USDA Forest Service

Wildland Firefighter Health & Safety Report

Summer 2009 Missoula Technology and Development Center No. 13

In This Issue

- Featured Topic: Sleep
- Research: Field Studies
- Risk Management: Stress
- Field Notes: Health Hazards of Smoke

Background

This report, the 13th 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 areas:

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

Energy and nutrition: Improve energy intake, nutrition, hydration, 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.

This Issue

MTDC and cooperators at the University of Montana's Human Performance Laboratory have studied human factors related to wildland firefighting for many years. The featured topic of this report focuses on the influence of sleep on the health and performance of incident management teams and firefighters. Job-related stress can contribute to sleep loss and sleep disturbances.

The research section reviews project-related field studies conducted on wildland firefighters during the 2008 fire season, including shift food (small food items eaten throughout the shift rather than a standard lunch), incident management stress, and the influence of meals on muscle glycogen. The risk management section reviews recent information on stress management. The field notes section outlines recent activities related to the effect of smoke exposure on firefighter health.

Naps restore alertness, enhance performance, and reduce mistakes.

MTDC Work Continues

Brian Sharkey is completing 45 years of association with MTDC and wildland firefighters. The center's work in this area will continue with an outstanding crew. Joe Domitrovich will work at MTDC while he completes his Ph.D. at the University of Montana. Domitrovich is a firefighter with a master's degree in exercise physiology and experience conducting field studies on wildland firefighters. Cooperators at the University of Montana Human Performance Laboratory include Drs. Steve Gaskill, Brent Ruby, and Charlie Palmer (a sport psychologist and one-time smokejumper).

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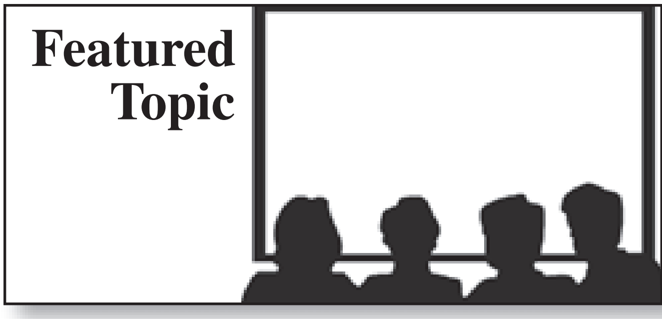


of sleep, ranging from 3.5 to 9.0 hours per night. On average, team members went to bed at 9:30 p.m. They reported being awakened an average of 2.2 times per night, awakening from zero to six times per night. When team members were asked to rate the quality of their sleep, the average was 6.6 on a 10-point scale. Nearly one-fourth (23.8 percent) reported feeling tired when they woke, while 53.6 percent felt somewhat rested, 20.2 percent felt rested, and 2.4 percent felt very rested.

Sleep

MTDC and University of Montana researchers have been conducting human factors studies on wildland firefighters for several decades. Incident management team (IMT) members asked MTDC to study human factors associated with their duties. In 2006, we began studying stress and cardiovascular risk in incident management team members. Those studies, which continued in 2007 and 2008, showed that sleep deprivation contributed to fatigue, stress, and impaired performance of team members. This report reviews some basic information concerning sleep and sleep deprivation, information that could be useful for incident management team members and wildland firefighters, as well as other agency personnel. Other information on studies of stress in incident management team members can be found in "Wildland Firefighter Health & Safety Report" Nos. 11 and 12.

"The most common source of stress I observe is probably directly attributed to lack of sleep…just as I observed in the military there are some folks who can function quite well on limited sleep, while others simply cannot." (Public information officer for a type I incident management team)

Sleeping in fire camp can be a challenge. Noise from generators, vehicles, and other firefighters all contribute to sleeplessness. Because almost all wildland firefighters need to sleep either in fire camps or in spike camps, they sleep in tents, on the ground, and in hot, smoky, and dusty conditions. Shift work interferes with sleep, especially for those on night shift.

