

THE EFFECTS OF FIRE DEPARTMENT SHIFT  
SCHEDULES ON SLEEP QUALITY

By

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Title of Study: THE EFFECTS OF FIRE DEPARTMENT SHIFT SCHEDULES ON  
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Major Field: FIRE AND EMERGENCY MANAGEMENT ADMINISTRATION

Abstract:

The purpose of this study is to investigate how fire department shift schedules affect sleep quality as measured using a modification of the Pittsburgh Sleep Quality Index (PSQI). Poor sleep quality increases sleep deprivation. Acute effects of sleep deprivation include a decrease in performance, alertness, cognitive thinking, reaction speed, and memory recall. Chronic effects of sleep deprivation include gastrointestinal problems, cardiovascular impairments, diabetes, fatigue, and a depressed immune system.

Linking research from fields as diverse as medical service, transportation, and physiology leads to the hypothesis tested in this study: sleep quality decreases with increasing sleep debt – with sleep debt defined as the length of workshift duration compared to recovery duration.

This study includes 109 participants from six medium-size career fire departments, with two departments representing three typical fire department shift schedules: 24on/48off, 48on/96off, and the Kelly schedule. The Kelly work schedule is modified 24-hour work schedule (OXOXOXXXX) and also known as the Berkeley, Dallas, Modified Detroit, or the '3/4' schedule. Each department averaged a call volume of 4,000 to 5,000 calls per year, operated out of 4 to 6 stations, and were staffed by 60 to 100 firefighters.

Study findings show that these six departments average scores exceeding the poor sleep quality threshold, meaning that most firefighters on each department have poor sleep quality. Of 109 firefighters, 80 (73 percent) calculated to have poor sleep quality. The 24on/48off shift schedule is associated with better sleep quality compared to the other two work schedules. Predicted probabilities of poor sleep quality were greatest for the Kelly schedule compared to the other schedules. In addition, nearly 64 percent of the firefighters have second jobs; those with second jobs are significantly more likely to have poor sleep quality compared to firefighters without second jobs. The results suggest that the 24on/48off schedule allows better sleep quality than the 48on/96off, and the Kelly schedule.

Recommendations for improving sleep quality in the fire service include transitioning to the 24on/48off schedule to allow for a better sleep debt. In addition, fire departments can incorporate minor structural enhancements to improve sleep quality.

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# CHAPTER I

## INTRODUCTION

On average, humans spend about one-third of their lives asleep. Without adequate sleep, people function at suboptimal levels. Over the last 50 years, researchers have developed a better understanding of the adverse effects of sleep deprivation, defined when an individual continually receives inadequate amounts of sleep (Luyster et al. 2012). Nevertheless, researchers do not fully understand how sleep restores optimal performance (Luyster et al. 2012; Sugden and Darzi 2010). The lack of consensus is due in part to the difficulty of operationalizing sleep as a variable (Majde and Krueger 2005). For example, it is difficult to treat sleep as an independent variable because researchers cannot control for other human processes as intervening variables. However, this study treats sleep quality as a dependent variables, which makes drawing inferences more possible than treating sleep quality as an independent variable.

Most organizations in the United States operate on a daily eight-hour work schedule. However, emergency occupations such as law enforcement, emergency medical services (EMS), and the fire service provide continuous service. This requires workers to remain alert and ready to respond throughout their shift. The problem occurs when trying to perform various work-related duties and tasks while at the same time obtaining a sufficient quantity and quality of sleep.

Sixty to seventy percent of shiftworkers complain of sleep disturbances (Rutenfranz, Haider, and Kooler (1995). While research on sleep quality in the fire services is absent, it can be assumed that the nature of the profession e.g., responding to emergencies during the night, has the potential to

influence firefighter sleep quality. Furthermore, a plethora of adverse health effects increase when poor sleep quality results in sleep deprivation.

It is possible that the design of fire department shift schedules can influence firefighter sleep quality. The combination of different work and non-work durations can affect the amount of recovery that firefighters receive. Insufficient durations for recovery may lead to adverse health effects and decrease performance levels. Overall, the design of a fire department shift schedule should allow firefighters to have good sleep quality to recover after each shift.

### **Purpose of this Research**

The purpose of this research is twofold: (1) to investigate whether sleep quality is a potential problem in the fire service and (2) to determine how sleep quality varies across fire department shift schedules. If a relationship exists between sleep quality and shift schedules, policy recommendations based on research are suggested to help increase sleep quality. Since quality of sleep relates to a variety of potential health concerns, increased attention to sleep quality should be a priority within fire departments. This study also investigates whether second jobs and sleep debt influences firefighter sleep quality.

## CHAPTER II

### REVIEW OF THE LITERATURE

This chapter summarizes how past research regarding sleep relates to human functions, injuries, performance, and shift schedules. Although few studies exist that relates to the fire service, research from other fields e.g., human physiology, medical science, transportation industry, and military can help form the theoretical argument for this research study. The following sections discuss the various sleep functions.

#### **Sleep Physiology**

In recent years, researchers has led to a better understanding of sleep, its effects, and its disorders (Shepard et al. 2005). Typically, people progress through five cycles of sleep in a normal night's rest, with each cycle including Rapid Eye Movement (REM) and Non-Rapid Eye Movement (NREM) sleep. Carskadon (1993:498) characterized REM sleep "by a complete absence of muscle tone in the muscles that support the body against gravity, although this atonia may be interrupted by twitches." She also characterized NREM sleep "by reduced levels of muscle tone, slow regular breathing, no eye movements or slow eye movements, reduced levels of neuronal activity in most brain regions, and high-voltage spindles and slow-wave brain activity." On average, NREM sleep accounts for approximately 75 percent of sleep duration and REM sleep accounts for the remaining

25 percent (Majde and Krueger 2005). NREM sleep further divides into three stages (Luyster et al. 2012) or four stages<sup>1</sup> (Joffe 2006). Each sleep cycle lasts between 90 to 110 minutes, indicated by electrooculography (EOG) patterns (Joffe 2006; Luyster et al. 2012) with increasing REM to NREM durations during each succeeding cycle. Figure 1 illustrates a typical sleep pattern (Gonnissen 2013).

