Firefighter Shift Schedules Affect Sleep Quality

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Objective: The aim of this study was to investigate the prevalence and severity of firefighter sleep quality across department shift schedules. **Methods:** Sleep quality was assessed using a Pittsburgh Sleep Quality Index in a sample of 109 male career firefighters from six fire departments in three Southwestern US states. The three shift schedules studied were 24on/48off, 48on/96off, and Kelly. **Results:** Seventy-three percent of firefighters report poor sleep quality. The 24on/48off shift schedule is associated with the best sleep quality and Kelly is associated with the worst sleep quality. Firefighters working second jobs report significantly poorer sleep quality than those who do not. **Conclusions:** Shift schedules that disrupt normal circadian rhythms more result in poorer sleep quality, which can lead to less effective emergency response and increased risk to firefighter health and safety.

Sleep research has been conducted during the last 50 years in fields as diverse as medical services, transportation, military, and industry. Few studies, however, have investigated sleep quality in the fire service and none have looked at the relationship between shift schedules and sleep quality.

The emergence of inquiries concerning the relationship of sleep quality to firefighter performance and safety has elevated the importance of sleep research in the fire service.[1–4] Investigators found that 59% of firefighters in a major US metropolitan city report sleep deprivation.[1] Firefighters in Finland report sleep disturbances after working more than 50 hours in a week.[2] In a study conducted in Tehran,[3] 69.9% of firefighters report poor sleep quality compared with 37% of the general adult population.[5] Finally, in a study of South Korean firefighters,[4] 51.6% of shiftwork firefighters suffer poor sleep quality compared with 38.5% of nonshiftwork firefighters.

Acute health impairments from sleep deprivation include short-term memory loss, slower reaction time, reduced vigilance, and mood changes.[6] Chronic effects include impairments to cardiovascular,[7–11] immune,[12,13] and gastrointestinal functions and contributes to obesity.[14]

Sleep deprivation also increases the risk of workplace injury.[15] Inadequate sleep has led to human error that contributes to large occupational accidents such as the Three Mile Island,[8,16–18] Davis–Besse reactor,[16] Chernobyl,[8,16–18] and Bhopal.[8,17,18] Workers experiencing excessive daytime sleepiness (EDS) exhibit a higher injury rate than those who are not experiencing EDS.[15]

The urgency of comprehensive research on the effects of shift schedule design on sleep quality is obvious. Such schedules may be associated with an increase in health and fireground injury risks as well as decreases in mental and physical performance.[19] Proper shift design requires accommodation to normal sleep patterns while on shift and include sufficient time between shifts to restore circadian sleep rhythm.[20–22]

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The purpose of this study is to investigate the effect of fire service shift schedules on sleep quality. This may be a result of frequent interruptions from emergency responses during the night that affects circadian rhythm.

DISTURBANCE OF CIRCADIAN RHYTHM

The National Sleep Foundation recommends seven to nine (average of eight) hours of sleep each night for most adults.[23] Each sleep bout should include several consecutive and uninterrupted cycles of rapid eye movement (REM) and nonrapid eye movement (NREM) sleep. Deeper stages of NREM sleep, which takes about one hour to reach, are required to restore wakefulness and cognitive function.[18]

In the fire service, frequent interruptions from emergency response actions prevent firefighters from properly cycling through sleep stages of sufficient duration. Frequent disturbances and irregular sleeping patterns lead to sleep deprivation, increase firefighter stress, contribute to fatigue,[24,25] and affect physiological function.[26] (Although daytime naps may provide short-term benefits,[27] they are not a substitute for long-duration sleeping.)[28]

If normal cycles of wakefulness and sleep each day (circadian rhythm) are frequently interrupted, restoration of normal rhythm requires at least two days and as many as four days for more severe circadian dysrhythmia.[29–31]

Estimation of Circadian Dysrhythmia Associated With Shift Schedules

Thousands of rotating and permanent shift schedules are used worldwide.[20] The fire service is no exception. In the US, 150 fire department shift schedules have been reported.[32] We believe that disturbances to normal sleep caused by emergency response calls can cause circadian dysrhythmia, and that the severity of the dysrhythmia is related to shift schedule.

For example, in a 24on/48off shift schedule (Table 1), the normal sleep cycle is disrupted for one day. As two days separate each work shift, we believe that the return to normal sleep patterns is possible such that no further circadian rhythm disturbance is accrued after the work shift is over. Therefore, the circadian dysrhythmia associated with this schedule remains at one day.

