

Fatigue, Sleep and Mood State in Wildland Firefighters.

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General Summary:

During the 2001 and 2002 fire seasons data was collected which allowed us to do a preliminary analyses of the effects of extended work and hours of sleep on physical fatigue, mood state profiles and upper respiratory tract infection (URTI) risk. These data were collected on four hot shot, Type I crews during actual fire fighting duties.

The data suggest that physical fatigue is more related to accumulated total work than to accumulated loss of sleep, though both are contributors. URTI is weakly related to both lack of sleep and accumulated work but may have a longer delayed response to lack of sleep and high work output than these data were able to evaluate. Mood state (primarily negative mood state), in the short term, is more strongly related to quantity of sleep in the one to two nights prior to evaluation, but in the longer term (over 5 and maybe more days) is well related to accumulated work.

Physical fatigue, URTI and mood state changes were not observed during periods of light duty and adequate sleep but were increased with decreasing sleep and increasing work intensity.

In order to reduce URTI, physical fatigue and negative mood state, adequate sleep along with work intensity cycling (2-3 days of hard work followed by one day of easier intensity work) needs to be maintained.



Introduction:



During the 2001 and 2002 fire seasons Missoula Technology Development Center (MTDC), U.S. Forest Service funded research by the Human Performance Laboratory Staff to evaluate a variety of questions concerning fatigue and immune function in wildland firefighters. The data from this research has yielded a variety of interesting results.

Though cognitive function and mood state related to fatigue and immune function was not a main priority research question during these two fire seasons we did ask all

subjects (N=56, 47 males, 9 females) over a course of 276 subject days (average study time per subject was 4.93 ± 2.2 days) to complete a mood state questionnaire including sleep recall data, complete a questionnaire asking for symptoms of upper respiratory tract infections (URTI) and to wear activity monitor (CSA actigraphs) during actual field work. Each morning, before breakfast subjects also completed a Physical Fatigue Index test using resting, submaximal step and recovery HR data to evaluate physical recovery from the previous day's work.

This report shows that relationships between sleep duration, daily total work (CSA actigraph counts), physical fatigue index (PFI) and indices of mood state.

Methods Results and Discussion by Variable:

Table 1: Intraclass (within subject) correlations for all firefighting data for 2001-2002 summers for firefighters with 3 or more days of data. CSA counts refer to the total activity epochs recorded each day.

	<i>Hours sleep previous night</i>	<i>Ave sleep previous 2 nights</i>	<i>CSA Counts previous day</i>	<i>Average CSA Counts per previous 2 days</i>
HR-Physical Fatigue Index	-0.2252	-0.2843	0.5632	0.5824
URTI Index	-0.2093	-0.2563	0.2178	0.2436
CSA Counts for Current day	0.3048	0.3248	NS	NS
Positive Mood State	0.2163	0.2097	-0.1895	-0.2047
Negative Mood State	-0.4583	-0.4610	0.2844	0.3358
Mood State-Anxious	-0.2551	-0.2937	0.1433	0.2460
Mood State-sad/ depressed	-0.3507	-0.3572	0.2044	0.2792
Mood State-Confused	-0.4294	-0.4690	0.2795	0.4024
Mood State-Angry	-0.4931	-0.5145	0.1679	0.3539
Mood State-Energetic	0.2040	0.2454	-0.1675	-0.2735
Mood State-fatigued	-0.3378	-0.2543	0.2680	0.3672

All correlations > 0.1246 are significant at $p < 0.05$

All correlations > 0.2104 are significant at $p < 0.01$

All correlations > 0.2922 are significant at $p < 0.001$

Physical Fatigue Index:

The Physical Fatigue Index (PFI) is the sum of the morning resting HR, an exercise step HR (HR at end of 1 minute of stepping on an 8 inch step at 120 steps [30 cycles] per minute) and recovery HR's at 30 and 60 seconds. The test was administered before breakfast. The PFI increases as a subject becomes more fatigued.

The PFI was positively related to both the amount of work done the previous day and the previous two days ($r = 0.563$ and $r = 0.582$ respectively). In a smaller data set of subjects for which we have 6-11 days of data there was an increasing relationship between PFI and average daily work up to 5 days ($r = 0.692$, $p < 0.01$ at 5 days) after which we have no reliable data. This suggests that arduous work output is cumulative over time in causing fatigue. During periods of low work output the PFI did not increase with time, but as daily work output increased, the relationship between PFI and work over time increases. The practical solution to reducing accumulated fatigue appears to be periods of 2-3 days of hard work followed by at least one day of lower intensity work to allow for recovery from fatigue.