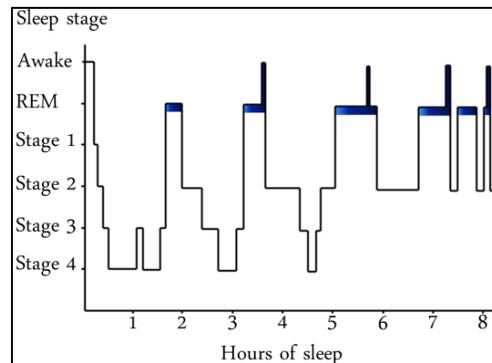


Figure 1: Sleep Hypnogram

In each cycle, the sleeper moves from stages one to three (or four) of NREM sleep. In stage one, sensory stimuli such as light, sound, smell, and touch can easily awake a sleeper. In stage two, waking is more difficult. Stage three is characterized by synchronized slow-wave brain wave patterns and is most difficult to arouse. During this stage, sensory stimuli must be more robust and repeated to awaken the sleeper. Thus, firefighters have trouble waking up during this stage.

A direct correlation exists between NREM sleep stage and level of alertness (Joffe 2006; Williams, Holloway, and Griffiths 1973). When awakened from stage one, a person is likely to feel awake and refreshed. That same person will experience lower levels of alertness after waking up from stage two. When awakened from stage three, the person will experience symptoms of sleep inertia<sup>2</sup>.

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<sup>1</sup> In the Joffe's four-stage version, Luyster et al.'s third stage is divided into two stages.

<sup>2</sup> Sleep inertia is the feeling of grogginess and low alertness upon awaking from deep stages of sleep (Tasso and Muzet 2000).

The effects of sleep inertia can impair alertness and performance (Jewett et al. 1999). The effects of sleep inertia divide into two classifications: subjective alertness and cognitive performance. The duration of effects from sleep inertia can last up to four hours (Tassi and Muzet 2000). Jewett et al. (1999) studied the time course of sleep inertia dissipation. They found subjective alertness levels returned to normal after 40 minutes and cognitive performance levels returned to normal after 70 minutes.

Findings by Jewett et al. (1999) are similar to other studies. In fact, Achermann et al. (1995, as cited in Ficca et al. 2010) found that sleep inertia can influence neurobehavioral performance for two or more hours, and the severity can vary among people. Tassi and Muzet (2000:1) noted that, “Prior sleep deprivation usually enhances sleep inertia since it increases SWS [slow wave sleep].” They also noted that lasting effects rarely exceed thirty minutes in non-sleep-deprived individuals. Furthermore, these persons experience the lowest levels of alertness and reaction speed. Moreover, human awareness is low after awakening from deep sleep (Joffe 2006) and performance tends to decrease throughout the day (Duchon and Smith 1993). This means that while firefighters experience a delayed alertness and cognitive performance upon awakening during the night, alertness will decrease throughout the day.

As alertness, reaction time, and cognitive performance decreases throughout the day and night, firefighters are at higher risk of injury. For example, it is legal for firefighters to exceed posted speed limits, drive through red light intersections, and travel across various lanes of traffic while responding to an emergency. It is possible that if these firefighters are also suffering from sleep inertia, the risk of automobile accidents could increase. Furthermore, it is possible to injure patients unintentionally when providing medical care.

## ***Recovery***

A firefighter's alertness and cognitive performance may not recover fully if they respond to several incidents in one night. Researchers have linked frequent calls to increased stress and fatigue in paramedics (Takeyama et al. 2001, as cited in Takeyama et al. 2009). In addition, Takeyama et al. (2005) found the sudden alarms also increase firefighter stress. It is important therefore to understand the need of sleep to recover from incidents throughout the day and night.

Joffe (2006) explains that recovery consists of two important needs: quality and quantity. Recovery is not simply lying in bed for eight hours. Effective recovery requires several consecutive, complete cycles of REM and NREM sleep. The quality of sleep is important because deeper stages of NREM sleep are responsible for restoring functions, psychological well-being, and cognitive rebuilding (Joffe 2006). It takes about one hour to reach deeper stages of sleep. A firefighter may never progress into deep sleep if awakened several time a night. Upon returning to sleep (e.g., after an alarm), a firefighter will start the sleep process from the beginning.

Effective recovery is also a function of length (Joffe 2006). The National Sleep Foundation recommends adults receive seven to eight consecutive hours of sleep each night. If an individual does not properly cycle through the stages of sleep and of inadequate duration, sleep deprivation results.

Sleep deprivation can cause both acute and chronic health effects. Acute adverse effects from withholding sleep are fatigue, sleep inertia, poor cognitive performance, decreased reaction speed, and slowed memory recall. Chronic sleep debt can result in brain anomalies, obesity, gastrointestinal disorders, cardiovascular disease, diabetes, stress, fatigue, immune deficiencies, and mortality (Costa 1996; Joffe 2006; Luyster et al. 2012; Yaggi, Araujo, and McKinlay 2006).

## **Injuries, Accidents, and Time of Day**

Karter (2009) found a relationship between firefighter injury occurrence and time of day. Between 2005 and 2009, 64.7 percent of the reported fires occurred between noon and midnight. About 33.5 percent of these fires occurred between noon to 6:00 p.m., and 31.2 percent of the fires occurred between 6:00 p.m. to midnight. Only 14.9 percent occurred between midnight and 6:00 am. Although, the greatest number of reported injuries occurred between noon and midnight, Karter found that the injury rate per fire incident peaked between 2 a.m. and 4 a.m.