In a 48on/96off shift schedule (Table 2), the disturbance to circadian rhythm during the work shift is greater, totaling two days. However, as four days are provided between shifts, rhythm can return to normal and no further dysrhythmia occurs. We believe that it is appropriate to judge the circadian dysrhythmia associated with this schedule as two days.

In a Kelly schedule (24on/24off/24on/24off/24on/96off, Table 3), the disturbance is much greater. We can see that a firefighter goes five days before sufficient time off is provided to return to normal rhythm. Therefore, we conclude that the circadian dysrhythmia associated with this schedule is five days.

RESEARCH DESIGN

A focus group composed of a current fire chief and two retired fire chiefs provided expert advice on the selection of fire service shift schedules, design of a fire department sampling strategy, and construction of the interview questionnaire.

Selection of Shift Schedules

As our study is focused on sleep quality caused by sleep disturbances while on the job and restoration of circadian rhythm

TABLE 1. 24on/48off Shift Schedule

S	M	T	W	T	F	S
On	Off	Off	On	Off	Off	On
Off	Off	On	Off	Off	On	Off

The 24on/48off schedule typically operates with three shifts, with all shifts starting at 7:00 a.m. on their work day, and departments choose to either pay Fair Labor Standards Act overtime or assign time off to avoid overtime depending on their designated work period.

TABLE 2. 48on/96off Shift Schedule

S	M	T	W	T	F	S
On	On	Off	Off	Off	Off	On
On	Off	Off	Off	Off	On	On

The 48on/96off schedule typically operates with three shifts, with all shifts starting at 7:00 a.m. on their work day, and departments choose to either pay Fair Labor Standards Act overtime or assign time off to avoid overtime depending on their designated work period.

TABLE 3. Kelly Shift Schedule

S	M	T	W	Th	F	S
On	Off	On	Off	On	Off	Off
Off	Off	On	Off	On	Off	On

The Kelly schedule typically operates with three shifts, with all shifts starting at 7:00 a.m. on their work day, and departments choose to either pay Fair Labor Standards Act overtime or assign time off to avoid overtime depending on their designated work period. The Kelly schedule is also commonly referred to as the Berkley, Modified Detroit, and 3/4 schedule.

afterward, we decided to investigate only shift schedules that are at least 24 hours long. Although five 24-hour work schedules have been reported,[19] the focus group advised that few departments in the Southwest US study region adopt 24on/24off and 24on/72off schedules. Therefore, the shift schedules examined in this study are the 24on/48off, 48on/96off, and Kelly shift schedules.

Selection of Fire Departments

The United States Fire Administration (USFA) divides fire departments into four categories: volunteer, mostly volunteer, mostly career, and career. As this research concerns firefighters who sleep at fire stations, only career departments that employ full-time firefighters were considered.

To minimize the effect of variables other than shift schedule, we decided to investigate departments in the Southwestern US with similar characteristics regarding the number of fire stations, annual call volume, number of firefighters, and shift start time. We elected to include two departments for each of the three shift schedules. These departments each had between four and six fire stations, 60 and 100 firefighters, 4000 and 5000 calls per year, and shifts starting at 7:00 a.m.

Selection of Respondents

Only full-time firefighters with at least one month of current continuous shift-work experience were recruited to participate in interviews held at their fire stations. This assured that the respondents worked the entire shift, responded to alarms for emergency response when these occurred, and had sufficient experience on the shift schedule to reliably report sleep quality.

Interview Protocol

At each fire station in a department, the lead investigator conducted group meetings with about five firefighters in each session. After discussing the purpose of the study, reviewing the interview protocol, and obtaining written consent, the investigator asked each respondent to complete a sleep quality questionnaire and a demographic characteristic questionnaire. Immediately after completion, each questionnaire was reviewed for errors and missing values, and corrections/additions were made as necessary. Each interview session lasted between 15 and 20 minutes. In all, 109 career firefighters completed questionnaires at 26 stations in the six departments. The interviews were conducted during a three-month period in early 2014.

HYPOTHESES AND VARIABLES

Hypotheses

The first hypothesis, H1, is that average firefighter sleep quality will be reported as poor regardless of shift schedule because all three schedules disrupt circadian rhythm. The null hypothesis, $H1_0$, is that sleep quality will be reported as good regardless of shift schedule.