Sleep log data were collected on members of five incident management teams at fire camps in California and Montana during 2008. Data for 140 team members (36 percent female, 64 percent male) indicated that they averaged 6.1 hours

Human Factors

According to the National Academy of Sciences, research on human factors is "Concerned with the performance of persons in a task-oriented environment interacting with equipment and/or other people."

What Is Sleep?

Sleep consists of stages of light and deep sleep (figure 1). We begin in light sleep, progress to deep sleep, and then to rapid eye movement (REM) sleep. Deep sleep is believed to be essential for recovery from fatigue and for restoration. When awakened from deep sleep, we do not adjust readily and often feel groggy and disoriented for several minutes. During REM sleep we breathe more rapidly, our eyes move rapidly, and the muscles in our limbs become temporarily paralyzed. Heart rate and blood pressure increase. As the night progresses, REM sleep becomes longer and the periods of deep sleep are shorter.

We dream during REM sleep, perhaps because our inhibitory neurons are relaxed and previously unconnected thoughts mix in our subconscious. If REM sleep is disrupted, we tend to catch up with more REM sleep the next

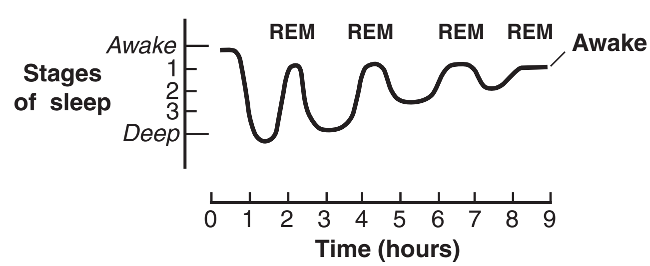


Figure 1—The stages of sleep. REM stands for rapid eye movement sleep.

night. Disruption of REM sleep in a controlled study led to irritability. Continued disruption of REM sleep can lead to neurotic behavior. While laboratory rats normally live 2 to 3 years, they survive only about 5 weeks when deprived of REM sleep. When rats are deprived of all sleep, they live only about 3 weeks.

How Much Sleep?—Those who sleep 6 hours or less per night are not as healthy as those who sleep 7 to 8 hours per night. Those who sleep 9 hours or more are slightly less healthy than those sleeping 7 to 8 hours. Sleep allows neurons to rest and recover. Proteins, including hormones such as growth hormone, are manufactured during sleep.

Too little sleep leaves us drowsy and unable to concentrate. Our memory suffers, as does our physical performance, and we aren't as good at carrying out math calculations. If sleep deprivation continues, mood swings and hallucinations may occur. Sleep deprivation also impairs immune function, increasing the likelihood of upper respiratory and other infections.

Sleep Deprivation—Sleep deprivation can lead to impaired mental and physical performance, to accidents and injuries, increased blood pressure, strokes and heart attacks, and even obesity. Higher order cognitive tasks are affected early; tests show that speed deteriorates before accuracy is affected. Total sleep deprivation for 1 week has led to cognitive impairment when work requires multitasking. In driving, accidents increase as sleep duration is decreased. In tasks requiring judgment, risky behaviors emerge when sleep is limited to 5 hours per night.

Sleep deprivation could influence cognitive performance because of an increase in periods of microsleep, several second periods of sleep-like brain activity. Microsleep increases with sleep deprivation, impairing cognitive function and possibly leading to failures in performance. Other possible explanations for performance impairment include perceptual impairments, such as reduced vigilance.

Circadian Rhythms—Circadian rhythms are regular changes in mental and physical characteristics that occur in the course of the day. If you have ever worked a night shift, you have experienced the challenge of working during the low point of your circadian rhythms. It is extremely hard to concentrate, perform, or even stay awake during the low point of the rhythms (2 to 6 a.m.). Sleep, hormones, and body temperature respond to rhythms dictated by the brain (actually the hypothalamus). The brain sets the body's clock based on light cues, causing us to sleep overnight. By morning, body temperature, cortisol level, and wakefulness all increase. Interrupting the circadian rhythms leads to sleep deprivation. It takes weeks to adjust to a new shift and the adjustment is never complete. Operations that require workers to maintain high levels of alertness over extended periods, such as firefighting, require managers to consider the consequences of sleep loss and the disruption of circadian rhythms.