Karter's report from the National Fire Protection Association's (NFPA) Fire Analysis and Research Division fell short of suggesting that poor sleep quality or sleep deprivation was the primary cause of increased accident rates. Although his analysis revealed a strong correlation between sleep deprivation and accident rate, it is inappropriate to assume that these accidents directly result from sleep deprivation or quality because other factors may also influence accident rates. For example, the inability to see at night compared to during the day may be associated with the increase in accidents. Another factor is weather; ice formed during the night can increase the possibility of slipping and falling. Overall, Karter's findings illustrate an important correlation, but without further analysis, a causal relationship cannot be concluded.

Violanti et al. (2012) examined injury rates among police officers. After adjusting for age, they conclude that injury rates during night shifts are 72 percent higher than day shifts. Unlike Karter (2009), Violanti et al. (2012) found a relationship between injury rates and sleep hours. Police officers who receive five or fewer hours of sleep had an injury rate 88 percent higher than police officers who slept more than five hours. This research shows both correlation and casual relationships between injury rates and sleep duration.

Researchers have also examined occupational errors and accidents. Milner et al. (1988:105) note that the most serious human-error commercial accident in the US occurred at the Three Mile Island

plant on March 28, 1978 at 4:00 a.m. and resulted from workers failing to monitor coolant water levels. Human error was also cited in two other incidents that occurred at nuclear power plants: the Davis-Besse reactor at Oak Harbor, Ohio in 1985 and the Rancho Seco reactor near Sacramento, California in 1985. Lastly, the Presidential Commission on the Space Shuttle Challenger Accident concluded that a lack of sleep contributed to human error (Milner et al. 1988:106). Researchers cited sleep deprivation as the leading for Chernobyl and Bhopal disasters (Costa 1996; Folkard, Lombardi, and Tucker 2005; Joffe 2006). Price and Holley (1990) confirmed that shift schedules and fatigue heavily influenced the occurrences of the Three Mile Island, Bhopal, Chernobyl, and Exxon Valdez disasters (as cited in Folkard and Åkerstedt 2004:A161).

## **Performance**

Research suggests that prolonged wakefulness affects workers' performance (Raslear, Hursh, and Van Dongen 2011) and alertness (Dinges 1995; Åkerstedt 1995). The effects of long work hours on performance exist in the transportation industry (Drobnick 2005; Philip 2005), medical services (Samkoff and Jacques, 1991), aviation (Drumer and Dinges 2005), and the military (Caldwell and Caldwell. 2005).

The combination of driving while sleep deprived may lead to an increase in fatigue and risk of errors (Gaba and Howard 2002; Phillip et al. 2005). Two important studies illustrate the relationship between performance and continued wakefulness against the equivalent effects of alcohol consumption. Dawson and Reid (1997) developed two experiments that tested cognitive performance level. In the first group, they asked volunteers to remain awake for 28 hours. In the second group, they asked volunteers to consume 10-15 grams of alcohol every 30 minutes until their Blood Alcohol Concentration (BAC) reached 0.10 percent (p. 235). They found that after being awake for 17 hours, participants' performance levels were equivalent to 0.05 percent BAC. Furthermore, after 24 hours of sustained wakefulness, cognitive performance reached levels

equivalent to those with a 0.10 percent BAC, which most states of the U.S. consider illegally intoxicated.

In a more comprehensive study, Williamson and Feyer (2000) re-examined the comparison between alcohol and sustained wakefulness with cognitive performance. Instead of using the measurement that Dawson and Reid (1997) used (i.e., hand-eye coordination), Williamson and Feyer (2000:649) used a variety of tasks including attention, cognitive reaction speed, and coordination. Similar to the Dawson and Reid (1997), Williamson and Feyer (2000) found that between 16.91 and 18.55 hours of sustained wakefulness, individuals produced an equivalent BAC of 0.05 percent. However, an equivalent BAC of 0.10 percent occurred between 17.74 and 19.65 hours of sustained wakefulness – much sooner than previously reported. Furthermore, Williamson and Feyer (2000) noted that 17 to 19 hours of being awake produce considerable unsafe performance levels for vehicle operation. Phillip et al. (2005) identified an increase in traffic errors and fatigue with sleep-deprived participants compared to fully rested individuals during a driving experience that simulated driving home after a night shift.

Costa (1996) and Raslear, Hursh, and Van Dongen (2011) found that attention, coordination, cognitive performance, and motor speed decrease as wakefulness decreases, resulting in increases in accident and injury rates. Similar findings are reported for medical residents (Samkoff and Jacques 1991) and airline pilots (Durmer and Dinges 2005). After a study of accidents by long-haul truck drivers (Drobnich 2005; 2005), the National Highway Safety Administration developed regulations that limit the driving time (Mitler 1997). Similarly, the FAA restricts the number of flight hours for pilots to allow for recovery from fatigue and sleepiness.

## **Shift Schedules**

Knauth (1993) studied shift schedules and identified five characteristics in the design of shift schedules: permanent night work verses slow/quick rotating systems<sup>3</sup>, duration of shifts, start time of shifts, leisure time within system, and direction of shift rotation. Characteristics relevant to this research include duration of shifts, start time, and leisure time. Most career fire departments operate on a 24-hour shift schedule, which obviates the need to consider ‘permanent night work verses slow/quick rotating systems’ and ‘direction of shift rotation’ characteristics in this study.

### ***Work Shift Duration***

The relationships among work shift duration, sleep, and performance are equivocal. Some researchers argue that different shift lengths are not statistically and significant to sleep deprivation. Some suggest shorter lengths are better, while other argue for longer shift durations.

