Wildland Firefighter
Health & Safety Report

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Cooperative Research and Development

Since 1962, the Missoula Technology and Development Center (MTDC) has maintained a cooperative research agreement with the University of Montana Human Performance Laboratory. The featured topic of this report describes the development of this 45-year relationship, outlines past and recent projects, and seeks the support of readers in identifying additional areas in need of study. The *Research* section summarizes findings from feeding studies conducted on firefighters during the 2005 fire season. The *Risk Management* section looks at conditions that can complicate the diagnosis and treatment of heat disorders. The *Field Notes* section shows how to avoid less common but serious heat disorders: hyponatremia and rhabdomyolysis.

Background

This report, the 10th in a series, reviews activities related to the Missoula Technology and Development Center's (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 employees.
- Energy and nutrition: Improve the energy intake, nutrition, immune function, and health of wildland firefighters.
- Fitness and work capacity: Use work capacity and medical standards to ensure the health, safety, and productivity of wildland firefighters.

In this 1965 photograph, MTDC employee Cliff Blake is a subject during a study of energy, cardiovascular, and thermal demands of wildland firefighting.

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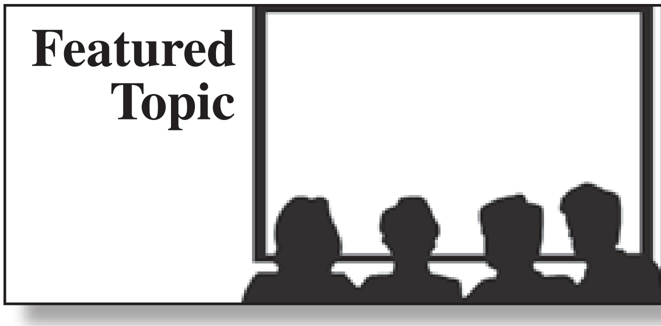

Research and Development in Wildland Firefighting

Brian J. Sharkey, Ph.D., MTDC; Brent Ruby, Ph.D., and Steven Gaskill, Ph.D., University of Montana Human Performance Laboratory

During the late 1950s, a group at the U.S. Department of Agriculture Forest Service's Aerial Fire Depot in Missoula, MT, began working on equipment for smokejumping and air cargo drops. This work led to the establishment of the Missoula Equipment Development Center (now the Missoula Technology and Development Center). In 1962, Center Director Herb Harris met with Charles Hertler and Walter Schwank of the University of Montana to discuss the importance of human factors in equipment design. Those conversations led to a cooperative research agreement and a longstanding relationship between MTDC and the University of Montana Human Performance Laboratory.

Since then, MTDC has maintained the agreement with the University's Human Performance Laboratory, working with university researchers and graduate students to improve the quality of laboratory and field studies. The agreement provides for studies to solve equipment, health, and safety problems.

MTDC uses a research and development model to develop and test solutions for field use. The model involves field and laboratory studies, product development and evaluation, and dissemination of results, leading to field adoption of solutions.

MTDC personnel involved in the cooperative agreement have included Cliff Blake (1962–1967), Art Jukkala (1968–1989), Dick Mangan (1990–1999), George Jackson (2000–2003), and Leslie Anderson (2004 to present). University researchers have included Wayne Sinning, Ph.D. (1962–1964), Brian Sharkey, Ph.D. (1965–1997), Brent Ruby, Ph.D. (1996 to present), and Steve Gaskill, Ph.D. (2000 to present). Brian Sharkey retired from the University in 1997 and coordinates the agreement at MTDC. This paper reviews the results of this cooperative agreement and considers wildland firefighting problems for future study.

Past Projects

Under the cooperative agreement, the initial work was conducted by Dr. Sinning and several graduate students. It included studies of energy expenditure and fatigue while firefighters were packing loads in backpacks of different design. Information was gathered from the field and in the laboratory on a treadmill designed and built by MTDC. Another study investigated the energy cost of building fireline with a motorized flail trencher. Since Sinning's departure, Dr. Sharkey and his graduate students have conducted work in the following areas.