Naps?—Naps can allow workers to recover. To avoid waking up groggy and exhausted, workers should nap for 20 to 30 minutes or for longer than 90 minutes. Figure 1 on page 2 shows that a 1-hour nap places you in the middle of deep sleep, making it difficult to wake up. You will be disoriented and clumsy, might make poor decisions, and could be at risk of an injury. A 20-minute nap ends before you descend into deep sleep; a 90-minute nap catches you rising out of deep sleep. Naps restore alertness, enhance performance, and reduce the risk of mistakes.

Sustained Performance Despite Sleep Deprivation

When 10 male soldiers were subjected to 72 hours of prolonged work, sleep deprivation, and caloric restriction, they were able to maintain militarily relevant physical performance. They did so despite arduous work, just 2 hours of sleep for every 24 hours, and a daily caloric intake equal to just one-third of their energy expenditure. This study indicates that fit, trained, and motivated individuals can sustain performance despite a daily workload (4,500 kilocalories per day) equal to that experienced by wildland firefighters (Pandorf and others. 2002. Physical performance responses to 72 hours of prolonged work, sleep deprivation, and caloric restriction. Medicine and Science in Sports and Exercise. 34: S194.).

Sleep Deprivation and Performance

One study compared the effects of sleep loss with those of alcohol intoxication on performance during a hand-eye coordination test. Forty subjects tracked a moving circle on a computer screen at half-hourly intervals:

- **After drinking 10 to 15 grams of alcohol at 30-minute intervals until their blood alcohol level reached 0.10 percent.**
- **After 29 hours of sleep deprivation**

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. Afterward, performance declined to as low as 6 percent below the starting level (figure 2).

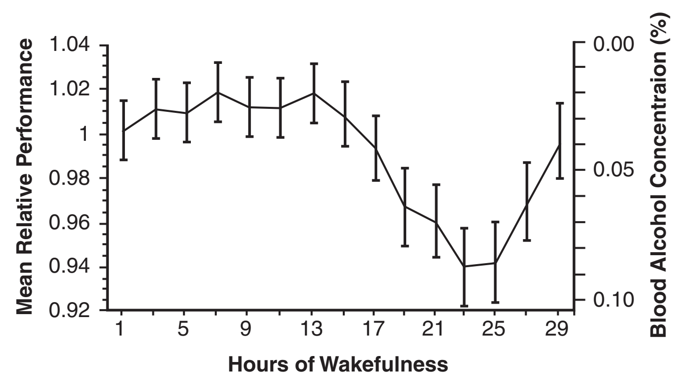


Figure 2—The relative effects of sleep loss (sustained wakefulness) and blood alcohol concentration on performance during hand-eye coordination tests.

Performance rebounded almost to 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.

While performance on the simple tracking task declined overnight, it rebounded in the morning, after 24 hours of sleep deprivation, confounding the blood alcohol analogy.

The overnight decline and morning recovery of tracking performance illustrate a typical circadian rhythm.

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

Summary

Sleep deprivation can impair cognitive performance and decisionmaking. If prolonged, sleep deprivation can cause a number of physical problems, including a decline in immune function, hypertension, heart problems, obesity, and increased stress. Performance problems include slow reaction time, impaired vigilance, errors of omission, and impaired memory, reasoning, and complex decisionmaking. As sleep deprivation continues, problems may include irritability, neurotic behavior, anxiety, and depression.

Behavioral alertness and a range of cognitive functions, including sustained attention, and working memory deteriorate when nightly sleep is limited to between 4 and 7 hours. Decisionmaking skills, such as the ability to assess risk, assimilate changing information, and revise strategies to solve problems based on new information are likely to suffer.