**No Significant Difference.** Findings on shift durations are inconsistent and often criticized because of the method selected to measure dependent variables (Majde and Krueger 2005). If the difference in sleep deficit between 8- and 12-hour shifts is minimal, workers’ preference for 12-hour shifts is based most likely on social satisfaction with the greater number of non-work days associated with longer work shifts rather than sleep.

**Shorter Is Better.** Miller and Mackie (1980) found that performance decreases after seven to eight hours of driving. Others confirm that “positive correlation of time-at-work or overtime with accident frequency has been observed for lorry drivers (Hamblin 1987), work with ladders (Cohen and Lin 1991), sewing machine operators (Waersted and Westgaard 1991), coal miners (Hunting 1990), and industrial workers generally (Leigh 1986)” (Duchon et al. 1997:40).

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<sup>3</sup> Rotating shiftwork involves workers rotating from one shift (e.g., day shift) to another shift (e.g., night shift) and back again in a continuous loop (Paley and Tepas 1994).

Manacci et al. (1999) studied 24-hour shifts. They report that 24-hour shifts are becoming increasingly popular in professions such as the fire service and medical industries. After a 14-month study of flight nurses, they concluded that working 24-hour shifts results in poorer cognitive and motor skill performance compared to 12-hour shifts.

**Longer Is Better.** In contrast to research suggesting shorter shift durations are beneficial to sleep, others argue that longer shift durations improve sleep and performance. Studies of manufacturing workers (Volle et al. 1979) and law enforcement officers (Peacock et al. 1983) demonstrated higher performance with extended shift duration. Sleep quality and quantity increased for workers on a 12-hour shift compared to an 8-hour shift (Duchon et al. 1997). Smith et al. (1998) noted that although findings are inconsistent, persons working 12-hour shifts experienced lower stress levels, better sleep, improved physical and psychological wellbeing, and better family relationships than those working shorter shifts. However, safety measures were instituted to increase the comfort of those who switched to 12-hour shifts. Milia (1998) claimed that organizational interventions might include innovative compressed workweek schedules with longer shift durations and fewer working days.

Duchon and Smith (1993) illustrated that sleep quality improves without a decrease in sleep length in a 12-hour schedule as compared to an 8-hour schedule. In addition, others noticed an increase in sleep length during 12-hour shifts over 8-hour schedules (Peacock et al. 1983; Williamson, Gower, and Clark 1994).

**Conclusion.** It is apparent that the relationship between shift length, sleep quality, and performance is unclear, at least when differences between work shift durations are relatively small (e.g., 8 versus 12 hour). Smith et al. (1998) found no study that examined these relationships over extended periods. This suggests the need of more studies to resolve the inconsistencies among extant studies and investigate the long-term impact of shift duration on sleep quality and work performance.

Given the large variation in shift durations in the fire service, this study offers a unique and important opportunity to explore further the effect of work shift duration on sleep quality.

### ***Time-Off Duration Relative to Work Shift Duration***

Knauth (2006) described *duration of time off* as distribution of leisure time following a shift cycle<sup>4</sup>. Rest and sleep are required to restore sleep debt, fatigue, and other consequences of shiftwork. An increase in rest days results in improvements in sleep duration, sleep quality, and mood (Totterdell et al. 1995).

The duration of time off from work varies across organizations and workloads. A job that is mentally and physically demanding will require more rest and recovery than a job that has a lighter workload. Åkerstedt et al. (2000) found that recovery occurs after one day of rest in a traditional 8-hour, five days a week, with weekends off. Kecklund and Åkerstedt (1995:252) report the following:

Totterdell, Spelten, Smith, Barton, and Folkard (1995) have shown that one day off is insufficient for shift working nurses and that often three days may be required. Meijman (1981) showed that three days are required after a series of seven night shifts. On the other hand, Rosa and Colligan (1988) showed that two days of rest are sufficient for normalizing most psychological functions after a 60 hour week. Fischer et al. (1993) found that two days off between a series of night shift resulted in more naps and rest behavior during the working week than one with 4 days off. Patkai and Dahlgreen (1981) showed that the satisfaction was higher with 3-5 days off and few long periods off, than a system with two days off but more frequent long periods off. Nicholson, Jackson, and Howes (1978) showed that workers on a 6 days-on, 2 days-off system often added days of vacation or sick leave to create a longer series of days off. Using experimental night work, Knauth, Rutenfranz, Herrmann, and Poppel (1978) showed that it took two days for the body temperature rhythm to readjust after two night shifts, but 3-4 days after 21 night shifts. Our own studies have indicated a readjustment time of three days for three-shift workers after a sequence of night shifts.

Irregular and longer work schedules seem to require more than one day for recovery. During an 84-hour workweek, it took three to four days of rest for participants' sleepiness levels to decrease to

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<sup>4</sup> Shift cycle is the duration of one complete shift pattern. For example, a 24on/48off fire department shift schedule has the pattern of one day on and two days off (i.e., 24 hours on, 24 hours off, 24 hours off). In this shift schedule example, the three-day period is a cycle. This pattern is also known as a shift 'tour'.

baseline levels (Åkerstedt et al. 2000). Tucker et al. (1999, cited in Peach et al. 2010) found that 24 hours of rest between shifts did not allow enough time for recovery. They found sleep disturbances increased with 24 hours of rest between shifts and decreased when employees received 48 hours of rest between shifts.

Again, the wide differences in the duration of time off relative to the work shift duration among career firefighters' provide an opportunity to explore this relationship more thoroughly.

