Wildland Firefighter
Health & Safety Report

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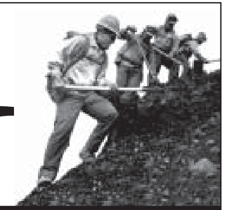

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Background

This report, the third in a series, reviews activities related to the Missoula Technology and Development Center (MTDC) project on firefighter health and safety. The Wildland Firefighter Health and Safety Project focuses on three main areas:

Work/Rest Issues— Development of an objective approach for the determination of work/rest standards, and recommended assignment lengths for crews and overhead.

Energy and Nutrition— Improvement of the energy intake, nutrition, and immune function of wildland firefighters.

Fitness and Work Capacity— Implementation of medical screening and work capacity standards, and improvements in the health, safety, and productivity of firefighters.

Fire Storm 2000

The 2000 fire season ranks as one of the worst in the past 50 years. With thousands of fires and over 7 million acres burned, the season strained human and physical resources. Army, Marine, and National Guard units, as well as personnel from Canada, Mexico, Australia, and New Zealand assisted in firefighting. According to a team that studied the effects of the long fire season on firefighter fatigue and stress, firefighters and overhead teams coped well with the demands of the prolonged season.

"Generally, we found fatigue to be present, but accompanied by good levels of awareness and action aimed at minimizing the effects of fatigue on performance and safety. The firefighters, crews, and fire management teams were obviously working very hard and demonstrated that safety was recognized as being the first priority within all assignments."

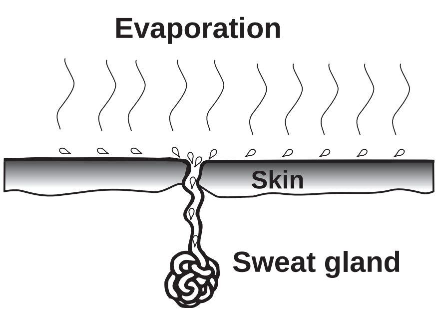
A new 14-day fire assignment guideline probably contributed to the health and safety of fire crews and overhead staff. Medical personnel noted the usual number of upper respiratory symptoms, injuries, and problems with the heat. Preliminary analysis did not indicate that problems were greater than usual. Firefighters, and overhead, medical, and safety staff took many steps to minimize the risks of illness, injury, and heat stress.

Heat Stress

Brian Sharkey, Ph.D.

Wildland firefighting is arduous work. Shifts are long, often in steep terrain, and at high elevations. The weather is usually hot and dry, and the fire increases exposure to heat. This report focuses on the risks of heat stress and the steps firefighters can take to minimize those risks.

When firefighters perform hard work in a hot environment, the body sends blood to the skin where sweat glands produce sweat. The sweat evaporates, cooling the body.



As sweating continues, the body loses a considerable quantity of fluid, often at a rate of more than 1 L/h. Dehydration can compromise heart and circulatory function and the ability to work. If fluids are not replaced, the temperature-regulating process begins to fail, work becomes impossible, and the possibility of life-threatening heat stroke increases dramatically.

Heat disorders—Heat disorders include heat cramps, heat exhaustion, and heat stroke.

Heat cramps are involuntary muscle contractions caused by failure to replace fluids or electrolytes, such as sodium and potassium. Cramps can be relieved by stretching and replacing fluids and electrolytes.

Heat exhaustion is characterized by weakness, extreme fatigue, nausea, headaches, and wet clammy skin. Heat exhaustion is caused by inadequate fluid intake. Symptoms can be relieved by resting in a cool environment and by replacing fluids and electrolytes.

Heat stroke is a medical emergency caused by failure of the body's heat regulating mechanisms. Sweating stops and the body temperature rises dramatically. Heat stroke is characterized by hot dry skin, a body temperature higher than 41 °C (105.8 °F), mental confusion, loss of consciousness, convulsions, and coma. If you are awaiting medical help while caring for a victim of heat stroke, begin cooling the victim with ice or cold water. Fan the victim to promote evaporation. Treat for shock if necessary. For rapid cooling, partially submerge the victim in cold water.

Measuring Heat Stress—Figure 1 illustrates how temperature and humidity combine to create moderate or high heat stress conditions.

The risk of heat stress increases when radiant heat from the sun or nearby flames is high, the air is still, or when someone is working hard and creating a lot of metabolic heat.