Fatigue and sleep loss compromise memory and attention functions including:

- Assessing the scope of a problem based on changing information

Sleep Tips

- Follow a schedule—try to go to sleep at about the same time.
- Avoid coffee, caffeinated soda, nicotine, and alcohol before bedtime.
- Don't nap before bedtime.
- Exercise at least 30 minutes a day.
- Avoid heavy meals or exercise close to bedtime.
- Relax at bedtime (reading, warm bath).
- If you can't sleep, read or listen to music until you become sleepy.
- Sleep until daybreak, if possible.

These tips, adapted from "The ABCs of ZZZs" by the National Sleep Foundation, also advise controlling the room temperature—difficult in fire camp. Try to place your tent in a quiet, shady spot if you can. If you have persistent problems sleeping in fire camp, you could consider spending a night in a motel if that's permitted. Keep a sleep diary before and after you try these tips (*http://www.sleepfoundation.org*). If the quality of sleep does not improve, discuss your findings with a physician.

- Maintaining focus
- Avoiding risks
- Recognizing ineffective actions
- Changing behavior based on new information

Individuals who are sleep deprived due to work or travel should get 10 to 14 hours to recover.

A military review of sleep research illustrates the recommended recovery times following sleep loss. It provides the basis for the 2:1 work-to-rest ratio. It also demonstrates the variability in recovery needs because of individual and situational differences. While the average worker will require 12 hours of sleep or rest to recover from 24 hours of sleep loss, some will need as much as 15 hours of sleep and some will need less than 12 hours. This variability should not be ignored when sleep, shift length, and work/rest cycles are considered.

Eight hours of rest between work periods is inadequate because only 50 to 75 percent of the rest period is devoted to sleep. Thus it is advisable to have longer rest periods (10 to 14 hours) so workers have time for adequate sleep.

You can learn more about sleep and sleep deprivation at the National Institute of Neurological Disorders and Stroke Web page: *http://www.ninds.nih.gov/disorders/brain_basics/understanding_sleep.htm*.

Research

This section reviews project-related field studies conducted on wildland firefighters during the 2008 fire season. The studies were conducted by researchers and graduate students from the University of Montana Human Performance Laboratory in cooperation with MTDC and the Air Force Research Laboratories with support from the National Wildfire Coordinating Group.

Improved Lunches for Wildland Firefighters

Studies conducted by the University of Montana Human Performance Laboratory have shown that eating regularly throughout the workshift can benefit wildland firefighters, improve work capacity, increase total work, improve immune function, reduce recovery times, improve reaction times late in the day, reduce fatigue, and improve alertness. In 2008 the Human Performance Laboratory team tested the satisfaction of 100 firefighters with shift food lunches provided during 9 days of wildland firefighting. Shift food lunches included 10 to 14 food units, ranging from 100 to 300 kilocalories each (2,000 to 2,300 kilocalories per lunch). Survey and interview data were used to evaluate food preferences, overall satisfaction with the lunch, and work capacity.

Firefighters returned questionnaires for 57 percent of the 900 experimental shift food lunches that were prepared. Participants represented a broad spectrum of the wildland firefighting community by ethnicity (white, 77 percent; Hispanic, 10 percent; Native American, 11 percent); years of experience (average 6 years); age (average 27 years); and resource type (type 1 firefighter, 10.4 percent; type 2 firefighter, 69.9 percent; engine crew, 7.4 percent; incident management team member, 7.2 percent). Of the lunches, 90.8 percent included meat and 9.2 percent were vegetarian.

Participants said they ate the shift food items as suggested (4.2 times per shift, ranging from 1 time to 10 times per shift) and said that they liked the shift food lunches much better than the normal sack lunches. Most respondents believed that the lunches helped them work better (80.7 percent) and were easier to carry (77 percent). Results were similar, regardless of the firefighters' ethnicity, experience, or resource type and regardless of the type of lunch (vegetarian or meat).