### ***Workshift Start Time***

Knauth (1993:20) argued for a later morning start time for three reasons: early morning starts reduce the amount of sleep obtained because people usually go to bed around the same time regardless of the time a shift starts; early morning starts correlates with increased fatigue; and early morning starts increase errors and accidents. Beginning a shift in the later morning or afternoon allows individuals to obtain sleep without disturbing sleep need (Åkerstedt 2003).

Bjerner, Holm, and Swensson (1955) identified two periods of sleepiness: 2:00 a.m. to 7:00 a.m. and 2:00 p.m. to 5:00 p.m. Joffe (2006) reported that decreases in body temperature correlates with sleepiness, creating a psychological nadir of sleepiness between 4:00 a.m. and 5:00 a.m. A Psychological nadir is the dip in performance usually in early or late mornings, depending on whether a person is an 'early bird' or 'night owl.' Psychological nadirs are closely associated with temperature nadirs—a precursor to sleepiness (Joffe 2006). This means that workers will experience a dip in alertness causing an increase in sleepiness. Moreover, Åkerstedt (2003) discovered that those awakening between 4:00 a.m. and 5:00 a.m. were likely to become sleepy throughout the day. In a study on pediatric medication errors, Kozer et al. (2002) noticed an increase in errors between 4:00 a.m. to 8:00 a.m. In short, research shows that shift start time matters.

### ***Fire Department Shift Schedules***

Considering the variety of characteristics involved in designing a shift structure, it is not surprising that a large number of rotating or permanent shift structures exist throughout the world (Knauth 1993). It is understandable that the fire service also employs a variety of shift schedules. Tasto and Colligan (1997, cited in Paley and Tepas 1994) claims that 150 different fire department work schedules exist, but the authors do not indicate whether a particular schedule or group of schedules is/are superior. However, Elliot and Kuehl (2007) identified 15 fire department work schedules, which include 10-hour days and 14-hour nights; 12-hour days and 12-hour nights; 8-hour shifts; 24 hours on and 24 hours off; 24 hours on and 48 hours off; 24 hours on and 72 hours off; and 48 hours on and 96 hours off. Comparing all shift schedules, they noticed that most career fire department operated on some type of 24-hour work schedule.

Fire departments operating under the 24 hours on and 24 hours off (24on/24off) shift schedule usually maintain two shifts (sometimes three): A-shift and B-shift. While one shift works 24 hours, the other shift has 24 hours off. Table 1 illustrates a 24on/48off two-shift schedule.

**Table 1. 24on/24off**

| Sunday  | Monday  | Tuesday | Wednesday | Thursday | Friday  | Saturday |
|---------|---------|---------|-----------|----------|---------|----------|
| A Shift | B Shift | A Shift | B Shift   | A Shift  | B Shift | A Shift  |

Fire departments operating under the 24 hours on and 48 hours off (24on/48off) shift schedule usually maintain three shifts: A-shift, B-shift, and C-shift. A-shift will work 24 hours and then has 48 hours off. B-shift will replace A-shift and work for 24 hours. C-shift will replace B-shift and work 24 hours (see Table 2).

**Table 2. 24on/48off**

| Sunday  | Monday  | Tuesday | Wednesday | Thursday | Friday  | Saturday |
|---------|---------|---------|-----------|----------|---------|----------|
| A Shift | B Shift | C Shift | A Shift   | B Shift  | C Shift | A Shift  |
| B Shift | C Shift | A Shift | B Shift   | C Shift  | A Shift | B Shift  |

Fire departments operating under the 24 hours on and 72 hours off (24on/72off) shift structure usually maintain four shifts: A-Shift, B-shift, C-shift, and D-shift. This pattern closely resembles the 24 on – 48 off shift schedule, but adds an additional shift. Larger departments usually incorporate this system; instead of 48 hours off, firefighters receive 72 hours off (see Table 3).

**Table 3. 24on/72off**

| Sunday  | Monday  | Tuesday | Wednesday | Thursday | Friday  | Saturday |
|---------|---------|---------|-----------|----------|---------|----------|
| A Shift | B Shift | C Shift | D Shift   | A Shift  | B Shift | C Shift  |
| D Shift | A Shift | B Shift | C Shift   | D Shift  | A Shift | B Shift  |

A different type of 24-hour rotating shift schedule is 48 hours on and 96 hours off (48on/96off). Different from the three other schedules, firefighters consecutively work for 48 hours. After their shift, they receive 96 hours off. This shift structure works with three shifts (see Table 4).

**Table 4. 48on/96off**

| Sunday  | Monday  | Tuesday | Wednesday | Thursday | Friday  | Saturday |
|---------|---------|---------|-----------|----------|---------|----------|
| A Shift | A Shift | B Shift | B Shift   | C Shift  | C Shift | A Shift  |
| A Shift | B Shift | B Shift | C Shift   | C Shift  | A Shift | B Shift  |

Fire departments may also modify one of the standard 24-hour rotating shift structures. One of the modified 24-hour shift schedules is the Kelly shift schedule. It is also known as the Berkeley, Dallas, Modified Detroit, and the ‘3/4’ schedule<sup>5</sup>. The Kelly shift schedule operates on a 24-hour basis in which firefighters work every other day for three days and then receive four days off (see Table 5). The only structural difference with the Kelly schedule is that firefighters receive four days off after three shifts. Thus, firefighters working the 48on/96off schedule receive four days off more frequently than the Kelly schedule.

<sup>5</sup> For consistency, the schedule illustrated in Table 5 will be referred to as the Kelly schedule.