Some organizations, including the U.S. Marine Corps, use the wet bulb globe temperature (WBGT) heat stress index. The dry bulb, wet bulb, and globe temperatures are weighted to indicate each measure's impact on the individual:

- Wet bulb (humidity) accounts for 70 percent.
- Black globe (radiant heat and air movement) accounts for 20 percent.
- Dry bulb (air temperature) accounts for 10 percent.

When the sum of the weighted temperatures exceeds 80 °F, instructors are advised to use discretion in training. When the index exceeds 85 °F, recruits must avoid strenuous activity. When the index exceeds 88 °F, they must cease physical activity. However, trained individuals who have been acclimated to the heat are allowed to continue limited activity.

The WBGT index does not take into account the cumulative effects of long hours of hard work or the impact of personal protective clothing and equipment. Studies of heat stress during wildland firefighting indicate that while WBGT values occasionally rise to dangerous levels, the low humidity and high air movement characteristic of fire weather combine to improve evaporative cooling.

In military studies, the frequency of heat illness has been related to the temperature of the previous day. When the temperature was hot, the frequency of heat illness increased even though the

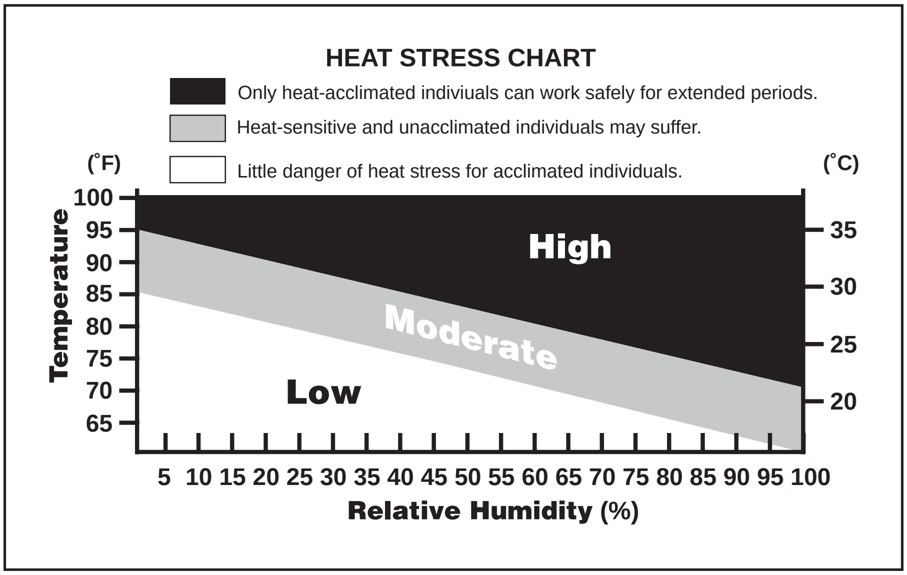


Figure 1—Measuring heat stress.

recruits were forced to rehydrate. High temperatures on one day should be viewed as a warning flag for the following day.

Clothing—Personal protective clothing needs to provide for firefighter safety and comfort. Australian researchers Budd and Brotherhood (1996) concluded that:

> ***Clearly, the task of firefighters' clothing is not to keep heat out but to let it out.***

About 70 percent of the heat load comes from metabolic heat generated by muscles during hard work. Only 30 percent of the heat load comes from the environment and the fire. Studies recommend loose-fitting garments to enhance air movement and cotton underclothing to help sweat evaporate. Firefighters should avoid extra layers of clothing that insulate, restrict air movement, and contribute to heat stress.

Individual Differences—Some workers are at greater risk for heat disorders due to individual differences in fitness and heat acclimatization, or heat intolerance. Some workers sweat profusely, while a few have an inadequate number of sweat glands. Excess body weight increases metabolic heat production and interferes with heat loss. Illness, sleep deprivation, medications, drugs, and alcohol can also influence the body's response to work in a hot environment. After an illness, workers need time to reacclimate to the heat.

A number of prescription and over-the-counter medications, as well as recreational drugs and alcohol, increase the risk of heat stroke. Workers should check with a physician or pharmacist if they are using medications or drugs, or if they have a medical condition. Large doses of the over-the-counter, anti-inflammatory drug, ibuprofen, can cause kidney damage if it is used by someone who is dehydrated.

Prevention—The serious consequences of heat stress can be avoided by increasing fitness and by acclimating to the heat.