Additionally, the PFI had a modest negative relationship with hours of sleep the previous night or two nights. In a smaller data set of subjects for which we have 6-11 days of data there was an increasing negative relationship between physical fatigue and average hours of sleep up to 4 days after which the relationship declined ($r = -0.329$, $p < 0.05$ at 4 days). This modest negative relationship suggests that quantity of sleep has a small effect on physical fatigue. It should be noted that most firefighters reported 7 or more hours of sleep 87% of nights.



Upper Respiratory Track Infection Index:

Upper Respiratory Track Infection (URTI) Index is based on a questionnaire which asks for symptoms of URTI. As URTI symptoms increase the index increases.

The URTI index was weakly and inversely related to hours of sleep and weakly related to average work completed. In a smaller data set of subjects for which we have 6-11 days of data there was an increasing relationship between URTI (up to $r = 0.3256$, $p < 0.05$ at day 5) and average daily work up to 5 days after which we have no reliable data. This suggests that work output and sleep loss are cumulative over time in causing URTI. A multiple regression analysis of both sleep and work related to URTI resulted in a multiple $R = 0.387$ with both sleep and work as significant contributing factors.

During periods of low work output the URTI did not increase with time, but as daily work output increased, the relationship between PFI and work over time increases. Since the URTI and the PFI were related to each other ($r = 0.4892$) this suggests that multiple days of hard work without lighter intensity work days interspersed every 2-3 days may result in both URTI and physical fatigue, thus reducing work output. The practical solution again appears to be to have a low intensity work shift between every 2-3 days of hard work.



CSA Counts for the Current Day

This is a measure of individual work that each person did. It is interesting that the work output for a given day is modestly related to the hours of sleep for the previous night (and up to 3 nights), but not to the work done the previous day or two days. These data may be the result of duty schedules assigned to crews on specific days. We would have expected that work output the previous day would have been inversely related to the current day's work. This requires more analysis. In the data set from one 9 day study during which the firefighters were working under similar conditions for the duty cycle there was a relationship between current work and average work for the previous 3 and 4 days ($r = 0.3892$ and $r = 0.4532$ respectively) suggesting that more study is needed in this area.



Mood State Data

A mood questionnaire was administered each morning before breakfast. The results show relationships between multiple aspects of mood with both sleep and work (CSA counts). In all cases (except fatigued and sleep) the relationships become stronger when average sleep and work accumulate for two days over one day. The relationships with mood state are also generally stronger with sleep duration than with work output. These relationships may reflect the timing of the survey administration (morning before breakfast) and further study is needed to determine if mood state changes during the workday.

The negative mood state, and negative aspects of mood state appear to be more related to lack of sleep and increasing work than are the positive mood state measures.

In the data set from firefighters for whom we have 6-11 days of data the relationship between mood state and sleep generally become stronger for two days. When mood state was evaluated compare to sleep for the previous three or more days the relationships was non-

significant. However negative mood state became more strongly related to work output for up to 5 days ($r = 0.5103$) when the firefighters were recording high work output (Kelly Creek Fire). These data suggest that the multi-day accumulation of physical work and short-term sleep deprivation are important factors in negative mood states in wildland firefighters.

In order to reduce negative mood state, adequate sleep along with work intensity cycling (2-3 days of hard work followed by one day of easier intensity work) needs to be maintained.



Discussion and Conclusions:

Because of the need for within subject analysis and the uncontrolled nature of the duty assignments these data represent only a snapshot of fatigue and mood related to work output and sleep. It is obvious that both quantity of sleep and total daily work are major factors in both physical fatigue and cognitive mood. Sleep and work were evaluated separated. Unfortunately, due to the nature of the data, the combined effect of sleep and work output cannot be evaluated.



Physical fatigue is more related to accumulated work than to accumulated loss of sleep, but both are contributors. URTI is weakly related to both lack of sleep and accumulated work but may have a longer delayed response to lack of sleep and high work output than these data were able to evaluate. Mood state, in the short term, is more strongly related to quantity of sleep in the one to two nights prior to evaluation, but in the longer term (over 5 and maybe more days) is well related to accumulated work.

Further study is required to evaluate the effect of sleep and accumulated work on decision making and cognitive function during wildland firefighting.