Wildland Firefighter
Health & Safety Report

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In this issue:

University of Montana researcher Dr. Brent Ruby rises early to collect immune function and fatigue data in fire camp (see page 7).

Background

This report, the fifth 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 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 work capacity and medical standards, and improvement of the health, safety, and productivity of firefighters

Work/Rest Issues

This report focuses on work/rest issues with special attention to shift length, length of assignment, rest/sleep guidelines, and fatigue countermeasures. Other work/rest issues include rest breaks, nutrition, hydration, and topics related to performance and fatigue. Earlier reviews of studies in this area (Sharkey 1980, Jukkala and Sharkey 1989) indicated that a number of factors influence workers' ability to maintain performance for extended hours, days, or weeks of work. Physically fit and motivated workers are able to perform for extended periods when the work is meaningful and the goal is worth attaining. In contrived or make-work studies, performance declines precipitously with time. Studies by MTDC show that workers perform above expectations when they are trained, motivated, and part of a cohesive group, such as a type 1 fire crew.

Work/rest issues are confounded by economic, personal, and social concerns. Changes in assignment or shift length may affect firefighters' income. Family concerns also influence the desirability of extended assignments. While these issues are important to the successful implementation of policy, they are outside the scope of this project.

Work and Fatigue in Wildland Firefighting

Steven Gaskill, Ph.D.

In 1980 and 1989 the Missoula Technology and Development Center reviewed studies related to fatigue during extended firefighting operations. Since then, MTDC and others have completed additional studies. This report summarizes recent recommendations from laboratory and field studies.

Definitions:

Fatigue—A sense of tiredness, either mental or physical, brought on by stress (lack of sleep, physical work, nutritional inadequacies, or mental stresses). Fatigue following work or sleep deprivation is a normal state and can be reversed with adequate recovery or rest.

Accumulated (Chronic) Fatigue—Fatigue from which normal rest does not produce recovery. Accumulated fatigue is often caused by extended periods of stress with inadequate recovery periods, resulting in decreased productivity, compromised immune function, and reduced alertness.

Fatigued workers perform poorly and behave carelessly, tolerate greater errors, and become inattentive. They display decreased motivation, increased irritability and depression, and low morale. Accumulated fatigue is more persistent, producing a wider array of effects on performance, health, and morale than ordinary fatigue. Accumulated fatigue requires longer recovery periods than ordinary fatigue.

Energy Balance and Nutritional Deficiencies

The total calories eaten by firefighters need to match the total calories expended over an entire duty cycle and, ideally, over an entire season of firefighting. This balance can generally be monitored by body weight. However, the type of food that is eaten and the time that the food is eaten may have a dramatic effect on the body's ability to recover from physical stress.

Recommendations for Maintaining Energy Balance

- Body weight should be maintained over the course of a work assignment. Daily fluctuations of 1 to 3 pounds are normal, due to water loss. Water loss should be replenished before sleeping each night. Loss of weight because of dehydration or loss of lean body mass is a sign of fatigue and decreased work productivity. Sustained weight losses of more than 1 to 2 pounds per week have been shown to decrease immune function.
- The wildland firefighter's diet should include at least 60 percent of calories from carbohydrates with less than 30 percent of calories from fats. The diet should include about 1.2 to 1.6 grams of protein for each kilogram (2.2 pounds) of body weight. This represents 84 to 112 grams of protein per day for a 70-kilogram (154-pound) individual and 120 to 160 grams of protein per day for a 100-kilogram (220-pound) individual (an ounce is 28.4 grams, about 70 percent of lean meat is protein). This recommendation is based on studies of individuals engaged in arduous aerobic or muscular fitness training.
- Blood glucose and muscle glycogen (carbohydrate stored in the muscle) need to be maintained or spared during extended, arduous work to maintain immune function, reduce upper respiratory tract infections (URTI), and promote work productivity, cognitive function, and safety. Supplemental foods and fluids containing carbohydrate need to be consumed regularly during the work day.
- Muscle glycogen levels need to be restored between work shifts through normal diet and also by carbohydrate intake during the "window of opportunity" when muscle glycogen is most easily restored. This window of opportunity is within 15 to 45 minutes after a work shift has been completed. Individuals should eat high-glycemic (quickly absorbed) carbohydrates during the window of opportunity. Crews might need to have supplemental food available between the end of the shift and the next meal. This food may need to be available when crews are being transported (or when they are waiting to be transported) or during any

situation when they will not receive a meal within 45 minutes after they have finished their work shift.

- Crewmembers must maintain hydration at the beginning of and during the work shift. Crew leaders need to watch for crewmembers who may not be carrying or consuming enough water, especially when crews are working in hot, dry conditions.