Fitness—Maintain a high level of aerobic fitness to avoid heat stress. The fit worker has a well-developed circulatory system and increased blood volume. Both are important for the regulation of body temperature. Fit workers start to sweat sooner, so they work with a lower heart rate and body temperature. They adjust to the heat twice as fast as the unfit worker. They lose acclimatization more slowly and regain it more quickly. In a heat chamber study conducted in the University of Montana Human Performance Laboratory, fitness was inversely related to the working heart rate. A subject with a high level of aerobic fitness (68 mL/kg-min) worked at a heart rate of 118 beats per minute (bpm), while a less fit subject (45 mL/kg-min) had a heart rate higher than 160 bpm (figure 2). In this 2-h treadmill test conducted at 90 °F, differences in fitness overshadowed the effects of variations in clothing systems.

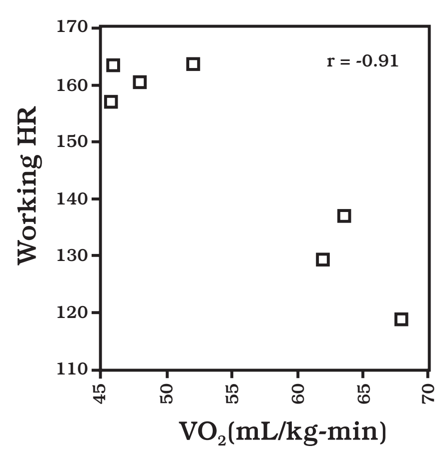


Figure 2—Fitness and heart rate.

***Acclimatization*—**With 5 to 10 days of heat exposure, the body:

- Begins sweating at a lower temperature.
- Increases sweat production.
- Improves blood distribution.
- Decreases the heart rate, and lowers skin and body temperatures.

Firefighters can prepare for work in heat-stress conditions by gradually increasing their work time in the heat, taking care to replace fluids, and resting as needed. They can maintain acclimatization with periodic exposure to work or exercise in a hot environment.

On the Job—When heat stress conditions exist, workers must modify the way they work and exercise. When possible workers should:

- Pace themselves.
- Avoid working close to heat sources.
- Do harder work during cooler morning and evening hours.
- Change tools or tasks to minimize fatigue.
- Take frequent rest breaks during work.

Most important of all, workers must maintain hydration by replacing lost fluids.

Hydration—Studies of wildland firefighters indicate that fire suppression activities generate about 7.5 kcal of heat each minute worked, or over 400 kcal/h. Additional heat (about 180 kcal/h) comes from the environment and the fire.

400 + 180 = 580 kcal/h

Complete evaporation of 1 L of sweat removes 580 kcal of heat. Firefighters need to evaporate about 1 L (1 L = 1.0567 qt) of sweat for each hour of work. These body fluids must be replaced. This can be accomplished by drinking before, during, and after work.

***Before Work*—**Drink 1 to 2 cups of water, juice, or sport drink before work. Avoid excess caffeine because it hastens fluid loss in the urine. Studies of glycerol-induced hyperhydration (temporary storage of extra fluids) do not support its use by wildland firefighters (Swan et al. 2000).

***During Work*—**Workers should take several fluid breaks every hour, drinking at least 1 qt of fluid each hour and as much as possible during lunch (figure 3). Water is the body's greatest need while working in the heat. Studies show that workers drink more fluids when lightly flavored beverages are available. Providing a portion of fluid replacement with a carbohydrate/electrolyte (C/E) beverage helps firefighters retain fluids and maintain their energy and electrolyte levels. The carbohydrate also helps maintain immune function (Nieman 1998) and mental performance (Puchkoff et al. 1998). The sodium in the C/E beverage reduces urinary water loss.

***After Work*—**Continue drinking to replace fluid losses. Thirst always underestimates fluid needs. Workers should drink more than they think they need. Rehydration is enhanced when fluids contain sodium and potassium, or when

Figure 3—Workers should avoid sharing water bottles except in emergencies.

foods with these electrolytes are consumed along with the fluid.

Sodium lost in sweat is easily replaced at mealtime with liberal use of the saltshaker. Unacclimatized workers lose more salt in the heat, so they need to pay particular attention to salt replacement. Salt intake should not be overdone; too much salt impairs temperature regulation, causes stomach distress, fatigue, and other problems. Firefighters should eat potassium-rich foods like bananas and citrus fruits and drink plenty of lemonade, orange juice, or tomato juice. In fire camp, limit caffeine drinks such as coffee and colas because caffeine increases fluid loss in the urine. Alcoholic drinks also cause dehydration.