**Table 5. Kelly Shift Schedule**

| Sunday  | Monday  | Tuesday | Wednesday | Thursday | Friday  | Saturday |
|---------|---------|---------|-----------|----------|---------|----------|
| A Shift | B Shift | A Shift | C Shift   | A Shift  | C Shift | B Shift  |
| C Shift | B Shift | A Shift | B Shift   | A Shift  | C Shift | A Shift  |
| C Shift | B Shift | C Shift | B Shift   | A Shift  | B Shift | A Shift  |
| C Shift | A Shift | C Shift | B Shift   | C Shift  | B Shift | A Shift  |

It is evident that schedule preference varies. Currently no empirical research exists that examines the differences of the 24-hour fire department shift schedules on sleep quality. This research investigates the effects of different shift schedules on firefighter sleep quality.

## CHAPTER III

### METHODOLOGY

By combining sleep research with research on work schedules, it is possible to determine whether issues of sleep quality exist in the fire service, and whether a particular type of shift schedule is associated with better sleep quality.

#### **Hypotheses**

With respect to alertness, prior research would support the claim that significantly longer work duration (e.g., 24 versus 12 hours) results in decreased sleep quality (Kecklund and Åkerstedt 1995; Duchon et al. 1997)

Despite the equivocal results of non-shift duration applicable to other work industries, two research findings emerge: the greater the job demand, the more time needed for recovery, and the longer duration off, the better the recovery (Åkerstedt et al. 2000). In addition, when working irregular hours, two days are needed for recovery (Tucker et al. 1999, cited in Peach et al. 2010). Therefore, the following hypotheses are offered:

H<sub>0</sub>: No relationship exists between sleep quality and the fire department shift schedules.

H<sub>a</sub>: Sleep quality decreases with increasing sleep debt (increasing workshift duration coupled with decreasing recovery durations).

### **Dependent Variable: Sleep Quality (ordinal scale and dichotomous measures)**

Sleep quality requires a valid and reliable measurement. The Pittsburgh Sleep Quality Index (PSQI, see Appendix A) measures several aspects of sleep quality (Buysse et al. 1989). The PSQI is a valid and reliable testing measurement for sleep related inferences (Patterson et al. 2010), with the internal consistency of PSQI scales showing a reliability coefficient (Cronbach's  $\alpha$ ) equal to 0.83 (Buysse et al. 1989). The PSQI consists of 19 questions that measure seven components: (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. 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 (see Appendix B). These values are then summed across the seven components for 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." Any score greater than 5 is associated with "poor sleep." Therefore, two analyses can be conducted: one treating PSQI as an ordinal variable and the other treating PSQI as a dichotomous variable.

The nature of the PSQI is to measure sleep quality of individuals who usually experience one sleep bout. The PSQI, cannot measure sleep quality of firefighters without modification to some of its questions. The modifications that expanded the original questions only affects how the three components (i.e., duration of sleep, sleep latency, and sleep efficiency) are calculated (See Appendix C for the modified scoring), but does not affect the output score of the index. Overall, the modifications should not affect the modified PSQI from being a valid and reliable instrument to measure sleep quality (see Appendix D for further explanation of the modifications).

### **Primary Independent Variable: Shift Schedule (nominal and dichotomous)**

A focus group, which included a current fire chief, a retired chief that is now in academia, and another retired fire chief, was formed to help define a sampling strategy, review extant research questionnaire, and offer perspectives on practices in the fire service related to sleep behavior. Although Elliot and Kuehl (2007) indicated five 24-hour work schedules, the focus group indicated that few departments actually use the 24on/24off and 24on/72off schedules. Therefore, the shift schedules considered in this research were restricted to 24on/48off, 48on/96off, and Kelly shift schedules.

### **Control Variables**

Selected demographic variables were defined and included in the survey to control for other factors that may influence sleep quality. These control variables include years of service (interval), chronological age (interval), marital status (dichotomous), children at home (dichotomous), hours of work per week in secondary employments (interval), and pre-existing sleep related disorder, such as sleep apnea (dichotomous).

### **Research Design**

Fire departments are divided into four categories: career, paid-on-call, volunteer, and combination departments. The research question restrains this research to firefighters who sleep at their associated fire departments. Of the four types of departments, career departments are the only category that includes 100 percent full-time firefighters. Therefore, this study includes only a sample of fire departments that United State Fire Administration (USFA) classifies as career.

The USFA maintains a list of all fire departments in the US. Using their database, and based upon a geographical sampling convenience, a list was developed that included departments from three regional states. A phone call was made to each medium-sized (60-100 firefighters) public career

fire department in these states to identify its shift schedule. Analysis of the shift schedules confirmed a limited use of the 48on/96off shift schedule in these states. This finding required the identification and recruitment of other departments using the characteristics of the 48on/96off shift schedules.

The final selection of departments was based on the convenience to the researcher. Two departments on each of the three shift schedules were selected to participate. The six departments are similar in many respects and respond to an average 4,000 to 5,000 calls a year, operate 4 to 6 fire stations, and employ 60-100 firefighters, and have the same shift start time<sup>6</sup>.

After selecting the departments, the fire chief or training officer was contacted to ask for permission to participate in the study. A site visit was scheduled after fire chief/training officer gave permission (written/verbal) to conduct the study.

The sample population includes only full-time, front-line firefighters with at least month of current continuous shift-work experience were interviewed because their performance is most likely to be sensitive to sleep quality. Therefore, the survey included three screening criteria: full-time appointment versus part time, discretion on response participation (required to respond to a call versus discretion not to respond), and continuous experience in shift work (at least one month working in a shift schedule). Firefighters with less than one month of experience might not be adjusted fully to the shift schedule. In addition, upon advice and recommendation of the focus group, allowing at least one month of continuous work experience should allow adjustment to the associated shift schedule. Therefore, only those firefighters passing these three screens (full-time, front-line, and continuous experience) were eligible for participation in the survey. The unit of

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<sup>6</sup> Unfortunately, all department contacted had similar start times and therefore cannot test the effects of different start times. However, Knauth (1993 and 1996) noted that later start times allow for more recovery because workers tend to sleep until necessary to report to work.

analysis therefore is the individual, front-line, full-time firefighter with at least one month of continuous current experience in that particular shift schedule.