Environmental Stresses

Environmental stresses add to the total stress of a wildland firefighter's duties and should be considered when crew leaders evaluate situations that may increase accumulated fatigue. Increases in altitude, heat, humidity, and smoke increase the risk of fatigue. In addition, rough, steep terrain and dangers such as rolling rocks and snags increase physical and mental stress, leading to a high level of fatigue. More rest may be required to recover adequately before the next work shift when crews are working in such conditions.

Recommendations for Acclimatization to the Environment

- Acclimatization periods are necessary for extended work at elevations higher than 6,000 feet or when crews are working in areas with high temperature or humidity. Guidelines should be developed to help managers decide when acclimatization periods are necessary.
- Work shifts should be shortened with reduced workloads for 2 to 3 days while workers acclimatize to heat stress.
- Acclimatization to altitude depends on elevation, but a general guideline would be to reduce the duration and intensity of the work shift for 1 day for each 1,000 feet in elevation above 6,000 feet. Individuals differ in their response to environmental stress. Crew leaders need to watch each crewmember for signs of heat stress or altitude-related problems.

Shift Length and Sleep Duration

The recommendations of the 1989 Wildland Firefighter Work/Rest Cycles Review are still valid. Crew leaders should adhere to the 2:1 work/rest requirement (for each 2 hours of duty time—portal to portal—crewmembers should receive 1 hour of rest or sleep). Longer shift lengths require additional sleep. These data are supported by research for shift lengths up to 24 hours.

Recommendations on Shift Length and Sleep Duration

- The current two-shift system (12 to 14 hours) is the preferred alternative, providing that firefighters are provided 1 hour of sleep or rest for every 2 hours worked.
- Most rested individuals can tolerate up to a 24-hour work shift without substantial loss of cognitive or physical performance, so long as adequate recovery is given between shifts.
- Long work shifts (such as shifts over 20 hours) may impair recovery of the immune system (see *Research*, page 7).
- Cognitive function is best maintained if the task is interesting or demanding. Changing tasks improves performance during a long shift.
- Crew leaders need to be especially careful that they get enough rest. Long shifts and lack of sleep impair cognitive function more quickly than they impair physical productivity.

Assignment Length

Many studies of extended operations have been conducted during military training exercises. Wildland firefighters worked 21-day assignments until the 2000 fire season. Athletes perform prolonged strenuous activities for periods of up to 21 days (such as during the Tour de France bicycle race). Research studies and real-world experience agree that workers or athletes with adequate fitness, nutrition, motivation, and rest can maintain performance for as long as 21 days (for more on assignment length see *Risk Management*, page 10).

Recovery Between Assignments

A large number of factors need to be evaluated to meet the goal of having crewmembers and leaders begin an assignment in

a rested state. No data have been collected on wildland firefighters to evaluate whether the 2-day break between assignments is adequate, or whether the crewmembers and leaders are able to recover adequately during the 2-day break. A related question about rest and recovery is the state of fatigue when crews begin an assignment. Do transport or other logistical factors result in a lack of sleep? A change in time zones or transport to an extreme environment (high altitude or increased heat and humidity) could increase the potential for stress and fatigue.

Recommendations for Evaluating Fatigue at the Start of Arduous Work

- In all situations, the crew leaders should evaluate the need for additional sleep and rest, or the need to acclimatize before beginning an arduous shift.
- Further research is needed to evaluate the effects of various stressors on the ability to recover between assignments.

Guidelines for Monitoring and Enhancing Recovery from Accumulated Fatigue

This section summarizes basic guidelines crew leaders can use to identify signs of accumulated fatigue. Visible symptoms that an individual is not recovering adequately from daily stresses vary and depend on the individual. Crew leaders should pay attention to individuals who complain about or manifest two or more of the following signs, especially when the crew has been exposed to situations that can increase the risk of accumulated fatigue. In addition, the field tests described below may prove helpful in situations where leaders expect fatigue to be excessive.

Many of the symptoms of accumulated fatigue, when viewed independently of other symptoms, may not indicate accumulated fatigue. When multiple symptoms occur simultaneously, crew leaders should take appropriate actions to reduce stress and enhance recovery for the crewmembers who are affected, or for the entire crew.