Hydration can be assessed by observing the volume, color, and concentration of urine; low volumes of dark or concentrated urine indicate a serious need for rehydration. Other signs of dehydration include a rapid heart rate, weakness, excessive fatigue, and dizziness. Rapid loss of several pounds of body weight signals dehydration. Workers should rehydrate before returning to work. Continuing to work while dehydrated can lead to serious consequences, including heat stroke, muscle breakdown, and kidney failure.

Summary

The risks of heat stress and heat disorders can be reduced dramatically if workers comply with the following guidelines:

Prevention	• Improve/maintain aerobic fitness. • Acclimate to the heat.
On the job	• Be aware of weather conditions (temperature, humidity, air movement). • Take frequent rest breaks. • Do not wear unnecessary layers of clothing. • Pace yourself. • Change tasks or tools.
Hydrate	• Before work—drink 1 to 2 cups of water, juice, or sport drink. • During work—take frequent fluid breaks (1 qt/h). • After work—keep drinking to ensure rehydration.
Partner	• Always work or train with a partner.

It is dangerous to work or exercise alone in heat stress conditions. Firefighters should always train and work with a partner who can provide assistance in the event of a problem. They should remind each other to drink lots of fluids, keep an eye on each other, and call for help and start treatment immediately if their partner shows signs of a heat disorder.

This paper is an updated version of Dr. Sharkey's presentation at the Wildland Firefighter Health and Safety Conference hosted by MTDC in April 1999. Dr. Sharkey, a project leader at MTDC, is professor emeritus of the University of Montana Human Performance Lab.

Research

California Studies of Firefighter Clothing

The California Department of Forestry and Fire Protection (CDF) and the University of California, Davis (UCD) agreed to evaluate and improve the protective clothing system for wildland firefighters. The first phase of the project involved three studies: 1) assessment of the radiant heat protection of single- and multiple-layer fabrics, 2) physiological evaluation of current and prototype clothing during work in moderate and hot conditions, and 3) subjective evaluation of standard and prototype garments. Clothing for wildland firefighters must protect from cuts, abrasions, sparks, radiant heat, and occasional flame exposure to the lower legs, without impeding the evaporation of sweat. The traditional view of firefighter protective clothing may have put too much emphasis on thermal protection and underestimated or ignored other important aspects of the garments.

The radiant protection assessment compared several two-layer clothing systems and the one-layer system used by the USDA Forest Service on a thermally instrumented mannequin. When the mannequin was exposed to an average heat flux of 80 kW/m^2, producing a flame temperature of 1,800 to 2,000 °F for 4 s, the two-layer systems provided significantly more protection from burns than the one-layer system. The experimental conditions, designed to simulate a burnover, exceed the exposures typically experienced by firefighters (less than 2 kW/m^2).

The physiological evaluation compared current CDF and Forest Service clothing and a prototype developed by UCD. Experienced firefighters exercised for 90 min in warm (30 °C, 32-percent relative humidity) and hot (38.5 °C, 23-percent relative humidity) conditions, performing treadmill walking, hose pulling, and raking with a McLeod. Work intensity was set at 47.5 percent and 42 percent of maximum oxygen intake (VO_2 max) for warm and hot conditions respectively. Rectal and skin temperatures, total sweat, and subjective responses were lower for the single-layer Forest Service uniform. Results indicate that the two-layer clothing system restricts evaporative cooling and increases the risk of hyperthermia (heat exhaustion and heat stroke). The authors emphasized the importance of fitness, heat acclimatization, and hydration in preventing heat disorders.

The subjective evaluation compared current CDF and Forest Service clothing with the UCD prototype. The CDF clothing was perceived to be heavier, stiffer, and significantly less breathable, comfortable, and flexible than either the UCD prototype or Forest Service clothing. While ratings generally agreed with objective measures, such as air permeability of the fabrics, the slightly heavier UCD prototype was perceived to be lighter than the CDF uniform, perhaps because of the softer material (fire-retardant cotton) and the use of pleats to improve range of motion. Additional field and laboratory testing is planned.

Rucker, M.; Adams, W. 2000. *Evaluation of thermal protective properties and heat stress responses to protective clothing for wildland firefighters*. University of California, Davis. For information, contact Galen McCray, safety officer, CDF (galen_mccray@fire.ca.gov).