Our second hypothesis, H2, is that sleep quality decreases with shift schedules that cause greater circadian dysrhythmia. The null hypothesis, $H2_0$, is that sleep quality does not decrease with shift schedules that increase circadian dysrhythmia.

Dependent Variable: Sleep Quality

The Pittsburgh Sleep Quality Index (PSQI) includes 19 questions that measure seven components of sleep quality: (1) subjective sleep quality, (2) sleep latency, (3) sleep duration, (4) habitual sleep efficiency, (5) sleep disturbances, (6) use of sleep medication, and (7) daytime dysfunction.[33] The PSQI has been shown to be a valid and reliable testing measurement for sleep-related inferences.[34] Its scales exhibit high internal consistency with a reliability coefficient (Cronbach's α) equal to 0.83.[33] This measurement has been a popular choice in prior studies in the fire service[1,3,4] and in numerous other occupational studies. Therefore, the combination of these scaled components into one sleep quality index is justified and appropriate to measure sleep quality.

Each component of the survey receives a value of 0, 1, 2, or 3. These values are then summed across the seven components to yield a global PSQI score, ranging from 0 (best sleep quality) to 21 (worst sleep quality). A global score of 5 or less is equated to good sleep quality; thus, any score greater than 5 is associated with poor sleep quality.[33]

The PSQI was designed to measure average sleep quality over the previous month, assuming that respondents experience only one sleep bout per day. However, firefighters frequently experience several bouts of sleep in a 24-hour period due to emergency calls. We modified the calculation of sleep duration by summing the reported average sleep duration for each bout during a day over the previous month. It is unclear how past firefighter studies[1,3,4] addressed the calculation of sleep duration over multiple bouts per day.

The global PSQI score was treated as both an ordinal variable and a dichotomous variable in our statistical analyses.

Primary Independent Variable: Shift Schedule

As described above, the focus group advised that only the 24on/48off, 48on/96off, and Kelly shift schedules are commonly used in the study region. Therefore, only these schedules were considered. Shift schedule was treated as a nominal variable in our statistical analyses.

TABLE 4. Characteristics of Firefighter Respondents

Characteristic	Distribution (All Schedules)	24on/48off Schedule	48on/96off Schedule	Kelly Schedule
Number working each shift schedule	109 (all male)	31 (28%)	38 (35%)	40 (37%)
Marital status	94 (86%)	27 (87%)	33 (87%)	34 (85%)
Children living at home	79 (72%)	22 (71%)	27 (71%)	30 (75%)
Working a second job	70 (64%)	17 (55%)	22 (58%)	31 (78%)
Reporting sleep-related disorder	13 (12%)	2 (6%)	5 (13%)	6 (15%)

Characteristic	Mean (All Firefighters)	24on/48off Schedule	48on/96off Schedule	Kelly Schedule
Age (Range = 20–59)	38.0	40.8	35.9	38.0
Years of Service (Range = 1–34)	12.7	15.3	10.5	12.8
Average number of interruptions/ work night (Range = 0–5)	2.0	2.2	2.0	1.9

Control Variables

The focus group agreed with our selection of four demographic characteristics that can also affect sleep quality by interfering with restoration of circadian rhythm. These included one interval variable: years of service and three dichotomous variables: children living at home, working a second job, and existence of a diagnosed sleep-related disorder such as sleep apnea.

RESULTS

Table 4 summarizes demographic and sleep quality characteristics of the career firefighters interviewed for our study. All respondents are male and most are married, have children living at home, work a second job, and worked in the fire service an average of nearly 13 years. Nearly all firefighters report no sleep-related disorder and the average number of sleep interruptions per night is two.

Calculation of PSQI scores and statistical analyses were conducted using STATA software.[35] Figure 1 illustrates the distribution of PSQI scores. Although these scores can range from 0 to 21, the highest score found was 15. The distribution of scores within this range approaches normality, though slightly positively skewed. Eighty (73%) of the 109 firefighters report poor sleep quality (PSQI global score greater than 5).

A one-sample mean-comparison analysis was performed to determine whether the mean global PSQI score for each shift schedule is significantly greater than 5 (the threshold of good sleep quality). The result of this analysis confirms that the mean PSQI score for each of the three shift schedules is significantly greater than 5 (Table 5), demonstrating that the average firefighter on all three shift schedules suffers from poor sleep quality.