The symptoms of accumulated fatigue include:

- Loss of body weight
- Decreased appetite
- An increase in resting heart rate
- An increase in submaximal heart rate at a fixed work load
- Perception that standard work tasks are more difficult
- Small (to large) losses in coordination and the ability to do tasks requiring coordination
- Muscle soreness that lasts more than 24 hours
- Increase in upper respiratory tract infections such as colds or flu
- Decreased cognitive function
- Constipation or diarrhea
- A change in moods that may include irritability or decreased motivation or desire

Crew leaders should know and apply measures to enhance recovery from accumulated fatigue. The basic measures include:

- Increased sleep in an environment conducive to sleep
- Reduced duration and frequency of physical work (possible change of duty the following day)
- Adequate supplemental nutrition and fluids during and immediately after physical work
- A high carbohydrate diet
- Monitoring the individuals for recovery

Avoiding Accumulated Fatigue

All of the symptoms listed above, except the resting and submaximal heart rates, appear only after accumulated fatigue is evident. Of the easily measured field symptoms, only the heart rate measures seem to give some advance warning that an individual is approaching a state of accumulated fatigue. When a crew leader recognizes symptoms in crewmembers, the leader should take steps to enhance recovery.

When crews are placed in environments that might increase their risk for accumulated fatigue, when crews are starting an assignment in a fatigued state, or when increased mental and physical stresses are anticipated, crew leaders may choose to monitor individuals. This monitoring is in addition to attention paid to normal symptoms of accumulated stress. Monitoring

crewmembers in the field may require some equipment and take a short period of time each day. Current suggestions include two tests that may also be used to evaluate when workers have recovered from accumulated fatigue.

Recommendations for Monitoring Accumulated Fatigue

- Compare daily body weight to baseline weights. During stressful assignments, daily body weight should be recorded when possible each morning before any food or fluids are consumed. This requires that data be maintained over the fire season, including the baseline weight of individuals in a rested state. Daily fluctuations are expected based on dehydration and fluid loss that can be replaced during meals. Consistent patterns of weight loss suggest environments and work that do not allow adequate recovery, or reflect inadequate nutritional intake. Generally, supplemental carbohydrate intake and maintenance of fluids should be adequate to enhance recovery for fit individuals.
- Monitor morning heart rate response to a standard 4-minute test (requiring 1 minute of easy bench stepping and 3 minutes of rest) for early signs of fatigue and impaired recovery. This fatigue test was evaluated during the summer of 2001 and compared to clinical measurements of immune function. Athletes have used morning resting and submaximal heart rate responses to monitor overtraining. The fatigue test might be appropriate for crews in "at-risk" situations or when accumulated fatigue might be expected. Using this test requires taking baseline measurements and maintaining data on individuals over a period of time to establish patterns (see *Field Notes*, page 12).

For these tests to be practical in a fire camp, the medical tent would need to include a scale and an 8-inch bench. Another alternative would be for type 1 crews to carry a scale and bench.

Additional Fatigue Countermeasures

Fatigue countermeasures have been studied in military populations and endurance athletes. Although many questions remain to be answered, work cycling is one area of interest that may yield positive benefits for wildland firefighters.

Work Cycling—Athletes and coaches have long understood that one of the most effective methods to counteract overtraining (accumulated fatigue) is to vary the training in both intensity and duration so that days of arduous activity are interspersed with less stressful days. This concept allows athletes to avoid illness and accumulated fatigue by scheduling time to recover between hard work periods. The result is reduced time lost to illness, improved alertness, increased total work, and higher productivity. The same principles should apply to wildland firefighters if stressful days are interspersed with less stressful days. This might be done for an entire crew or just for certain individuals. Most physically fit individuals can sustain 1 to 2 days of very arduous work, if they have a less stressful period (1 to 2 days) for recovery. Recovery days do not require inactivity, but do require a change of duty, generally to a duty with less total stress. Little is known about duty cycling for wildland firefighters, but further study might be beneficial. Recommendations for ways to vary the daily intensity and duration of arduous duty should be developed.

Fitness—Physical fitness is another known factor in accumulated fatigue in athletes and workers. When team members are asked to do similar training for extended periods, athletes who are physically fit generally exhibit fewer symptoms of accumulated stress than do individuals who are less fit. Research during the summer of 2001 with two type 1 crews suggested that the fit workers did more work (both in absolute terms and adjusted for body weight) and experienced less fatigue.

Fitness Recommendations for Wildland Firefighters

- Aerobic and muscular endurance training before the fire season that is maintained throughout the season would benefit firefighters who routinely work in situations requiring multiple extended arduous work shifts with moderate to high energy output. Fitness standards that are higher than the pack test (walking 3 miles with a 45-pound pack in 45 minutes) should be considered. A

fitness training manual should be available to type 1 crews.

- Individuals who have been relatively sedentary but who wish to take the pack test should begin a training program gradually and slowly build up to the work capacity required for a wildland firefighter. The pack test should be considered a minimum fitness requirement. Individuals who will be working on the fireline should be encouraged to improve their aerobic (endurance) and muscular fitness.
- The onset of fatigue as a result of work depends on the individual and is related to many factors. Methods to monitor fatigue within fire crews need to be developed to determine when individuals or entire crews need time to recover.

but their long-term effects are not yet known. Commercially available supplements containing ephedra may contribute to life-threatening consequences during exertion and heat stress. It is beyond the scope of this report to consider the growing list of ergogenic aids.