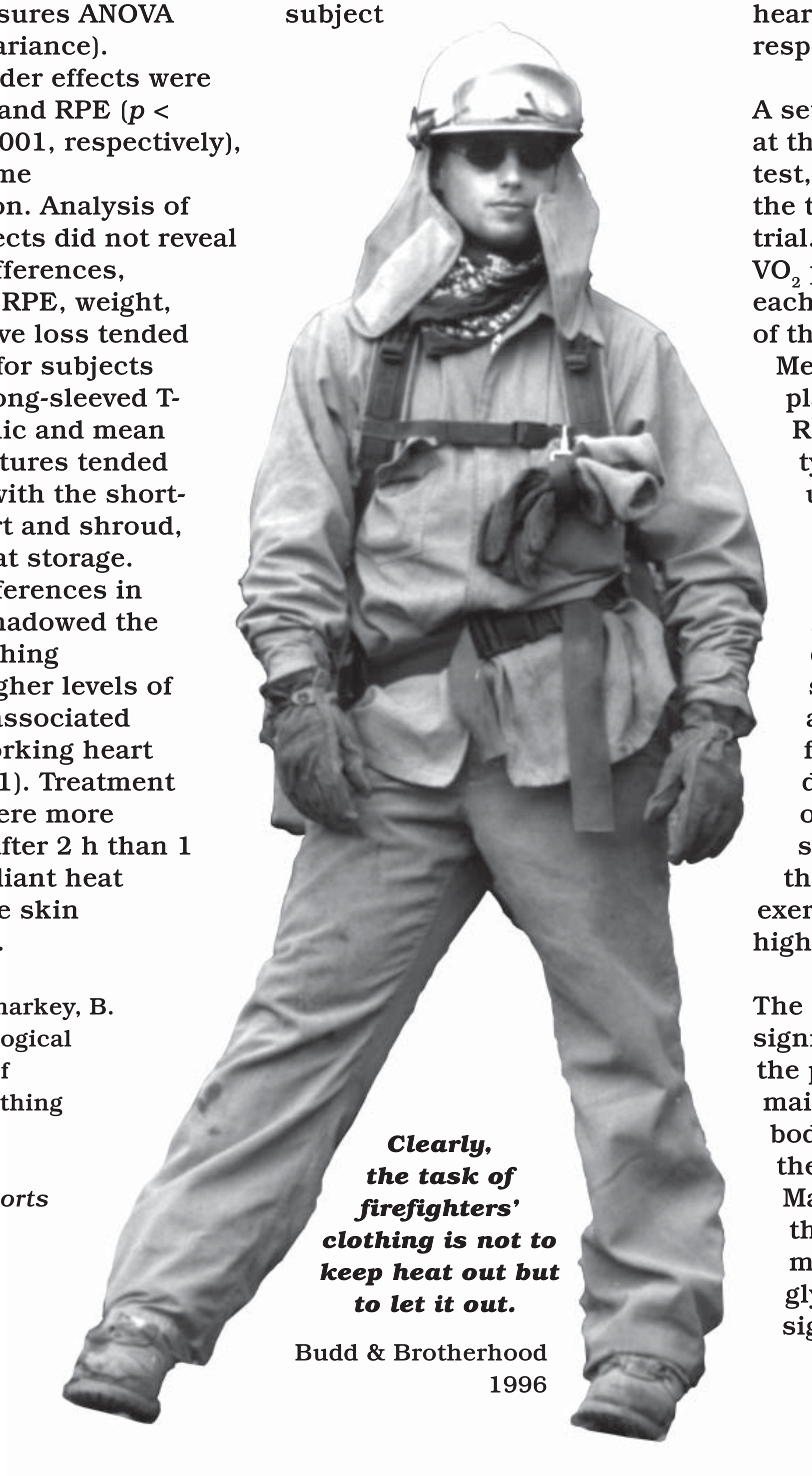
Clothing, Fitness, and Firefighting

The standard on protective clothing and equipment for wildland firefighters (NFPA 1977 and NFPA 1993) addresses outer garments and some accessories. This study compared proposed uniform variations. Four male and four female volunteers performed prolonged (2-h) treadmill tests with four variations of the standard uniform: no T-shirt, a short-sleeved T-shirt, a long-sleeved T-shirt, and a short-sleeved T-shirt plus a shroud for face and neck protection. Test order was determined by a balanced Latin square design. The 2-h tests were conducted with a 3-d rest interval and consisted of a treadmill walk at 5.65 km/h (3.5 mi/h) and 4.5-percent grade, with a 10.9-kg (24-lb) pack. These conditions reflect the energy expenditure of firefighting tasks (7.5 kcal/min).