This 1963 study measured the energy cost of using a flail trencher to build fireline.

Job Demands—Field studies to determine the energy, cardiovascular, and thermal demands of fireline tasks led to the development of work capacity tests for wildland firefighters.

Equipment Carriers—One- and two-person motorized and human-powered equipment carriers were tested on the steep trail that switchbacks on Mount Sentinel behind the university campus.

Tools—Fireline construction tools were evaluated for performance and energy cost. MTDC developed the Combi tool that allows firefighters to produce 22 percent more fireline than the Pulaski, at a lower energy cost per foot of line (4.1 ft of fireline per liter of oxygen consumed, rather than 3.4).

MTDC's Art Jukkala participated in a fireline tool study during the 1970s.

Firefighters using a Combi tool rather than a pulaski produce more fireline for each liter of oxygen consumed.

Aerobic Fitness—Studies demonstrated a strong relationship between aerobic fitness and performance of fireline tasks, heat tolerance, and safety (as indicated by the ability to escape to a safety zone). Aerobic fitness was highly correlated to a firefighter's speed when escaping to a safety zone ($r = 0.87$).

Work Capacity Tests—Lab and field studies of fireline tasks led to the development of a test to measure aerobic fitness. The Step Test estimated the minimum aerobic fitness standard of 45 mL/kg-min. This test, introduced in 1975, was used until 1998 when new job-related tests were introduced. The Pack Test, Field Test, and Walk Test were developed to evaluate arduous, moderate, and light levels of work capacity.

Muscular Fitness—Field studies identified the relationship of muscular fitness to performance in wildland firefighting tasks. The Pack Test and Field Test incorporate elements of muscular fitness while maintaining the aerobic fitness standard.

Fitness Programs—The booklet, *Fitness and Work Capacity* (1977), helped readers learn how to develop and maintain aerobic and muscular fitness. A second edition was published in 1997.

Health Screening Materials—Health screening materials were prepared to help employees evaluate their readiness for training, testing, and wildland firefighting.

Employee Health Programs—Employee health (wellness) materials were introduced in 1980 and updated in 1993.

Health Hazards of Smoke—MTDC coordinated an 8-year program that focused on the effects of wood smoke on the health of wildland firefighters. The program included: employee exposure, epidemiology, health effects, risk assessment, and risk management. The program's progress was summarized in 12 issues of *Health Hazards of Smoke*. A project summary and the recommendations of a consensus conference were published in 1997.

Fatigue—MTDC conducted literature reviews and field studies to determine work/rest standards (2/1 ratio), shift length, assignment length, and fatigue countermeasures. Measures of immune function and fatigue were used to determine the effects of long shifts and assignments.

Uniforms—Uniforms have been studied in the Human Performance Laboratory's environmental chamber. The balance between protection and comfort has been analyzed. The lab's findings agree with those of Australian researchers: "Clearly, the task of firefighters' clothing is not to keep heat out, but to let it out" (Budd and Brotherhood 1996).

Heat Stress—Heat stress has been studied in the lab's environmental chamber and in the field. While early studies used a rectal probe, recent studies use an ingested pill to transmit core temperature to a recorder on the subject's hip. Studies show the value of acclimatization and fitness, and the need to hydrate before, during, and after work.

Hydration—Firefighters generate 7.5 kcal of heat during each minute of work, or more than 400 kcal/h. Additional heat (about 180 kcal/h) comes from the environment and the fire. This heat load (400 + 180 = 580 kcal/h) can be dissipated with the evaporation of 1 L of sweat. Firefighters should consume 1 L of fluid for each hour of work to avoid fluid loss, fatigue, and heat stress. Carbohydrate/electrolyte (C/E) beverages increase fluid intake and maintain fluid levels, blood glucose, work output, cognitive function, mood, and immune function.

Energy Balance—Firefighter energy expenditure has been studied since the 1960s. Our latest studies, using doubly labeled water techniques during several days of actual fire suppression, document exceedingly high levels of energy expenditure (3,500 to 6,300 kcal/day) and an overall loss of total body water and body weight. Analysis of fire camp meals showed that the meals provide enough energy, if firefighters eat enough.

