legumes, seafood, chocolate
Manganese	1.8/2.3 mg	Energy metabolism	Nuts, grains, tea, leafy vegetables
Molybdenum	45 μg	Enzymes	Organ meats, legumes, cereals
Phosphorus	700 mg	Bones, teeth, acid/base balance	Milk, meats, poultry, fish, eggs
Potassium	4,700 mg	Nerves and muscles, fluid and acid/base balance	Meats, milk, fruits, vegetables, grains, coffee
Selenium	55 μg	Antioxidant	Seafood, meats, grains
Sodium	1,500 mg	Nerve function, fluid and acid/base balance	Salt (in food)
Zinc	8/11 mg	Enzyme activity, wound healing	Meat, poultry, fish, milk, grains, vegetables

Field Notes



Food Portions

This section, based on the *Dietary Guidelines for Americans* 2005, will help you meet your micronutrient needs. The new guidelines increase the emphasis on fruits, vegetables, and whole-grain products.

A serving is a method of describing food portions. Everyone should eat a minimum of four servings (2 cups) of fruit and four to five servings (2 to 2½ cups) of vegetables daily. Those involved in arduous work should increase the amount of fruit to five servings (2½ cups) and vegetables to eight servings (4 cups). Examples of fruit and vegetable servings include:

Fruit	**Vegetables** (1 cup raw or ½ cup cooked)
1 apple or ⅓ cup apple juice	Cabbage
1 orange or ½ cup orange juice	Celery
1 cup vegetable juice	Cucumber
4 apricots	Green onion
¾ cup blueberries	Green, red, or hot peppers
½ banana	Lettuce
12 cherries	Mushrooms
½ grapefruit	Radishes
15 grapes	Spinach
1 nectarine	Zucchini
1¼ cup strawberries	
1¼ cup watermelon	
4 rings of dried apples	
3 prunes	
2 tablespoons of raisins	

Choose from a variety of fruits and vegetables each day. Make sure that you select vegetables from all five subgroups several times a week: dark green, orange (carrots), legumes, starchy vegetables, and other vegetables.

Whole Grains

Whole-grain products are important sources of energy, fiber, and micronutrients. Everyone should eat six servings of whole grains, enriched, or whole-grain products daily. When you are doing arduous work, increase the intake of whole-grain products to meet your energy needs.

Whole grains

1 slice (1 ounce) whole-grain bread

1/2 cup cooked oatmeal

1/3 cup All Bran

1 cup whole-grain flaked cereal

1/2 12-inch whole-grain tortilla

1/2 whole-wheat English muffin

1/2 whole-grain bagel

1/2 cup shredded wheat

1/2 cup cooked, whole-wheat pasta

For additional information, review the *Dietary Guidelines for Americans* 2005 at:

http://www.health.gov/dietaryguidelines/dga2005

Sample Food Plan

Here is a sample food plan that meets the protein, carbohydrate, and fat requirements for a firefighter (70 inches tall, weighing 175 pounds) doing very hard work. The plan provides: 5,000 calories, 182 grams of protein (2.3 grams per kilogram of body weight), 725 grams of carbohydrate (9 grams per kilogram of body weight), and 164.5 grams of fat.

All micronutrient needs meet the recommended daily reference intake.

Breakfast

Large whole-grain bagel (4 ounces)

2 tablespoons peanut butter

16 ounces orange juice

1 cup applesauce

Snack

2 granola bars

16 ounces Gatorade

Lunch

1 medium apple

4 ounces Swiss cheese

4 ounces lean ham

2 teaspoons mustard

4 slices whole-wheat bread

Lettuce

Carrots

Snack

1/4 cup pecans

1/4 cup raisins

1/4 cup apricots, dried

16 ounces Gatorade

Dinner

6-ounce chicken breast

2 medium sweet potatoes

2 tablespoons soft margarine

1 cup broccoli

2 packets of hot cocoa mix

2 cups salad greens

2 tablespoons oil and vinegar dressing

2 whole-wheat rolls

1 tablespoon soft margarine

Also

2 bananas

3 cups grape juice

4 ginger snaps

Library Card

Sharkey, Brian. 2005. Wildland firefighter health & safety report: No. 9. Tech. Rep. 0551–2803–MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 16 p.

This issue focuses on vitamins and minerals for wildland firefighters. Generally, current scientific data do not support the need for vitamin or mineral supplements, but do support the need for a balanced and nutritious diet, which will provide all the essential vitamins and minerals. The Research section provides summaries of recent field studies of supplemental feeding and its effect on cognitive function. When firefighters consumed supplemental carbohydrates, they worked harder (even though they didn't feel they had done so) and improved their decisionmaking skills on simple tasks. Another field study considered the influence of hydration on core temperature in wildland firefighters. The Risk Management section outlines the need for vitamins and minerals and summarizes the recommended daily intake and sources of common vitamins and minerals, as well as the functions they perform. The Field Notes section explains how servings of fruits and vegetables are measured and includes a sample food plan that would meet a wildland firefighter's vitamin and mineral needs, as well as other general nutritional needs.

Keywords: body temperature, carbohydrates, cognition, core temperature, electrolytes, fruits, guidelines, hydration, minerals, nutrition, micronutrients, performance, supplements, vegetables, vitamins

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