The tests were conducted at 32.2 °C (90 °F) and 30-percent relative humidity, with an airspeed of 5 km/h (3.1 mi/h), and radiant heat of (0.1 W/cm^2) during the first half of each hour. Heart rates (HR), skin and tympanic temperatures, and rates of perceived exertion (RPE) were recorded every 10 min. Weight loss and evaporative loss were determined after each trial. Values for males and females were not significantly different, so the data were pooled for repeated measures ANOVA (analysis of variance). Significant order effects were found for HR and RPE ($p <$ 0.029 and 0.0001, respectively), indicating some acclimatization. Analysis of treatment effects did not reveal significant differences, although HR, RPE, weight, and evaporative loss tended to be greater for subjects wearing the long-sleeved T-shirt. Tympanic and mean body temperatures tended to be higher with the short-sleeved T-shirt and shroud, indicating heat storage. Individual differences in fitness overshadowed the effects of clothing variations; higher levels of fitness were associated with lower working heart rates (r = -0.91). Treatment differences were more pronounced after 2 h than 1 h, and the radiant heat influenced the skin temperatures.

Cordes, K.; Sharkey, B. 1995. Physiological comparison of protective clothing variations. *Medicine and Science in Sports and Exercise.* May.

Hydration and Blood Glucose
This study examined the differential effects of three hydration methodologies (carbohydrate, glycerol, and placebo) on the mental performance of 10 subjects during 3 h of treadmill walking and simulated line digging in a heated environment. Each subject



Clearly, the task of firefighters' clothing is not to keep heat out but to let it out.

Budd & Brotherhood 1996

completed one 3-h exercise trial for each hydration methodology. The paced auditory serial addition task (PASAT) was used to assess mental performance; each subject was given three practice tests before the first trial. The test required subjects to add pairs of single-digit numbers heard on a tape recorder and to respond verbally.

A set of 61 numbers was given at three speeds for each PASAT test, and subjects were given the test three times during each trial. All subjects completed a VO_2 peak test. Intensity for each trial was set at 50 percent of the subject's peak VO_2. Measures of blood glucose, plasma volume, body weight, RPE, heart rate, core and tympanic temperatures, and urine output were recorded at regular intervals throughout each trial.

A statistically significant difference between final scores in the carbohydrate and placebo trials was found at the speed of one digit every 1.6 s. At a speed of one digit every 1.2 s, scores after 90 min and at the end of 180 min of exercise were significantly higher than baseline scores.

The carbohydrate trial showed significantly higher values than the placebo trial. Females maintained more consistent body weights than males at the end of the exercise trial. Males gained more weight than females during the 90-min prehydration period. The glycerol trial resulted in significantly higher plasma volume values. Females exhibited a greater ability to maintain plasma volume. Blood glucose values were higher at all data collection points, beginning with 60 min, during the carbohydrate trial. The RPE scores were significantly higher than baseline measures beginning at 90 min of exercise.

The results of this study suggest that mental performance improves after long-duration submaximal exercise in a heated environment and is better maintained with carbohydrate hydration than with glycerol or water. The increase in scores could be attributed to increased attention and arousal of the central nervous system. The improvement with carbohydrate is probably due to the increase in blood glucose, which is needed for cognitive function.

Puchkoff, J.; Curry, L.; Swan, J.; Sharkey, B.; Ruby, B. 1998. The effects of hydration status and blood glucose on mental performance during extended exercise in the heat. *Medicine and Science in Sports and Exercise.* May.

Hydration Strategies

This study examined gender-specific physiological differences in response to long-term exercise in a heated environment. Nine trained subjects (four males and five females) performed 180 min of treadmill walking at 50-percent VO_2 peak followed by a timed performance measure. Exercise was performed in a heat chamber set at 32 °C and 30-percent relative humidity. Hydration strategies included:

- W+W Trial—Water (24.1 mL of water per kilogram of body weight) before exercise and water (5 mL of water per kilogram of body weight per 30 min) during exercise.
- Gly+W Trial—Glycerol solution (1 g glycerol per kilogram of body weight + 24.1 mL of water per kilogram of body weight) before exercise and water (5 mL of water per kilogram of body weight per 30 min) during exercise.
- W+CHO Trial—Water (21.4 mL of water per kilogram of body weight) before exercise and a 7-percent carbohydrate (CHO) solution (5 mL of CHO per kilogram of body weight per 30 min) during exercise.