We conducted field studies of supplemental carbohydrate drinks and rations to provide energy throughout the work shift. Crossover studies demonstrated maintenance of blood glucose and an increase in self-selected work output when supplemental carbohydrates were consumed throughout the day. We have also demonstrated that immune function was better maintained when supplemental carbohydrates were consumed.

Nutrition—We have analyzed the energy and nutrient value of fire camp meals, and the need for vitamin/mineral supplements. 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.


Fire

Tech Tips

United States Department of Agriculture
Forest Service

Technology & Development Program

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Feeding the Wildland Firefighter

Brian Sharkey, Project Leader; Brent Ruby, Physiologist; Carla Cox, Registered Dietitian

Recent research has identified nutritional strategies that will improve the health, safety, and productivity of wildland firefighters. The right food sources, properly timed, provide energy and nutrients that help sustain work output and maintain the function of the immune system. Supplemental high-energy foods delay fatigue and enhance immune function while maintaining the firefighter's ability to think and make decisions during periods of hard work. This Tech Tip outlines simple strategies for maintaining health, safety, and performance during prolonged periods of arduous work.

Energy

Research by the University of Montana Human Performance Laboratory and the Missoula Technology and Development Center (MTDC) has demonstrated the energy demands and energy intake of wildland firefighters. In a recent field study (Ruby and others 2002), male firefighters burned an average of 4,758 kilocalories a day while they consumed only 4,068 kilocalories. The daily caloric deficit of 690 kilocalories results in a 1.25-kilogram (2.76-pound) weight loss over the course of a 14-day assignment. Female

For additional information, contact:

Immune Function—We have used salivary immunoglobulin A (sIgA), the first line of defense against respiratory tract infections, as an objective measure of fatigue during prolonged work shifts and assignments. Using sIgA, we found recovery from fatigue was adequate after a 14-hour shift, but not after 21 hours of arduous work. Working a 21-hour shift led to several days of suppressed immune function.

Technology Transfer

Laboratory and field studies have been reported at national and international meetings and in research journals. Projects have been reported in tech tips (such as *Feeding the Wildland Firefighter*), booklets (such as *Fitness and Work Capacity*), and reports (*Health Hazards of Smoke*; *Wildland Firefighter Health and Safety Reports*). In addition to project work, MTDC has provided technical services, developed video and presentations (such as *Fatigue Awareness*), and advised the Forest Service in numerous areas.

Recent Work

Since 1996, Dr. Brent Ruby (University of Montana) has conducted studies of wildland firefighters. Based on the similarity of wildland firefighting to military operations, Ruby and Sharkey received a U.S. Department of Defense grant to study energy expenditure and hydration in wildland firefighters. Dr. Steve Gaskill joined the lab in 2000. Dr. Carla Cox, a registered dietician, has become actively involved in firefighter nutrition issues. Relationships with scientists at several universities and in military research groups expand the scope of the work. During the past fire season, equipment loaned by the U.S. Army Research Institute of Environmental Medicine and several equipment manufacturers was used in field studies. The university relationship allows substantial funding to be leveraged through other partners, making these studies cost effective for Federal agencies.

Summary

This work has led to tests, programs, tools, hydration and nutrition guidance, informed purchasing decisions, and other accomplishments. It has improved the performance, health (immune function), and safety of wildland firefighters. According to a study for the U.S. Fire Administration (TriData Corp. 2002), wildland firefighter standards of physical fitness are associated with a much lower rate of death from heart attacks (7 percent for wildland firefighters compared to 47 percent for other firefighters).

New Directions

MTDC and cooperators at the University of Montana will continue to study factors that maintain cognitive function during prolonged arduous work, including supplemental feeding, hydration, work/rest guidelines, and fatigue countermeasures. We will study the relationships among hydration strategies, temperature regulation, and heat disorders. We will look at the relationships among diet, fitness, and immune function. We will work with the U.S. Army Research Institute for Environmental Medicine to test alternative feeding strategies in field conditions. We hope to extend these studies to include the role of micronutrients and their relationships to performance and health in wildland firefighters. Doing so will require field studies of food intake, body composition, and energy expenditure; development of a nutritional guidance program; and, if needed, introduction of a ration component to meet micronutrient needs.