At each department, the researcher began each group meeting, averaging five firefighters, by discussing the consent process and obtained written consent from each participant. The questionnaire is presented in (Appendix E). Upon completion, each questionnaire was reviewed for errors or missing value. In total, 109 firefighters completed complete questionnaires for this study.

### **Data Collection**

Data collection took place between February 2014 and March 2014. All six departments contacted agreed to participate in the study. In addition, during the site visits, all firefighters on shift completed the survey. One firefighter's survey was eliminated from the results due to ineligibility (being on shift for only two weeks). Overall, 109 firefighters completed the survey resulting in a 99 percent completion rate.

### **Data Analysis**

Survey responses were coded and entered into a database for analysis. PSQI scores were computed from the PSQI scaled responses and entered both as raw ordinal scores (varying from 0 to 21) and "good" versus "poor" dichotomous scores (0, 1). All other values were entered as recorded in the survey. In addition to the main analyses, tables, graphs, bar charts, histograms, and show important relationships.

Several analyses were performed from the collected data. Descriptive statistics were computed from the PSQI scores and independent variables. A one-sample mean-comparison analysis was used to determine significance of the relationship between sleep quality and shift schedule. A chi-square analysis illustrates the pattern of sleep quality related to each shift. However, chi-square cannot report that differences in and impact of shift schedule and sleep quality. Therefore, a

Kruskal-Wallis analysis was used to explore the differences among the three shift schedules. A post-hoc analysis was then used to analyze comparisons between the three pairs of shift schedule. Finally, logistic regression and predicted probabilities was used to explore the statistical probabilities of sleep quality for each shift.

### **Data Interpretation**

Regression results were interpreted from the regression coefficients relating each of the three independent variables (shift schedules) with the PSQI dependent variables (ordinal and dichotomous). Patterns of work schedules (work shift durations and work/off duration ratios) against sleep quality were revealed, which were used to reach conclusions and base recommendations to minimize poor sleep quality.

## CHAPTER IV

### RESULTS

This chapter describes the statistical results of each analysis including descriptive statistics on demographics, sleep characteristics, and sleep quality.

#### Demographics

All 109 (100 percent) participants were male. The average age of firefighters is 38 years, ranging from 20 to 59 years of age. Ninety-four (86 percent) firefighters are married and 79 (72 percent) firefighters have children. Seventy (64 percent) firefighters have secondary employment. Those who have second jobs recorded an average of 27 additional working hours per week. Thirteen (12 percent) firefighters have a sleep related disorder such as sleep apnea. The number of years served in the fire service average 12 years, ranging from 1 to 34 years (Table 6).