Measured variables included: heart rate, plasma osmolality, core temperature, tympanic temperature, sweat rate, urine output, body weight, performance time, and plasma volume. Females lost less plasma volume than males. ($p < 0.05$). Plasma volume was preserved better during the Gly+W trial than during the W+W trial ($p < 0.03$). However, no significant differences were found between the Gly+W and W+CHO trials when hydration was maintained during exercise-induced heat stress. Females demonstrated a significantly lower sweat rate than males. The difference in weight loss was nearly significant between males (3.5 percent) and females (2.7 percent). These data indicate that females may have more efficient physiological adaptations to an exercise-induced heat stress, including decreased loss of body weight and plasma volume, and a lower sweat rate.

Swan, J.; Ruby, B.; Sharkey, B.; Puchkoff, J. 2000. Gender comparison of long-term exercise and three hydration strategies in a heated environment. *Medicine and Science in Sports and Exercise*. May.

Risk Management

During the 80 years from 1910 to 1990, there were four recorded deaths of wildland firefighters attributed to heat stroke. Over the following decade, from 1991 to 2000, three firefighters died from heat stroke, two on fires and one during training.

Obesity and Heat Stress

Obese individuals have a lowered tolerance to heat. The excess weight compromises cardiac function by raising the work and metabolic heat, and by lowering fitness per unit of body weight. Heart rate at rest and during exercise is higher than in lean individuals. Obese individuals have a lower surface-area to body-mass ratio, which diminishes the body's ability to lose heat to the environment. In addition, there is an inverse relationship between sweat gland density and percentage of body fat, compromising the body's ability to lose heat by evaporative cooling. For a given heat load, the elevation in tissue temperature of obese persons is likely to be higher, increasing the likelihood of heat disorders. In a related report, workers were advised to maintain a body-mass index below 28 for work in the heat (Donoghue, A.; Bates, G. 2000. *Occupational Medicine*). Other factors associated with heat intolerance are low aerobic fitness, lack of acclimatization, heavy clothing, illness, and drugs.

Epstein, Y. 1990. Heat intolerance: predisposing factor or residual injury? *Medicine and Science in Sports and Exercise.* 22: 29–35.

Drugs and Heat Intolerance

A number of therapeutic agents and drugs of abuse have been associated with heat intolerance. Alcoholism and the use of certain drugs are among the 10 major risk factors for heat illness in the general population. Amphetamines are among the most widely used drugs among active, healthy individuals. High body temperature and fatal heat stroke are relatively common occurrences in cases of acute amphetamine overdose.

Therapeutic agents include over-the-counter and prescription drugs such as: diuretics, laxatives, antihistamines, beta-blockers, tricyclic antidepressants, vasoconstrictors, and others.

Drugs of abuse include: amphetamines, cocaine, LSD, cannabinoids, opiates, and alcohol.

A number of pharmacologic agents interfere with the body's ability to maintain normal body temperature during work or under conditions of environmental heat stress. Life-threatening elevation of body temperature may occur. Workers using therapeutic agents or drugs of abuse should consult a physician or pharmacist before they return to work as wildland firefighters.

Vassallo, S.; Delaney, K. 1989. Pharmacologic effects on thermoregulation: mechanisms of drug-related heatstroke. *Clinical Toxicology.* 27: 199–224.

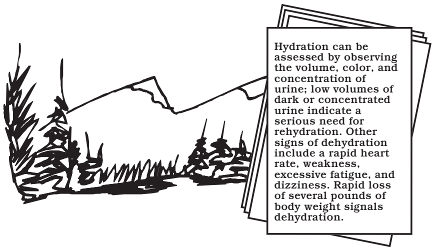
Water Intoxication

Several reports have described hyponatremia (abnormally low concentration of sodium in the blood) as a result of excessive water intake during endurance races, due to a desire to prevent heat injury. The military has adopted hydration guidelines to maintain performance and minimize the risks of heat casualties. As military personnel increase their fluid intake, the risk of hyponatremia as a result of water overload increases. Garigan's and Ristedt's paper reports the first known death of an Army trainee as a result of acute water intoxication. The misdiagnosis of his symptoms as those of dehydration and heat injury led to continued efforts at oral hydration until catastrophic cerebral and pulmonary edema developed.

Garigan, T.; Ristedt, D. 1999. Death from hyponatremia as a result of acute water intoxication in an Army basic trainee. *Military Medicine* 164: 234–238.