To control for the effects of years of service, children living at home, working a second job, and affliction with a sleep disorder, we performed a logistic regression (Table 6). These results demonstrate that shift schedule, personal average number of night interruptions at work, and working a second job are the only demographic variables that adversely affect sleep quality.

Table 7 presents the mean PSQI global scores for each shift schedule, for each department and across both departments. Figure 2 illustrates that these scores increase with increasing circadian dysrhythmia estimates associated with each shift schedule. [Note that we did not include shift schedules with dysrhythmia estimates of three or four because such schedules would be rare, if they exist at all.]

To examine more carefully how sleep quality varies across shift schedules, we first used a Kruskal–Wallis test, which suggests that sleep quality weakly varies across the schedules [$\chi^2(2, 106) = 4.451$, $P = 0.108$]. To explore this variance more closely, a posthoc comparison between the three pairs of shift schedules demonstrates that only two of the three comparisons are statistically different: the 24on/48off schedule versus Kelly and the 48on/96off schedule versus Kelly. The difference between the 24on/48off and 48on/96off schedule is not statistically significant (Table 8), which explains the relative weakness of the Kruskal–Wallis test result.

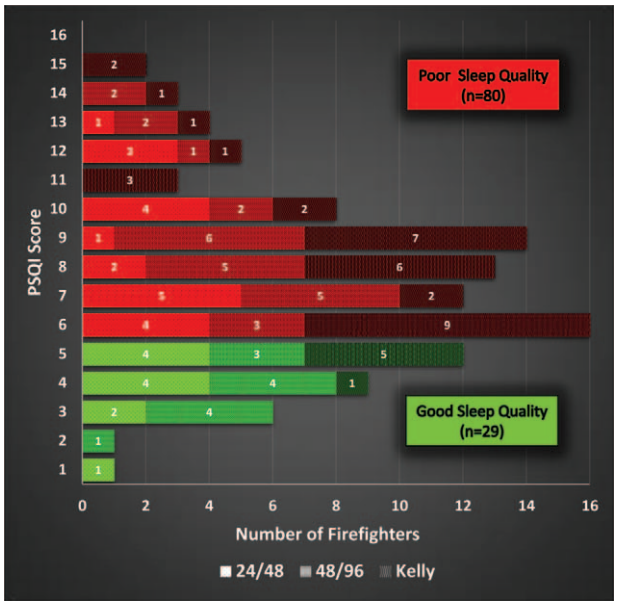

FIGURE 1. Distribution of PSQI scores from 109 firefighters.

TABLE 5. Comparison of Sleep Quality Scores Across Shift Schedules

Shift Schedule	Number of Observations	Mean PSQI Score	Standard Error	Standard Deviation	*t* Score	*P*
24on/48off	31	7.0	0.55	3.0	3.6	0.001
48on/96off	38	7.3	0.52	3.2	4.5	0.000
Kelly	40	8.3	0.45	2.8	7.2	0.000

PSQI, Pittsburgh Sleep Quality Index.

TABLE 6. Logistic Regression of Independent and Control Variables on Sleep Quality

Variable	β	Standard Error	*P*
Shift schedule	0.73	0.34	0.03
Average number of interruptions/ work night	1.34	0.37	0.00
Reporting a sleep-related disorder	1.70	1.17	0.15
Working a second job	0.87	0.52	0.09
Children living at home	−0.55	0.61	0.93
Years of service	0.01	0.03	0.70
Constant	−3.62	1.34	0.01
N observations	109		
X^2 test	30.81		0.000

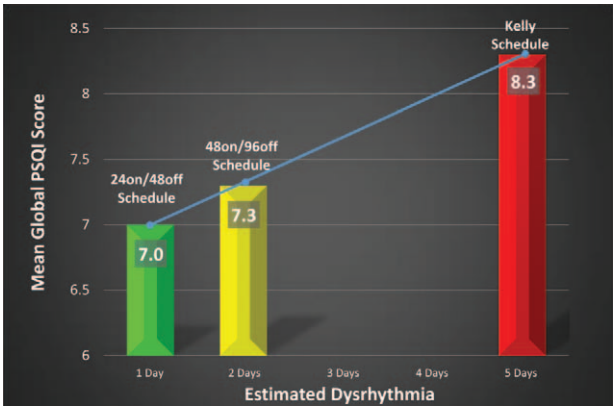

FIGURE 2. This figure illustrates how mean PSQI score per shift schedule compares with the number of days with disturbed circadian rhythm.