This project shows that it is possible to prepare and deliver a shift food lunch at fire camp and that wildland firefighters recognize that the shift food lunch helps them perform their jobs better. Basic guidelines for these lunches should include:

- A total of 2,000 to 2,500 kilocalories per lunch
- A macronutrient breakdown of 55- to 65-percent carbohydrates, 25- to 35-percent fat, and 10- to 15-percent protein
- 10 to 14 food units per lunch with from 100 to 300 kilocalories apiece, including entrées, drinks, fruits, energy bars, breads, and snacks

Gaskill, S.; Palmer, C.; Gaskill, H.; Hamilton, M. (all from the University of Montana); Domitrovich, J. (MTDC). 2008.

Conducted under terms of a memorandum of understanding between the MTDC and the University of Montana Human Performance Laboratory.

Stress and Coping Among Incident Management Team Members

During the summer of 2008, the University of Montana Human Performance Laboratory and MTDC examined stress and coping among incident management team members. During this study, 129 team members responded to a questionnaire designed to better understand their perceptions of stress and how they coped with the stress. Respondents included men and women in a broad spectrum of incident management positions with a wide range of experience fighting fire and serving on incident management teams.

Questionnaires were administered at the incident command post during the respondents' fire assignments. Team members were asked about:

- Their fire background
- Their level of perceived stress
- Their evaluation of how well they coped with stress
- Their perceptions of their workload
- Their view on organizational constraints to getting their jobs done
- Their interpersonal relations with other incident management team members

While team members do report stress related to their assignments, they feel well equipped to deal with the stress. For most respondents, the relationships they have with other team members are a source of support that contributes not only to their ability to cope with stress, but also to effectively achieve their goals.

A more detailed study is needed to identify the specific steps incident management team members use to cope with stress on their assignments. Because team members generally report having good coping strategies, looking at the commonsense things they do can help MTDC document the work practices that succeed.

Other members of the wildland firefighting community feel that they could benefit from an examination of stress and coping behavior on their jobs. The Northern Rockies dispatchers have asked MTDC to include them in future studies of stress and coping.

Miller, T.; Palmer, C. (both of the University of Montana); Domitrovich, J. (MTDC). 2008.

Conducted under terms of a memorandum of understanding between MTDC and the University of Montana Human Performance Laboratory.

Six interagency hotshot firefighters participated in the study on two consecutive days. The firefighters were spiked out (supporting themselves at an isolated location) and eating nothing but packaged meals known in the military as meals ready to eat or MREs. Muscle biopsies were obtained from each firefighter's thigh (vastus lateralis) before and after the work shift. Activity was measured using activity monitors on the firefighter's chest and on a boot. Firefighters consumed food as they desired and recorded their food consumption.

Body weight decreased on day 1 (average weight decreased from 89.6 to 89.0 kilograms, $p < 0.05$), but increased slightly on day 2. The measure of statistical significance, $p. < 0.05$, means that the results would be expected to occur by chance fewer than 5 times in 100. Muscle glycogen decreased on day 1 (from 115 to 82 micromoles per kilogram wet weight, $p < 0.05$), but decreased just slightly on day 2 (from 83 to 82 micromoles per kilogram wet weight, $p < 0.05$).

Muscle glycogen was higher before the shift on day 1 than on day 2 (115 compared to 83 micromoles per kilogram wet weight, $p < 0.05$). Activity patterns were similar on both days. Total energy and carbohydrate intake was greater on day 1 than on day 2.

These data suggest that the availability and palatability of provisions may compromise muscle performance during multiple work shifts.

Tucker, T.; Cuddy, J.; Slivka, D.; Hailes, W.; Ruby, B. Missoula, MT: University of Montana, Montana Center for Work Physiology and Exercise Metabolism. 2008.

Supported by Air Force Research Laboratories, Contract No. FA8650-06-1-679.

Effect of Meals on Muscle Glycogen

Wildland fire suppression offers a unique opportunity to study physiological stress during arduous job tasks (hiking steep terrain, digging, sawing, and moving water) in extreme environmental conditions while eating nothing but packaged meals. The energy demands of wildland firefighters during fire suppression have been well documented. However, previous studies have not determined the effect of laborious wildland fire suppression on muscle glycogen.