Note: *Wildland firefighters require about 1 L of fluid per hour, which is consistent with the revised military hydration guidelines.*

Field Notes



Assessing Hydration

During work in the heat, individuals never voluntarily drink as much water as they lose, replacing only two-thirds of the water loss. This phenomenon is called voluntary dehydration. Because of the delay between fluid loss and thirst, some individuals maintain a chronic state of dehydration equivalent to a water deficit of 2 L, or almost 3 percent of body weight. This voluntary dehydration increases with rising ambient temperature, work rate, and sweat rates. Workers in hot environments should be considered dehydrated unless they have recently been forced to drink more water. Remember:

Thirst always underestimates fluid needs.

Dr. Lawrence Armstrong of the University of Connecticut Human Performance Laboratory validated a urine color chart in a series of studies that confirmed the relationship of urine color to laboratory measures of hydration, including the specific gravity and osmolality of urine. Wildland firefighters can use the chart to evaluate hydration status before, during, and after work and exercise training. Urine darker than a pale yellow or straw color indicates dehydration. Urine color is best observed against a white background, such as a toilet bowl. Observing urine color may be more difficult in fire camp or in the field. A disposable white paper cup may be used in fire camp (dispose of cups in the trash, not in portable toilets). While urine color may change temporarily in response to illness, some medications, vitamin supplements, and food pigments, Dr. Armstrong's studies found these effects to be minimal.

Armstrong, Lawrence E. 2000. Performing in extreme environments. Champaign, Il: Human Kinetics (E-mail: humank@hkusa .com).

Food and Immunity

Upper respiratory problems account for 30 to 50 percent of the visits to fire camp medical tents. Ailments include coughs, colds, and sore throats. The fall 2000 edition of this report included a discussion of the human immune system and how factors in the wildland fire environment can suppress immune function. Exhaustion, stress, inadequate nutrition, dehydration, rapid weight loss, sleep loss, and exposure to smoke can suppress immune function. Conversely, good nutrition has been shown to maintain or enhance immune function, even in physically demanding environments.

Firefighters can burn up to 6,000 kcal daily in arduous work duties. The calories need to be replaced to avoid rapid weight loss and fatigue. How those calories are replaced can influence the function of the immune system. A recent study by Pedersen and others (2000) indicates that during a 7-week period of exertion, a high-fat diet (62 percent of calories from fat) was detrimental to the immune response when compared to a high carbohydrate diet (65 percent of calories from carbohydrate). Natural killer (NK) cell activity, one measure of immune response, increased 11 percent on the carbohydrate-rich diet, while it decreased 6 percent on the high-fat diet.

Fire camp meals can contain as much as 50 percent of calories from fat. Firefighters should limit fat intake and increase the intake of complex carbohydrates (whole grain breads, pasta, potatoes, corn, and rice). This is especially true during an extended fire season. A diet containing 55 to 65 percent of calories from carbohydrates, 15 percent from protein, and 25- to 30-percent fat provides the energy needed to fuel muscles during long days and weeks on the fireline.

Other studies indicate the value of maintaining energy during activity, using carbohydrate-rich energy bars and a carbohydrate/electrolyte (C/E) beverage. Immune function declines during and after

periods of exhausting work. Maintaining energy with energy bars between meals and C/E beverages minimizes the decline in immune function. In addition to the effect on the immune system, energy is available to fuel muscular contractions and maintain mental function during work. The body's use of carbohydrates increases during work in the heat. The brain and nervous system depend on carbohydrate energy. When blood-sugar levels drop, the worker becomes confused, irritable, and more prone to poor judgment and accidents.

Publications

Wildland Firefighter Health and Safety Report, Nos. 1 (0051-2825-MTDC) and 2 (0051-2855-MTDC), are available from MTDC.

Coming up. . .

Health Hazards of Smoke No. 13. A review of smoke exposures and health effects of the 2000 fire season, available from MTDC in spring 2001.

The next Wildland Firefighter Health and Safety Report in fall 2001:

- Work capacity
- Pack test
- Medical examinations
- Risks of exercise

If you have comments, questions, or suggestions about this report or project, send them to: bsharkey@fs.fed.us.

The National Wildfire Coordinating Group (NWCG) coordinates firefighting among Federal and State agencies. As part of the NWCG's mandate to ensure current, shared information, a report on wildland firefighter health and safety issues is published twice each year by the Missoula Technology & Development Center (MTDC). It includes activities related to the MTDC project on firefighter health and safety, including summaries of research, abstracts of related reports, articles, and field notes. Practical approaches to manage fatigue, environmental stress, and other factors that compromise the health and safety of wildland firefighters are reported, and upcoming events are announced.

Additional single copies of this document may be ordered from:

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