Other recommendations:

- Investigate drink or food supplements that could be used during extended operations to help maintain blood glucose.
- Compare supplements that contain energy and nutrients (such as antioxidants) and a stimulant such as caffeine. A joint effort with the U.S. Army Research Institute of Environmental Medicine or a similar group may be warranted.

Gaskill, S. 2002. Work and fatigue in wildland firefighting: a review of the literature. Missoula, MT: University of Montana Human Performance Laboratory. Copies of the complete review and a list of references are available from Brian Sharkey, *bsharkey@fs.fed.us*.

Dr. Steven Gaskill processes immune function samples as firefighters return from the line.

Related Topics

Caffeine and other ergogenic (performance-enhancing) supplements may prove beneficial in some extended operations involving arduous work. Studies of athletes have shown that caffeine can increase the utilization of fat during extended moderate work, sparing carbohydrates. In addition, caffeine has been shown to improve cognitive function during periods of extended work. Unfortunately, caffeine is a diuretic and is not advised during periods of heat exposure. A recent (2002) report by the U.S. Army has suggested that new drugs that postpone physical and mental fatigue may prove beneficial,

Research

Immune Function and Shift Length

This study compared the reduction in salivary IgA (sIgA) in response to a 14- or 21-hour work shift. Salivary IgA is the first line of defense against respiratory infection. Seventeen wildland firefighters (15 men and 2 women) from two interagency hotshot crews were tested. Subjects were studied in response to a short (13.9 ± 0.7 hours) or a long (21.4 ± 0.3 hours) work shift (table 1). Energy expenditure during a work shift was estimated using the method established by Heil (2001). Unstimulated saliva was collected for 4 minutes before work at 0530 and immediately after a shift. The firefighters' salivary IgA secretion rate (micrograms per minute) was calculated from an ELISA assay procedure.

Results—The energy expenditure during the long work shift was significantly higher ($p < 0.05$, 4,101 ± 578 kilocalories) compared to the short work shift (3,322 ± 478 kilocalories).

Salivary IgA was significantly decreased after the work shift but had returned to the values recorded before the shift by the following morning in both groups. The 14-hour work shift group showed a recovery in sIgA (morning values at days 5 and 6 were 85.8 ± 40.5 and 67.4 ± 32.0 micrograms per minute, respectively). In contrast, the 21-hour work shift group showed suppressed values for sIgA (27.3 ± 13.3 micrograms per minute) 6 days after the extended shift (figures 1 and 2).

Table 1—Shift length and salivary IgA.

Shift length (hours)	Salivary IgA before shift (μg/minute)	Salivary IgA after shift (μg/minute)	Salivary IgA the next morning (μg/minute)
13.9 ± 0.7 (*n*=6)	76.9 ± 23.1	14.0 ± 8.0*	82.4 ± 55.9
21.4 ± 0.3 (*n*=11)	54.1 ± 30.3	24.7 ± 26.5*	40.3 ± 29.0**

* $p < 0.05$ that the difference in values before and after the shift are due to chance.
** $p < 0.05$ that the difference in values between the 13.9-hour shift and the 21.4-hour shift are due to chance.

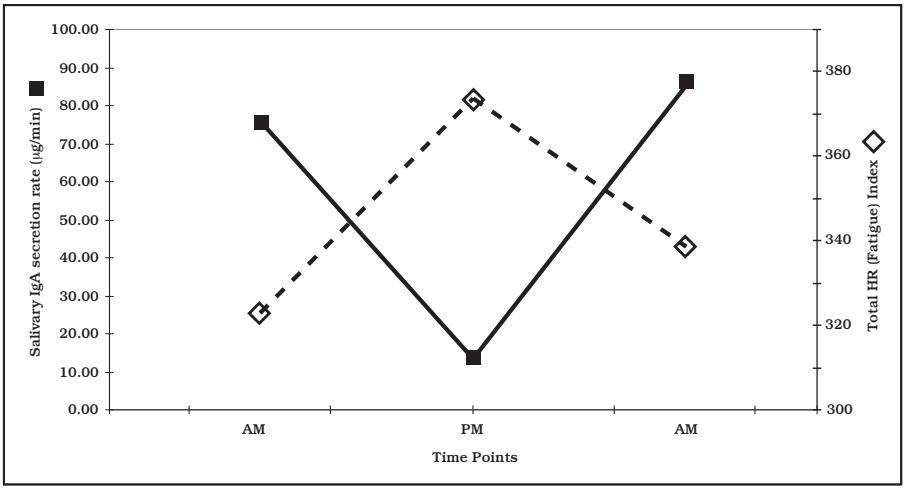


Figure 1—Changes in salivary IgA in response to a single work shift of 13.9 ± 0.7 hours ($n = 6$). The summary data for the fatigue index are also shown (heart rate response to a 1-minute step test). These data indicate adequate recovery after the single work shift.