The Wildland Firefighter Health and Safety project was outlined in 1999 with help from participants at the International Association of Wildland Fire Safety Summit. We need your advice to help us focus our work. We hope you will help us identify new directions for our work and priorities for future studies. Contact Brian Sharkey at *bsharkey@fs.fed.us* or 406–329–3989. We look forward to hearing from you.

For additional information, visit the MTDC Web site *http://www.fs.fed.us/t-d*

Note

The Murdock Charitable Trust has awarded the University of Montana Human Performance Laboratory a grant to expand its capabilities for field and laboratory research. The grant will be used to purchase equipment that will enhance studies of wildland firefighters, the military, and others involved in prolonged arduous work.

Research

This section reviews project-related field studies conducted on wildland firefighters during the 2005 fire season. The studies were conducted by researchers from the University of Montana Human Performance Laboratory in cooperation with MTDC, with support from the National Wildfire Coordinating Group and the U.S. Army Research Institute for Environmental Medicine.

First Strike Rations

Liquid carbohydrate supplementation during wildland fire suppression has improved work output (Ruby and others, *Medicine & Science in Sports & Exercise S219*, 2004). The purpose of this study was to determine whether including snack and caffeine items (called *First Strike Rations* or *Eat-on-Move* rations) would increase work output compared to an entrée-based field ration (*Meal Ready to Eat*) consumed whenever firefighters felt hungry during multiple days of work. Twenty-eight wildland firefighters received each ration (*First Strike Rations*: 3,067 kcal, 393 g carbohydrate, 675 mg caffeine; *Meal Ready to Eat*: 2,841 kcal, 373 g carbohydrate, 100 mg caffeine) for 2 consecutive days separated by 1 day. Diet order was counterbalanced across participants. Eating episodes were self-reported. Mood was assessed by the Profile of Mood State questionnaire. Work output was measured by actimetry (physical activity monitoring using devices that record movements).

The number of work shift eating episodes was significantly higher with the *First Strike Rations* compared to the *Meal Ready to Eat* (8.2 vs. 7.6 episodes; $p = 0.013$). Salivary caffeine was higher with the *First Strike Rations* compared to the *Meal Ready to Eat* (1.6 vs. 0.7 g/mL; $p = 0.01$). Subjective feelings of fatigue were similar after fire suppression, but depression was modestly lower with the *First Strike Rations* than with the *Meal Ready to Eat*. Total work output during fire suppression was significantly higher (14.6 percent; $p = 0.046$) when consuming the *First Strike Rations* compared to the *Meal Ready to Eat* with a trend ($p = 0.085$) for more minutes of activity (587 vs. 567 min).

Conclusions: Delivery of energy and caffeine in a manner that promotes snacking behavior helps increase self-selected work during arduous labor.

Intermittent Feeding

Eat-on-Move rations improve actimetry scores during wildland fire suppression. 2006. Scott J. Montain, Carol J. Baker-Fulco, Philip J. Niro, Andrew Reinert, Joseph Domitrovich, and Brent C. Ruby. Paper delivered at the annual meeting of the American College of Sports Medicine.

University of Montana researchers Brent Ruby (left) with MREs and Steve Gaskill with First Strike Rations for soldiers and wildland firefighters.

Our laboratory has previously demonstrated that liquid carbohydrate supplementation increases work output during wildland fire suppression (Ruby and others, *Medicine & Science in Sports & Exercise S219*, 2004). The purpose of this study was to determine the effect of two different eucaloric (equal or equivalent) feeding strategies on work output during wildland fire suppression. Twenty-nine Type I wildland firefighters from three hotshot crews (26 males, 3 females) were studied at two wildland fires in the Northwest United States during the 2005 fire season. The firefighters consumed either a sack lunch during the middle of their shift or snack foods throughout the day at 90-minute intervals after breakfast in a randomized crossover design. The total energy intake during the 12-hour shifts was eucaloric (1,534 ± 265 kcal) between days. We used a physical activity monitor (Mini Mitter, Bend, Or) to measure work output and determine activity counts. Ratings of perceived exertion were also assessed.