DISCUSSION

Hypothesis Testing

On the basis of a sample of 109 firefighters from the six fire departments, 80 of the 109 (73%) firefighters report poor sleep quality. Our finding of poor sleep quality compares favorably with the incidence of poor sleep quality in other studies (69.9% in Tehran study[3] and 51.6% in the Republic of Korea study[4]). Although no comparative investigation was conducted in this study, poor sleep quality has been reported in a different Tehran study[5] (37% in the general population) and in the Republic of Korea study (38.5% of nonshiftwork firefighters), indicating that shiftwork firefighters suffer poorer sleep quality than comparative samples.

The mean PSQI global scores are significantly greater than 5 for each department and shift schedule. The strong statistical relationship ($P = 0.000$) between the number of sleep interruptions in a night and sleep quality is consistent with the claim that disruption of normal sleep stages contributes to poor sleep quality. Therefore, we reject the first null hypothesis, $H1_0$, lending support to our claim that fire department schedules that include work shifts equal to or greater than 24 hours contribute to poor sleep quality through interruptions of normal sleep likely caused by emergency calls during the night.

In comparing the sleep quality differences between pairs of shift schedules, we find that sleep quality associated with the 24on/48off and 48on/96off schedules is not significantly different. Although we had hypothesized that a significant difference would be found, our results did show a difference in the predicted direction. We speculate that our failure to find a statistically significant difference may be that firefighters on the 48on/96off shift schedule are able to obtain some sleep during their shift given its 48-hour length that mitigates circadian dysrhythmia (or these departments may manifest other unique features/characteristics not captured in our study).

Nevertheless, differences in sleep quality between Kelly and the other two shift schedules show that the greater the dysrhythmia, the poorer the sleep quality. We believe these results allow us to tentatively reject the null hypothesis, $H2_0$, lending support to our primary hypothesis that sleep quality decreases as circadian dysrhythmia associated with shift schedules increases.

Second Jobs

Currently, no extant peer-reviewed literature explores how second jobs influence firefighters' overall well-being. An earlier study suggested that 25% to 50% of firefighters have second jobs but do not report how these percentages were estimated.[36] In a sample of 458 firefighters from departments in the Midwestern United States, 245 (53.3%) of firefighters were engaged in additional paid work outside of the fire department.[37] Another study found that 156 out of 379 firefighters (41.2%) work in a second job and that this was a predictor of poor sleep quality.[3] Our study finds that 70 of the 109 (64%) of firefighters work in jobs outside of the fire department. Our results suggest that working second jobs during time off between work shifts may further adversely affect sleep quality ($r = 0.24$, $P < 0.01$; $\beta = 0.87$, $P = 0.09$). Thus, it is reasonable to surmise that those who work a second job are more likely to have poorer sleep quality than those who do not because they do not have sufficient

TABLE 7. PSQI Scores, by Shift Schedule

Shift Schedule (Dysrhythmia Estimate)	Statistic	Department One	Department Two	Both Departments
24on/48off (1 day)	No. of observations	16	15	31
	Mean PSQI Global Score	6.8	7.2	7.0
	Standard deviation	2.3	3.7	3.0
48on/96off (2 days)	No. of observations	18	20	38
	Mean PSQI Global Score	7.0	7.6	7.3
	Standard deviation	2.7	3.6	3.2
Kelly (5 days)	No. of observations	23	17	40
	Mean PSQI Global Score	8.2	8.4	8.3
	Standard deviation	2.2	3.6	2.8

TABLE 8. Analysis of Difference in PSQI Scores Between Shift Schedules

Shift Schedule	χ^2 with Ties	*P*
24on/48off vs 48on/96off	0.115	0.734
24on/48off vs Kelly	3.967	0.046
48on/96off vs Kelly	2.979	0.084

time to restore normal circadian rhythms. We intend to investigate the influence of working second jobs more carefully in a follow-up study.

CONCLUSIONS

As the human body requires sleep tied to normal circadian rhythms, disruption of sleep patterns disturbs rhythm and therefore contributes to poor sleep quality. Poor sleep quality can lead to less effective emergency response, increased risk to firefighter health and safety, and affect services delivered to communities. Although the fire service cannot prevent interruptions during the night, departments can consider revising their shift schedules to decrease circadian dysrhythmia.

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