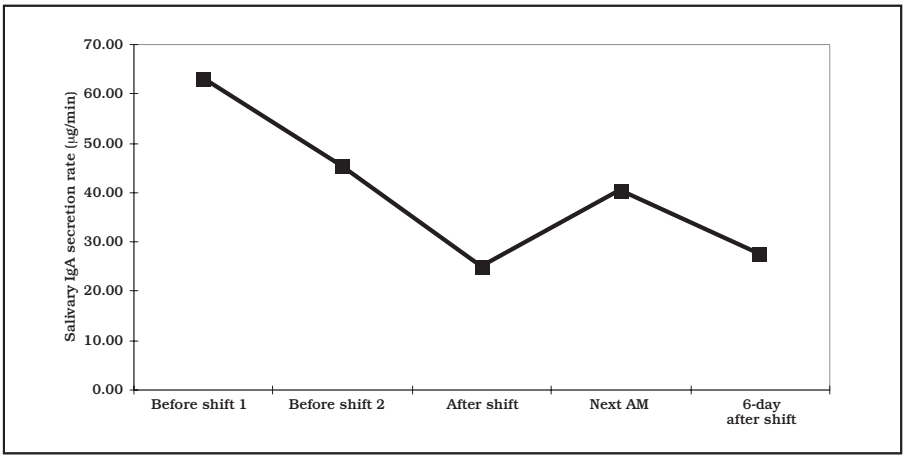


Figure 2—Changes in salivary IgA secretion rate in response to a single work shift of 21.4 ± 0.3 hours ($n = 11$) followed by 5 days of 14 ± 0.7-hour shifts. Although subjects demonstrate an acute recovery response, sIgA secretion rate is still suppressed 6 days after the 21-hour shift in comparison to the rate after a 14-hour work shift.

Conclusions—These data indicate that the sIgA secretion rate is significantly depressed after a single day of wildfire suppression. The energy expended during a work shift in combination with the shift's duration may impair recovery and increase the risk for upper respiratory infection during extended operations.

Ruby, B.; Gaskill, S.; Heil, D.; Sharkey, B.; Hansen, K.; Lankford, D., 2002. Changes in salivary IgA during arduous wildfire suppression relative to work shift length. Medicine and Science in Sports and Exercise. 34:s195 (study supported by MTDC).

Fitness and Fatigue

This study investigated work and recovery rates in wildland firefighters with differing levels of sustainable aerobic fitness. Eleven wildland firefighters from an interagency hotshot crew served as subjects. Subjects were grouped by levels of sustainable fitness as measured by oxygen intake at the ventilatory threshold and studied in response to work rates and recovery after single or multiple arduous days of wildland fire suppression (table 2). Work shift energy expenditure was estimated using the method established by Heil (2001). Recovery rates were measured using a submaximal heart rate (fatigue) index (page 12).

Work and recovery rates for 11 wildland firefighters who had low or high sustainable fitness, energy expenditure and change in heart rate index were compared (figure 3).

Conclusions—Wildland firefighters with higher sustainable fitness (40 to 49 milliliters per kilogram-minute VO_2) are able to do more absolute work and more work relative to their body weight during each day of a duty cycle compared to less fit firefighters (30 to 39 milliliters per kilogram-minute VO_2). Fit individuals recovered more quickly after multiple days of arduous work despite higher energy expenditures. Because the less fit group met or exceeded the minimal job-specific fitness requirements for wildland firefighting (the pack test), these data suggest that the current fitness requirements may need review. Increased sustainable fitness improves work output and recovery.

Gaskill, S.; Ruby, B.; Heil, D.; Sharkey, B.; Hansen, K.; Lankford, D. 2002. Fitness, work rates, and fatigue during arduous wildfire suppression. Medicine and Science in Sports and Exercise, 34:s195 (study supported by MTDC).