The total daily activity counts were significantly higher for the snack food days compared to the sack lunch days ($p < 0.05$). Activity counts between breakfast and lunch were significantly higher for the snack food days ($p < 0.05$). During the last 2 hours of the shift, activity counts were 41 percent higher on snack food days ($p < 0.05$). No statistically significant differences were found for perceived exertion at any time during the work shift. Satisfaction favored the snack food approach to the sack lunch approach in all categories (eight questions, $p < 0.05$).

Conclusions: Despite no differences in perceived exertion, the snack food group performed more overall work (8 percent) than the sack lunch group, especially during the last 2 hours of a shift (41 percent more work). Even when the total energy consumed during a work shift does not change, feeding at regular intervals increases self-selected work output during wildland fire suppression.

This project was funded by the Missoula Technology and Development Center.

Intermittent scheduled feedings increase work output during wildland fire suppression. 2006. J. Cuddy, J. Domitrovich, S. Gaskill, B. Sharkey, and B. Ruby. Paper delivered at the annual meeting of the American College of Sports Medicine.

A wildland firefighter sorts the day's food rations.

Risk Management

Heat Stress

In May of 2005, at the end of a 7-mile training run, a female hotshot crewmember became disoriented and began to show signs of heat-related stress. Emergency services were summoned and she was transported to the regional medical center.

During the months before the fire season, the crewmember participated in daily runs as long as 4 miles. Two days before the training run, the crewmember drove 14 hours, rested overnight, and drove 4 more hours to her duty station. That afternoon and evening, she consumed 32 oz of water. The next morning she met with the crew for a 7-mile training run at an elevation of 5,200 ft when the temperature was 71 ˚F. She did not eat breakfast before the run, but she did consume another 32 oz of water.

After 6 miles of running with the crew, the female crewmember "began to sprint ahead of the group." When she returned to the base, she began to suffer from "tunnel vision," and couldn't find the barracks. An emergency medical technician trainee and another employee saw the crewmember in distress and went to her aid. They found her to be extremely disoriented and acting irrationally, trying to climb a fence to get to a creek. Her color was "bad" and her pupils were fixed. They called 911 and began first aid. The crewmember was transported to the regional hospital, stayed overnight, and was released the next day.

The firefighter was determined to be suffering from a classic case of a heat disorder. While she had consumed 32 oz of fluid and was physically able to participate in the training run, she was not properly acclimatized to the heat.

Were Other Factors Involved?

When considering the causes of this incident, it would help to have additional information, such as blood measures (blood glucose, sodium), recent food intake, alcohol or drug use, medical issues, and so forth. In addition to heat stress, other factors that may have contributed to the difficulties she encountered include altitude, low blood glucose (hypoglycemia), water intoxication (hyponatremia), or a combination of other factors.

Heat Stress—The firefighter came from a moderately warm climate and the morning temperature was only 71 ˚F. She had been training before the season and the run wasn't that long. Bob Karwasky, an exercise physiologist with the Los Angeles County Fire Department, noted that the firefighter picked up her pace during the last mile, while performance usually declines with dehydration. (During the 1990s, a hotshot crewmember dropped out after 3 miles of a 4-mile run, wandered in the desert, and died from heat stroke.)

Altitude—The subject gained 2,000 ft in her trip from home to work. The elevation of the run would have a modest effect on performance, and some acclimatization would be required to minimize the effects of the elevation change. Yet the subject was able to increase her pace during the last mile.

Hypoglycemia—The brain uses glucose in the blood for fuel. Symptoms of low blood glucose include nervousness, faintness, confusion, inappropriate behavior, and visual disturbances (such as tunnel vision). Low blood glucose can lead to coma and seizures. The subject didn't eat on the morning of the run. Individuals prone to hypoglycemia should eat on a regular basis, especially before vigorous activity.