University of Montana Creates New Research Center

The University of Montana has created a new research center for the study of work physiology and exercise metabolism. Funded by the U.S. Air Force Research Laboratories and directed by Dr. Brent Ruby, the center explores ways to improve performance during extended operations. The center includes a new laboratory at the University of Montana with facilities for studying physiology in environmental extremes (heat, cold, and humidity) and for conducting exercise biochemistry. A mobile laboratory is used for field research. Dr. Ruby's work with wildland firefighters led to creation of the center. The enlarged laboratory at the University of Montana and the mobile laboratory will expand research capabilities for work with firefighters.

Figure 3—The mobile laboratory for the University of Montana's Center for Work Physiology and Exercise Metabolism.

Risk Management

Stress Management

Stress can be described as an imbalance between the demands of our environment and our ability to respond to those demands. Managing stress, or coping, requires adjusting the environment, our personal abilities, or the way we view our world. Situations that seem to be beyond our ability to respond may call for a combination of these coping behaviors.

Coping strategies that work for an individual depend on a host of factors, such as personal preferences, life experiences, the nature and duration of the challenges, and many others. Physical exercise promotes overall fitness and can help individuals manage stress. Exercise does so both by removing us temporarily from a stressful environment and by helping us to be at our best when we're dealing with stress.

Exercise and Stress

Regular moderate exercise minimizes the effects of stress. Exercise is relaxing and has been shown to lower blood pressure and reduce levels of epinephrine and cortisol, the stress hormones. Exercise may serve as a positive coping strategy, a diversion, a distraction, or a timeout from the problems and stresses of life.

Exercise occupies the mind, allowing time to pass during difficult periods. Regular exercise can substitute a good habit for bad ones, a positive addiction for negative ones. Exercise can be a form of meditation, providing the benefits of other forms of meditation along with improvements in health and fitness.

Regular exercise provides a sense of control and mastery over one dimension of life, and may improve mastery and control over other dimensions.

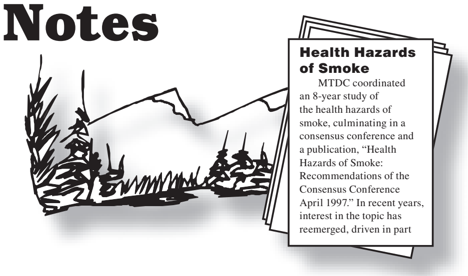
Better time management, changes in the physical and organizational environment, and a strong support system can help persons manage stress in a potentially stressful environment.

Adjusting the way we view or think about the world is another way to cope with life's challenges. Relaxation and meditation can help us adjust our perceptions. The practices range from those associated with specific religious beliefs to those focused purely on physical relaxation. In his 1975 book "The Relaxation Response," Herbert Benson, M.D., outlines the process.

Sit in a comfortable chair in a quiet room, eyes closed, and repeat a word (a mantra such as "easy") each time you exhale. Do this for 20 minutes. Concentrating on breathing and the mantra masks disturbing thoughts, and the body begins to relax. As you become more proficient with the technique, you may achieve an advanced state of relaxation, clear thought, and a sense of well being. With practice you will be able to use the skill while driving, at work, or even in sport (e.g., tennis), to relax and manage stress. Relaxation has been shown to lower blood pressure, improve immune function and improve one's sense of well-being.

Ways of coping with stress are personal, based on who we are and the particular challenges we face. It's important that we recognize when we are feeling out of balance and find healthy ways to regain control.

Field Notes



Health Hazards of Smoke

MTDC coordinated an 8-year study of the health hazards of smoke, culminating in a consensus conference and a publication, "Health Hazards of Smoke: Recommendations of the Consensus Conference April 1997." In recent years, interest in the topic has reemerged, driven in part by smoke exposure and by emerging information concerning the health hazards of smoke. This section discusses some of the activities that are underway now.

Followup on some of the 1997 recommendations has been inconsistent. One recommendation of the report was to increase medical surveillance of fire personnel. Pulmonary function tests were included in the medical evaluation for wildland firefighters. The National Institute for Occupational Safety and Health (NIOSH) is working to improve the quality of these tests and to help evaluate the records. NIOSH also conducted carbon monoxide and smoke sampling at a fire camp in California during 2008.