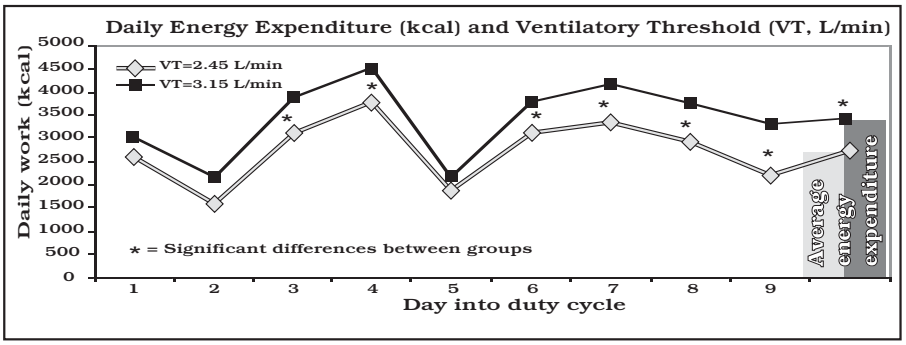


Figure 3—This graph shows the work (kilocalories per day) done by a hotshot crew over a 9-day period. The crew was divided into fit and less fit groups. The fit group did more work per day than the less fit group.

Table 2—Sustainable fitness (SF), energy expenditure (EE), and fatigue, represented by the change (Δ) in heart rate (HR) index.

	SF (milliliters per kilogram per minute)	EE (kilocalories per day)	EE (kilocalories per day per kilogram)	ΔHR index (1 arduous day)	ΔHR index (3 arduous days)
Low SF	34.6±3.5	2735±199*	39.7±3.8*	5.1±18.0	37.3±14.7*
High SF	43.7±3.9	3425±354	44.6±2.1	10.6±18.7	16.1±21.0

* $p < 0.05$ that the difference in values between the two groups is due to chance.

Sleep Deprivation

This study compared the effects of sleep loss with the effects of alcohol intoxication on subjects' performance during a hand-eye coordination test. Forty subjects tracked a moving circle on a computer screen at thirty-minute intervals after 28 hours of sleep deprivation or after ingesting 10 to 15 grams of alcohol at 30-minute intervals until their blood alcohol level reached 0.10 percent. During the first 12 hours of sustained wakefulness (8 a.m. to 8 p.m.), tracking performance improved 1 to 2 percent above the starting level; performance then declined to a low of 6 percent below the starting level. The decline occurred from 8 p.m. to 8 a.m., physiologically the lowest period for human performance. Performance rebounded to near starting levels during the final hours of sleep deprivation.

After 24 hours of sustained wakefulness, performance on the tracking task decreased to a level equivalent to the performance deficit observed at a blood-alcohol concentration of 0.10 percent, which meets or exceeds the definition of intoxication in all States. The authors suggest that the "blood-alcohol equivalent" may provide policymakers with an easily grasped index of the relative impairment associated with sleep loss.

(Dawson, D.; Reid, K. 1997. Fatigue, alcohol, and performance impairment. Nature. 388: 235.)

Editor's Note: While performance on the simple tracking task declined overnight, it rebounded in the morning after 28 hours of sleep deprivation, confounding the relationship to blood alcohol. The analogy to alcohol impairment may make sense for pilots or even bus drivers (where the relationship to tracking tasks holds), but it does not reflect cognitive performance or decisionmaking in wildland firefighting.

Forest Service photo by Ben Croft

Risk Management

Assignment Length

Before the 2000 fire season, the standard assignment for wildland firefighters was 21 days. The shift to a 14-day assignment was due, in part, to a comment in the *Wildland Firefighter Safety Awareness Study* (TriData 1998). In a discussion of the causes of fatigue, the report said: "Firefighter personnel often work too many consecutive hours, on too many consecutive days, and often on too many successive fires." The report went on to say that: "Data from a BIA [Bureau of Indian Affairs] study showed that the majority of injuries occurred among crews during the third week since they had left their home base" (page 5–57). The editor's attempts to locate and review the BIA study have not been successful. So this major policy shift was influenced by a study that has not been available for review.

In a study of fatigue and stress among firefighters and overhead conducted during the 2000 fire season, the 14-day assignment policy was the "problem" most often mentioned by firefighters and managers. Many argued that they should be able to use judgment to determine when to terminate an assignment. Crew leaders and overhead team personnel felt they were in the best position to judge the effectiveness of their respective groups. The 14-day policy should be evaluated in several areas, including: health, safety, and performance; logistics; social and family effects; and the effects on the firefighter's morale. The analysis should consider single compared to multiple assignments, crew types, overhead, and contractors.

Health, Safety, and Performance—Health issues can be evaluated with medical records and measures of immune function. Safety during extended operations can be evaluated with an injury surveillance system. The literature on physical performance in extended operations supports the ability of fit and motivated workers to perform for prolonged periods when they receive adequate rest and nutrition. A type 1 crew should be able to complete a 21-day assignment without adverse effects, while some type 2 crews may lack the training to complete a 21-day assignment without undue fatigue. When multiple assignments are involved, several options are possible: allow crew leaders to shorten the assignment to adjust to the crew condition and the difficulty of assignment; and/or develop a schedule that shortens the length of assignments as the season progresses.