Hyponatremia—Excess water intake (water intoxication) can disturb the body's fluid-electrolyte balance and lead to an abnormally low level of plasma sodium (less than 135 mmoles/L). The risk is more pronounced during long-duration exertion in the heat, in events like marathons, triathlons, and prolonged hard work (such as wildland firefighting or military training). When excess water intake is combined with loss of sodium in sweat, the risk of hyponatremia grows (sodium loss for a participant in the Ironman triathlon could approach 1 gram per hour during a 12-hour event). A moderate decline in plasma sodium may cause gastrointestinal symptoms or nausea. A more pronounced drop may cause unusual fatigue, confusion, disorientation, a throbbing headache, vomiting, wheezy breathing, and swollen hands and feet. Seizures, coma, and death are possible if plasma sodium reaches very low levels (less than 120 mmoles/L).

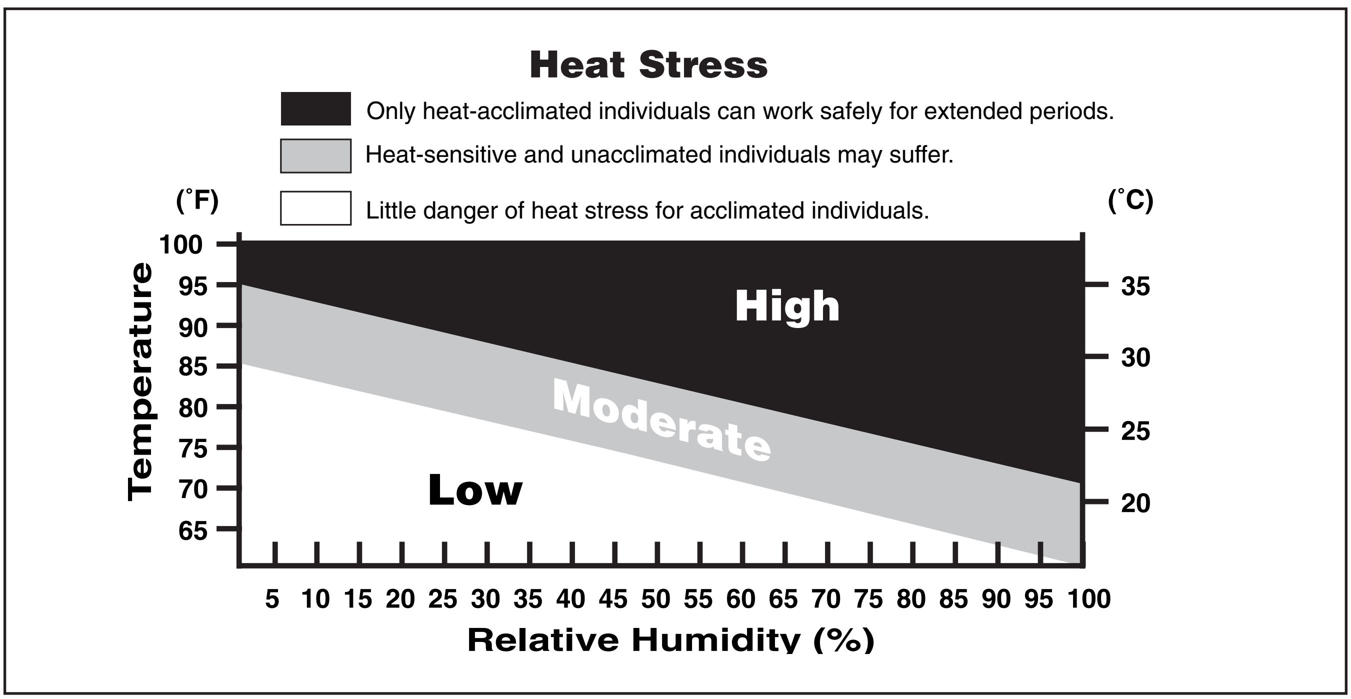
Those at greatest risk are small, slower athletes; those who sweat a lot; and those who lose lots of salt, drink lots of water before and during an event, and fail to replace electrolytes, especially sodium. Twenty-six cases of hyponatremia were diagnosed during several San Diego marathons. The average finishing time for runners experiencing hyponatremia was 5 hours and 38 minutes, a relatively slow time. Nine U.S. Marine recruits experienced hyponatremia on the same day, drinking 10 to 22 qt of water over a few hours of exertion. All survived after emergency treatment (*Military Medicine*, 2002).