Respiratory Protection

The 1997 recommendations said that respiratory protection should be considered only when other controls, such as training, tactics, and monitoring, fail to protect worker health and safety. In 2006, the National Fire Protection Association (NFPA) was asked to consider development of a respiratory protection standard for wildland firefighters. Work on that standard is progressing. Dave Haston of the San Dimas Technology and Development Center chairs the task group. The NFPA would like wildand firefighters to have a respirator that would protect firefighters from the health hazards of smoke, including particulate and other contaminants, such as carbon monoxide and aldehydes. This respiratory protection must be balanced against concerns related to the physiological burdens caused by carrying and wearing this type of PPE. Currently, there is no NIOSH-approved air-purifying respirator that removes all of the health hazards of wildland fire smoke, including carbon monoxide.

Monitoring and Mitigation of Smoke

For several weeks and months each year, wildland firefighters and support personnel work and rest where they are exposed to varying concentrations of smoke and fine air particulates. These prolonged exposures caused the National Wildfire Coordinating Group (NWCG) to focus on the health impacts of such exposures. Protocols for monitoring exposure, as well as for identifying exposure baseline(s) for various components of smoke, must be established. Methods to mitigate exposure should be identified. The NWCG requested that a group:

- Survey existing research and conduct an analysis to determine whether new information or technological advances since the publication of the "Health Hazards of Smoke" studies in 1997 would be a basis for changing current recommendations.
- Recommend alternatives for monitoring air quality at incident base camps. These alternatives should range from very simple, such as techniques relying on visibility, to sophisticated monitoring devices or technologies.
- Explore the need to identify exposure baseline(s) for smoke (and other associated airborne hazards) for firefighters and incident base camp personnel and to determine the exposure levels that would indicate a possible need for monitoring or mitigation.

A working group was formed that included agency personnel (Forest Service and the U.S. Department of the Interior) and Tim Reinhardt, an industrial hygienist with many years experience measuring the exposure of firefighters to smoke. The group also examined the neurobehavioral effects of carbon monoxide exposure.

The working group's report to the NWCG's Risk Management Committee included a review of new studies on inhalation hazards for wildland firefighters. It concluded: "The toxicological and epidemiological evidence of adverse effects for those with chronic exposure to smoke is troubling, especially so for those with preexisting cardiovascular health conditions." What the research means for healthy workers is less clear. It seems that the minor losses in lung function that are seen may be at least partially reversible after periods of no exposure.

The report discusses the impact of carbon monoxide and of ultrafine particles (less than 3.5 microns) and their effect on respiratory disease, cancer, inflammation, and coronary artery disease. The risks of other inhalation hazards, such as silica and asbestos measured in air samples, were also considered. The report focused on occupational exposure limits (OEL) for fire camps and the fireline.

Occupational Exposure Limits

Exposure limits for firefighters need to be adjusted to account for the extended shifts, firefighter exertion, and the mixture of contaminants at wildland fires. As an interim measure, the report recommends that the NWCG should adopt a standard reduction factor to adjust U.S. Department of Labor, Occupational Safety and Health Administration's (OSHA) exposure limits for wildland firefighting and fire camps.

Adopting an adjusted carbon monoxide (CO) exposure limit has the advantage of keeping CO levels below thresholds that may trigger neurobehavioral effects, but also contributes to lowering the average exposure to the mixture of respiratory irritants, aldehydes, and PM3.5 (particulate matter 3.5 microns in diameter or smaller). Table 1 shows the recommended interim CO and PM3.5 exposure limits.

The interim recommended CO exposures are well below the 50 parts per million exposure limit set by OSHA for an 8-hour work shift, even considering the adjustments for extended work shifts (14 hours) and for the possibility of 24-hour exposures in fire camp. The recommended OELs are well above the average exposures for work shifts at wildland fires in the West (2.8 parts per million, based on research by Reinhardt and Ottmar, 2000, "Smoke Exposure at Western Wildfires," Res. Pap. PNW-RP-525, Pacific Northwest Research Station), and at prescribed fires in the Pacific Northwest (4.1 parts per million, Reinhardt, Ottmar and Hanneman, 2000, "Smoke Exposure Among Firefighters at Prescribed Burns in the Pacific Northwest," Res. Pap. PNW-RP-526, Pacific Northwest Research Station).