Assignments longer than 14 days may have a greater physical impact on firefighters than on overhead personnel.

Logistical Issues—Travel, incident command team overlap, cooperator regulations, and other issues are affected by the 14-day policy. Increased travel increases the risk to health and safety. The period when incident command teams overlap increases with shorter assignments. Some State agencies have regulations that differ from Federal policies. The 14-day policy increases the need for additional firefighting personnel.

Social/Family Issues—Aside from health or performance issues, the 14-day assignment may encourage more participation by the "militia" (regular employees who volunteer for fire duty). Many employees appreciate the opportunity to get home more frequently.

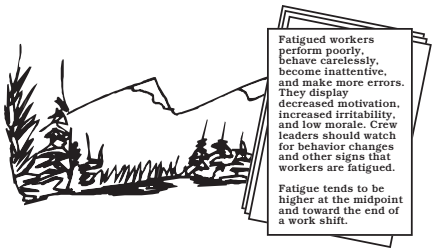
Paycheck Issues—Pay incentives that encourage fatigued firefighters to work long shifts or assignments should be eliminated. Policy changes must be revenue neutral if firefighters are to maintain their morale.

Firefighters' performance depends on their level of fitness, motivation, nutrition, previous assignments, acclimatization, hydration, immune function, and other factors. No single formula will account for the complex interactions among these factors. One approach would be assignment limits (such as 21 days for type 1 crews and 14 days for type 2 crews) tempered by judgment and adjusted for conditions and back-to-back assignments. The impact of fatigue during the 2000 season was tempered by a change in the mission, brought on by the immensity of the task. The intensity of the fires often precluded direct attack, so firefighters were more likely to pace themselves. The task became a marathon rather than a sprint.

Recommendations for Assignment Length

- Establish broad guidelines for assignment length that are appropriate for the demands of the tasks and are specific to the type of the crew.
- Develop work-capacity standards to reflect the current capacity and performance expectations for type 1 crews.
- Review the work-capacity test requirements for all personnel to ensure that each individual is taking the appropriate test.
- During extended operations, when multiple assignments are necessary during a fire season, empower crew leaders to use their judgment in determining when to terminate an assignment.
- Provide training to help crew and team leaders recognize the signs and symptoms of fatigue and to manage crews during extended operations (see *Field Notes* this page).
- Eliminate pay incentives that cause firefighters to continue working when they are severely fatigued.

Field Notes



Fatigue: Signs and Countermeasures

Fatigued workers perform poorly, behave carelessly, become inattentive, and make more errors. They display decreased motivation, increased irritability, and low morale. Crew leaders should watch for behavior changes and other signs that workers are fatigued.

Fatigue tends to be higher at the midpoint and toward the end of a work shift. Accidents peak during the last 2 hours of a 10-hour day. Alertness begins to decline from 1600 to 2300; after 2300, the likelihood of falling asleep increases dramatically. Sleep-deprived workers may suffer from short, intermittent episodes of fatigue. These episodes are characterized by very brief lapses in the performance of tasks, during which details are missed, accuracy is impaired, and performance is slowed.

Signs of Fatigue

- Poor and careless performance
- Greater tolerance for error
- More difficulty concentrating and thinking clearly
- Inattention to minor but potentially important details
- Increased lapses of attention
- Increased irritability
- Decreased motivation
- Slow reaction time
- Impaired communication and cooperation, particularly when working as a crew
- Complaints of headache, stomach, or other problems
- Feelings of depression
- Poor morale
- Loss of appetite
- Weight loss

While there is no substitute for adequate sleep, rest, or time off, crew leaders can employ some short-term countermeasures to minimize the hazards presented by fatigued workers.

Recommendations to Minimize Fatigue: Fatigue Countermeasures

- Ensure that workers are adequately rested before they begin a work shift.
- Slow the work pace to a moderate level on physically demanding tasks.
- Provide periodic rest breaks to allow physical and mental recovery.
- Alternate between heavy and light tasks.
- Change assignments to prevent boredom.
- Provide breaks, naps, or time off after tasks have been completed.
- Provide nutritional food before, during, and after work.

- Provide energy supplements between meals.
- Provide fluid energy supplementation and make certain it is used.
- Ensure that workers maintain good personal hygiene.
- Maintain high standards of physical fitness and work capacity.

Adapted from *Countermeasure*. 1998. Army Group Risk Management Publication (19 : 6) and material published in the U.S. Army Crew Endurance Leaders Guide. 1997.