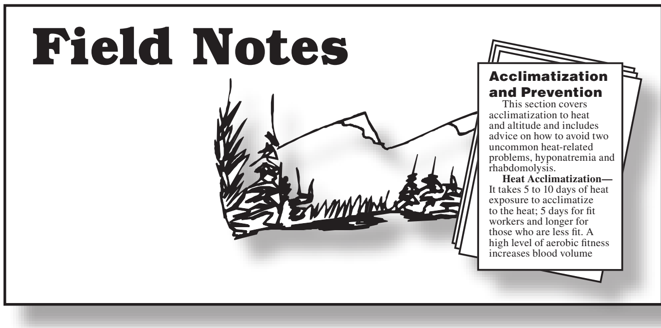
You can drink too much water!

See the *Field Notes* section for advice on avoiding hyponatremia and acclimatizing to heat. While we are on the subject of heat-related problems, let's consider another uncommon but serious condition, rhabdomyolysis.

Rhabdomyolysis

Exertional (exercise-induced) rhabdomyolysis is most frequently reported in military personnel (0.3 to 3.0 percent) and in law enforcement and firefighting trainees (0.2 percent) during hot, humid conditions. Damage occurs to muscle membranes, allowing cellular components (such as creatine kinase, myoglobin, and potassium) to leak out. Rhabdomyolysis can lead to renal failure, irregular heartbeats, and even death. Risk factors include sedentary lifestyle, high ambient temperatures, and intense exercise. Military and fire department records indicate that the risk goes down as fitness improves (*Physician and Sportsmedicine*, 2004). Persons taking cholesterol-lowering statin drugs may be at a higher risk for rhabdomyolysis. See the *Field Notes* section for advice on avoiding this uncommon condition.





Acclimatization and Prevention

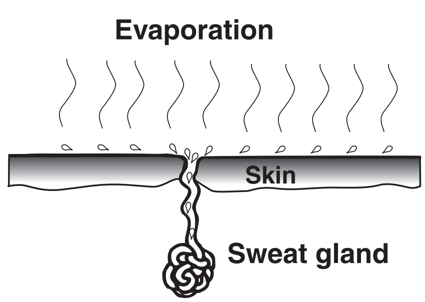
This section covers acclimatization to heat and altitude and includes advice on how to avoid two uncommon heat-related problems, hyponatremia and rhabdomyolysis.

Heat Acclimatization—It takes 5 to 10 days of heat exposure to become acclimatized: 5 days for fit workers and longer for those who are less fit. A high level of aerobic fitness increases blood volume and circulatory efficiency, both of which help the body regulate temperature. Gradually increasing work time in the heat leads to:

- Increased sweat production
- Improved blood distribution
- Decreased core and skin temperatures
- Lower working heart rate

To become acclimatized:

- Gradually increase work time, taking care to replace fluids and to rest as needed.
- Maintain acclimatization with periodic work or exercise in a hot environment.



Altitude Acclimatization—Elevations below 5,000 ft have little noticeable effect on healthy individuals. But as you ascend to higher elevations, barometric pressure declines, along with available levels of atmospheric oxygen. With less oxygen, altitude always leads to a reduction in aerobic fitness and endurance performance. It can take about 3 weeks to acclimatize to elevations between 5,000 and 9,000 ft, or about 1 week for each 1,000 ft of elevation above 5,000 ft. While athletes try to live high and train low (to maintain training intensity), workers usually live and work at the same elevation. Altitude acclimatization leads to increases in:

- Pulmonary function
- Blood volume and hemoglobin
- Numbers of red blood cells
- Numbers of lung and muscle capillaries
- Muscle myoglobin (allowing more oxygen to be transported in the muscles)

These adjustments improve the body's ability to take in, transport, and use oxygen, but they never eliminate the effects of altitude on endurance performance, including arduous work.