Table 1—Interim recommended occupational exposure limits for wildland firefighting. Fireline exposure is considered to be 14 hours a day, 7 days a week. Fire camp exposure is considered to be 24 hours a day, 7 days a week. Parts per million is abbreviated ppm.

Exposure conditions	Interim recommended adjusted CO exposure (parts per million)	Equivalent estimated $PM_{3.5}$ exposure
Fireline (14 h/d, 7 d/wk)	21 (14-h average)	2.4 mg/m^3
Fire camp (24 h/d, 7 d/wk	13 (24-h average)	1.5 mg/m^3

The PM3.5 estimated exposures are below OSHA's recommended occupational exposure limit for particulate (milligrams per cubic meter) but above the average exposures for firefighters work shifts at wildland fires in the West (0.5 milligrams per cubic meter) mg/m3) and at prescribed fires in the Pacific Northwest (0.63 milliters per cubic meter).

The report includes recommendations on monitoring smoke in fire camps and on the fireline (Reinhardt, Ottmar, and Hallett, 1999, "Guide to Monitoring Smoke Exposure of Wildland Firefighters," Gen. Tech. Rep. PNW-GTR-448, Pacific Northwest Research Station).

Neurobehavioral Effects of Carbon Monoxide

An extensive review by the U.S. Environmental Protection Agency (EPA) on the effects of carbon monoxide (CO) published in 2000 concluded that behavioral impairments in healthy adults are not significant when the carboxyhemoglobin (COHb) levels in the blood are below 20 percent. However, some studies showed mild impairments at 5 percent COHb. It would take an 8-hour exposure to a CO concentration of 50 parts per million to reach 5 percent carboxyhemoglobin. Cigarette smokers have COHb levels of 5 to 10 percent, sometimes as high as 15 percent.

Recommended Research

The report concludes with an extensive list of recommended research, focusing on unanswered questions and on preparing for the release of the National Fire Protection Association respiratory protection standard. It is essential to document the relationship between firefighter exposure to the health hazards of smoke and the incidence and severity of adverse health effects.

Smoke researchers will meet during the fall of 2009 to review current knowledge of smoke effects and to recommend occupational exposure limits for wildland firefighters and incident base camp personnel. Their recommendations will be reviewed by management and field personnel during the spring of 2010.

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, a Forest Service Technology Transfer Award, and the International Association of Wildland Fire Safety Award. He is past president of the American College of Sports Medicine and author of several books including "Hard Work," 2008, with Dr. Paul Davis, published by Human Kinetics.

Library Card

Sharkey, Brian. 2009. Wildland firefighter health & safety report: No. 13. Tech. Rep. 0951–2801P–MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 12 p.

The featured topic in this issue discusses the importance of sleep for wildland firefighters and includes the results of sleep surveys filled out by 140 incident management team members based at fire camps in California and Montana during 2008. An article discusses a draft report recommending changes in the occupational exposure limits for carbon monoxide and airborne particulate matter 3.5 microns and smaller on persons working on the fireline or at incident base camps. The research section includes information on:

- Studies of shift food lunches for firefighters
- Surveys administered to 129 incident management team members during the 2008 fire season to determine their perceptions of stress and how team members were coping with stress
- The effects of eating packaged meals on muscle glycogen while firefighters were supporting themselves in spike camps

Keywords: carbon monoxide, fire fighting, firefighting, food, glycogen, incident base camps, incident management teams, occupational exposure limits, particulate, safety at work, shift food, sleep, smoke, stress

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Additional single copies of this document may be ordered from:

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

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

For additional information about wildland firefighter health, contact Brian Sharkey or Joe Domitrovich at MTDC:

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