24-Hour Shifts

Australian bush firefighters may employ a 24-hour shift on the first day of a 7-day assignment. They work 24 hours (including travel time), followed by 8 hours of rest. They may work up to 16 hours a day for the rest of the 7-day assignment. According to Sue Ellis, health and fitness coordinator for Natural Resources and Environment in Victoria, she is not aware of a reported incident (injury or fatality) that could be attributed to fatigue on the 24-hour work shift.

A 1989 MTDC report notes that the 24-hour work/rest cycle should be considered a management option when the 2:1 work/rest ratio cannot be provided with the two-shift system, or when transportation, logistical, or safety problems exist. The report recommends 12 hours of sleep after the 24-hour shift. Furthermore, the report recommends a 12-hour rest period preceding prolonged work or expected sleep loss. For either shift alternative, the report stated that incident command and dispatching organizations should pay more attention to crew sleep/rest before they are assigned to the first shift on a fire. (Jukkala, A.; Sharkey, B. 1989. A study of wildland firefighting work/rest cycles. Tech. Rep. 8951–2235–MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center.)

Fatigue Index

This fatigue test can be used to evaluate recovery from physical work. The test requires that individuals establish normal values over a period of a few days when they are well rested. These values can be compared to values on mornings following days of hard physical work to evaluate recovery. Studies show that fatigue (as indicated by the fatigue test) is related to decreased performance and immune function. It is easiest to take this test using a heart rate monitor, but manual heart rates can be taken using a radial artery (wrist) or carotid artery (neck) pulse. The test is generally done in the morning, before eating breakfast or drinking stimulants, such as coffee.

Tools Needed

- Heart rate monitor (suggested, but not required)
- Stopwatch for timing
- Metronome (set for 120 beats per minute) or a large clock with sweep hands and clear second markings
- 8-inch (20-centimeter)-high bench

Procedure

After getting up in the morning, before eating breakfast or drinking stimulants, such as coffee:

1. Sit quietly in a chair for 3 to 5 minutes until your heart rate is stable.
   - ▼Record resting heart rate from the monitor, or take your resting pulse at the wrist or neck for 10 seconds and multiply the number of heartbeats by six to get the rate per minute.
2. Start a watch and begin stepping.
   - ▼Step up with one foot and then up with the next (so both feet are on bench). Step one foot down followed by the other so both feet are on the ground. This is done at the cadence of 120 beats per minute so that each beat represents a step. If an individual is watching a sweep hand on a clock, the two steps to step up onto the bench or stair should take 1 second and the two steps to step down should take 1 second. The entire sequence of stepping both feet onto the bench and both feet back to the ground should take 2 seconds.
3. After exactly 1 minute of stepping, stop. While standing:
   - ▼Note exercise heart rate from the monitor or take the exercise pulse at your wrist or neck, and sit down immediately.

4. Sit quietly, focusing on relaxation.

   ▾At 30 seconds after stopping exercise, take your heart rate.

   ▾At 60 seconds after stopping exercise, take your heart rate.

5. Record all heart rates:

   ▾Resting heart rate_____

   ▾Exercise heart rate_____

   ▾30-second recovery heart rate_____

   ▾60-second recovery heart rate_____

   ▾Fatigue index sum of heart rates_____

Understanding the Fatigue Index

The fatigue index is unique for each individual and must be compared to that person's average index for several days during a rested condition.

The more elevated the daily fatigue index from the rested average, the more likely the individual is not recovering from the prior day's work and stress, and the more likely the individual will be at risk for depressed immune function and upper respiratory track infections. The following guidelines vary depending on the individual.

Experience with athletes and data from the 2001 fire season would suggest that an individual with an increase in the fatigue index of 30 to 40 beats probably needs a day with reduced work stress. When the morning fatigue index is more than 40 above the resting average, individuals should be assigned duties with low stress until they are recovered to within 30 beats of rested values.

The fatigue test was developed by Steven Gaskill, Ph.D., University of Montana Human Performance Laboratory. For more information contact: *sgaskill@selway.umt.edu*.

Increase in fatigue index (sum of heart rates)	
0 to 30 above rested	–Not generally a concern
30 to 40 above rested	–Slightly increased risk
40 to 50 above rested	–Increased risk
More than 50 above rested	–High risk

Publications

Wildland Firefighter Health and Safety Report, Nos. 1 (0051-2825-MTDC), 2 (0051-2855-MTDC), 3 (0151-2817-MTDC) and 4 (0151-2840-MTDC) are available from MTDC.

Coming up. . .

The next Wildland Firefighter Health and Safety Report in fall 2002 will consider:

- Energy requirements
- Energy supplements
- Nutritional strategies
- Micronutrients
- Immune function

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

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