Hyponatremia—Sodium is available in fire camp meals, but that source of sodium may not be adequate during extremely hot weather.

To avoid hyponatremia:

- Drink carbohydrate/electrolyte (sports) beverages or put electrolytes (especially salt) in drinking water to ensure sodium intake.
- Drink half a quart of fluid (water and sports beverages) 2 to 3 hours before exertion in the heat.
- Drink a pint of fluid (water and sports beverages) 10 to 20 minutes before exercise.
- Replace fluids lost in sweat by drinking 6 to 12 oz of fluid (water and sports beverages) every 15 to 20 minutes during exertion.

During meals, long breaks, and after exertion, replace fluids to restore fluid balance, electrolytes, and carbohydrates.

Wildland firefighters should consume a quart (liter) of fluid (water and sports beverages) for each hour of work in the heat. We recommend that firefighters use sports beverages for one-third to one-half of their fluid needs. When hyponatremia is suspected, provide electrolyte fluids, such as sports beverages–not water.

Additional carbohydrate can be supplied by solid supplements, such as energy bars.

Rhabdomyolysis—Exertion-related muscle damage causes fatigue, muscle aches, and leads to myoglobin (which looks like blood) in urine. To minimize the risk:

- Increase training intensity gradually to give muscles time to adapt.
- Maintain a year-round activity/fitness program.

- Avoid exercise when the temperature and humidity are high unless you have trained for those conditions.
- Limit exercise during times of illness.
- Consult your physician if you have predisposing factors (if you take statin drugs or have sickle-cell trait, some viral infections, or are susceptible to hyperthermia).

If rhabdomyolysis is suspected, emergency medical personnel can begin saline infusion and prepare to transport the victim. Blood work (creatine kinase, potassium) will verify the diagnosis (*Physician and Sportsmedicine*, April 2004).

About the Author

Brian Sharkey, an exercise physiologist at MTDC, has done research and development work on fitness tests and programs, heat stress, hydration, nutrition, protective clothing, tools, fatigue, work/rest cycles, and employee health (wellness). His work has been honored with USDA Superior Service and Distinguished Service Awards, and a Forest Service Technology Transfer Award. He is a researcher, author of several books, and past president of the American College of Sports Medicine.

Library Card

Sharkey, Brian. 2005. Wildland firefighter health and safety report: No. 10. Tech. Rep. 0651–2810P–MTDC. Missoula, MT: U.S. Department of Agriculture Forest Service, Missoula Technology and Development Center. 12 p.

This issue describes the 45-year history of the cooperative research agreement between the University of Montana and the Missoula Technology and Development Center. This work has led to tests, programs, tools, hydration and nutrition guidance, and, most importantly, to improved performance, health (immune function), and safety of wildland firefighters. Research summarized in this issue includes studies showing that regular snacking (with some items containing caffeine) increased the activity of wildland firefighters compared to eating an entree-based field ration (*Meal Ready to Eat*) during a 12-hour shift. The problems of heat stress and drinking too much water (hyponatremia) are discussed, as is the problem of rhabdomyolysis (exercise-induced damage to muscle membranes that allows key compounds to leak out of cells).

Keywords: acclimatization, altitude, caffeine, first strike rations, heat stress, history, hyponatremia, meals, nutrients, nutrition, rations, research, rhabdomyolysis, snacks

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Single copies of this document may be ordered from:

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For additional information about wildland firefighter health and safety, contact Brian Sharkey at MTDC.

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Electronic copies of MTDC's documents are available on the Internet at:

http://www.fs.fed.us/t-d

Forest Service and Bureau of Land Management employees can search a more complete collection of MTDC's documents, videos, and CDs on their internal computer networks at:

http://fsweb.mtdc.wo.fs.fed.us/search/