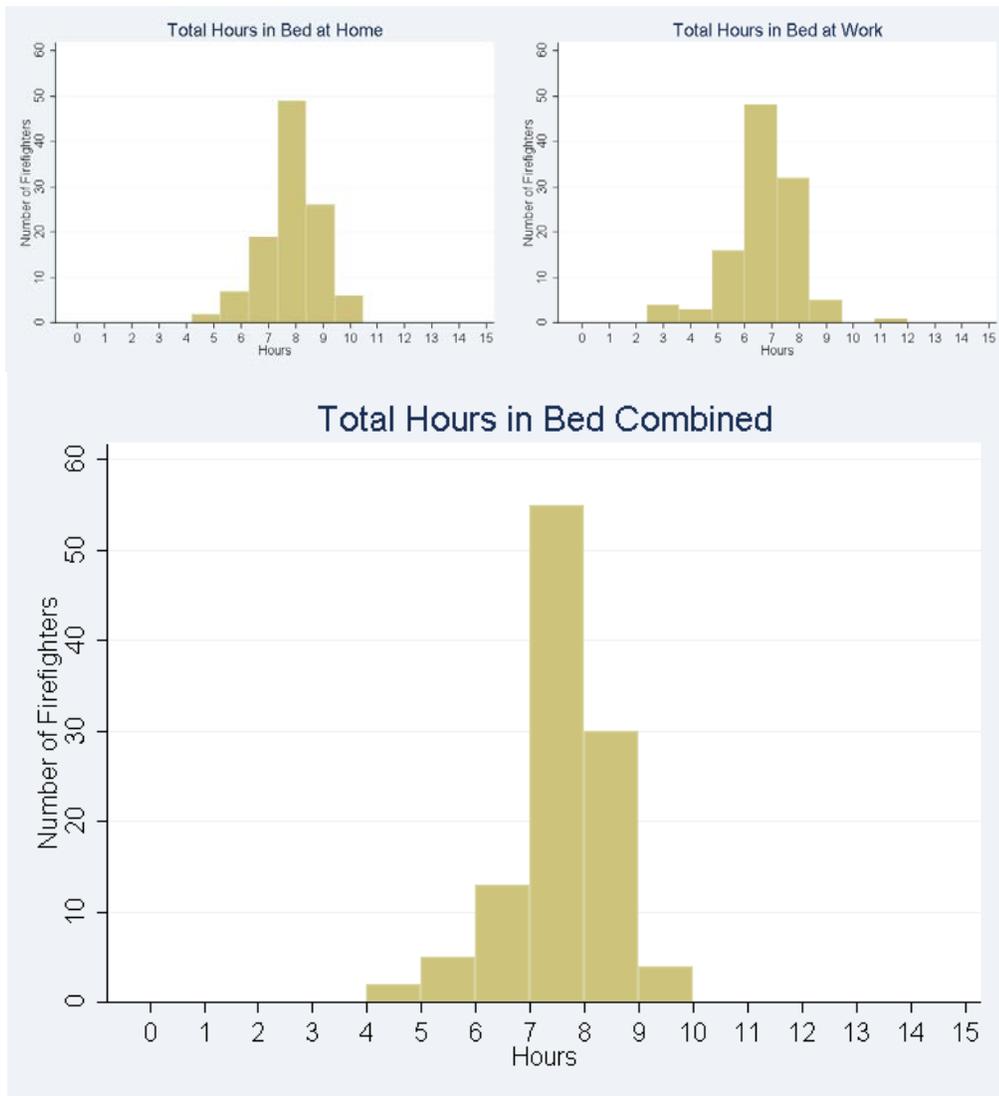
**Table 6. Demographics**

| <b>Variable</b>                 | <b>Results</b>  |
|---------------------------------|---|
| Gender                          | 109 Males   |
| Average Age                     | 38 Years (20-59)  |
| Marital Status                  | 15 (14 percent) Single<br>94 (86 percent) Married                 |
| Children                        | 30 (28 percent) Without Children<br>79 (72 percent) With Children |
| Second Job                      | 39 (36 percent) No Second Job<br>70 (64 percent) With Second Job  |
| Average Additional Weekly Hours | 27 Hours  |
| Sleep-Related Disorder          | 95 (88 percent) Without Disorder<br>13 (12 percent) With Disorder |
| Average Years of Service        | 12 Years (1-34)   |

## Sleep Characteristics

### *Total Hours in Bed*

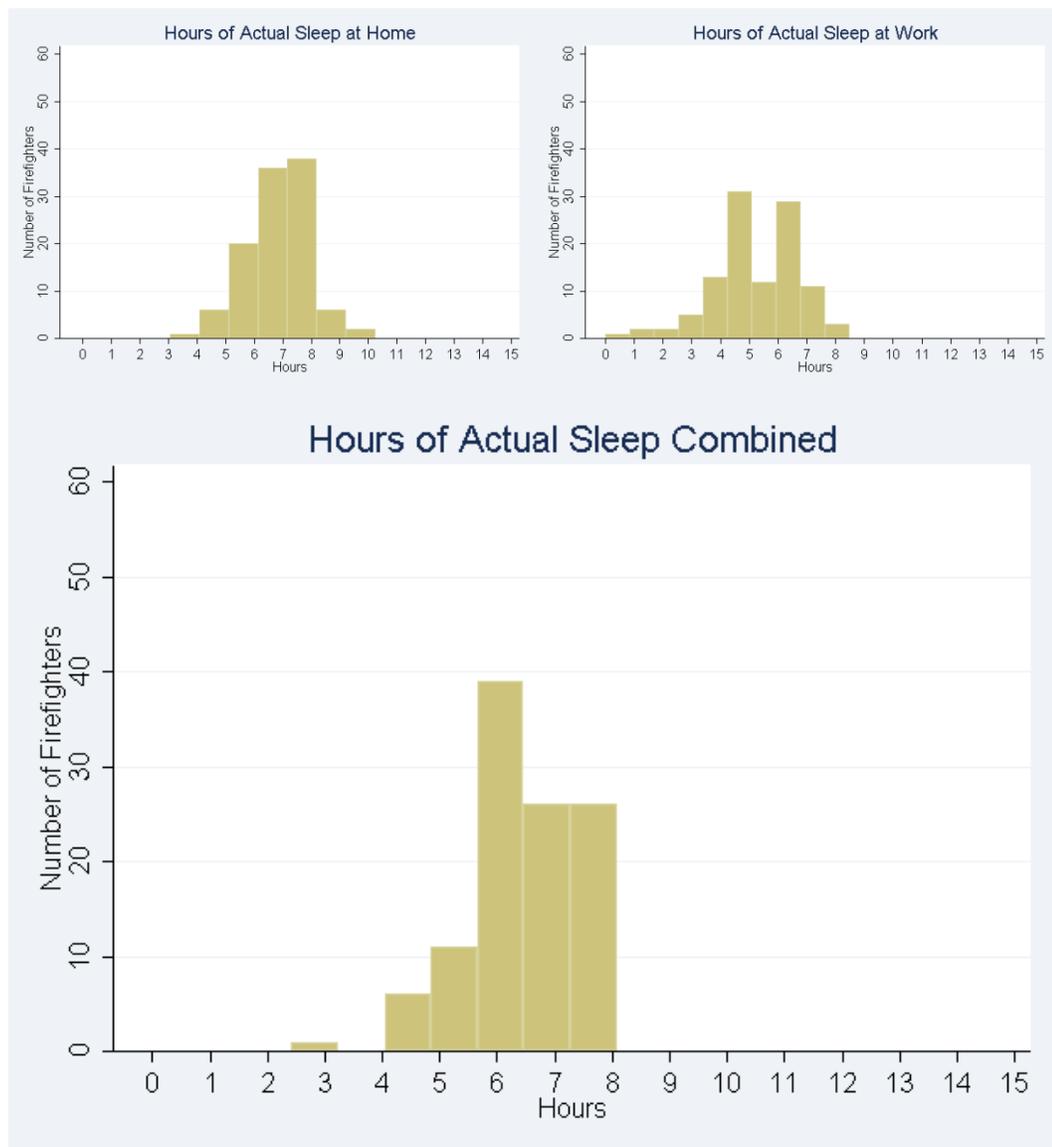
The total number of hours in bed accounts for time attempting to sleep and actual sleep. The average reported number of hours in bed at home is 7.9 hours (min 5, max 10). The average reported number of hours in bed while at work is reduced by one hour to 6.7 hours (min 2.5, max 12). Overall, both home and work totals average 7.5 hours. Figure 2 illustrates a histogram of the variance in hours.



**Figure 2. Total Hours Spent in Bed**

### *Hours of Actual Sleep*

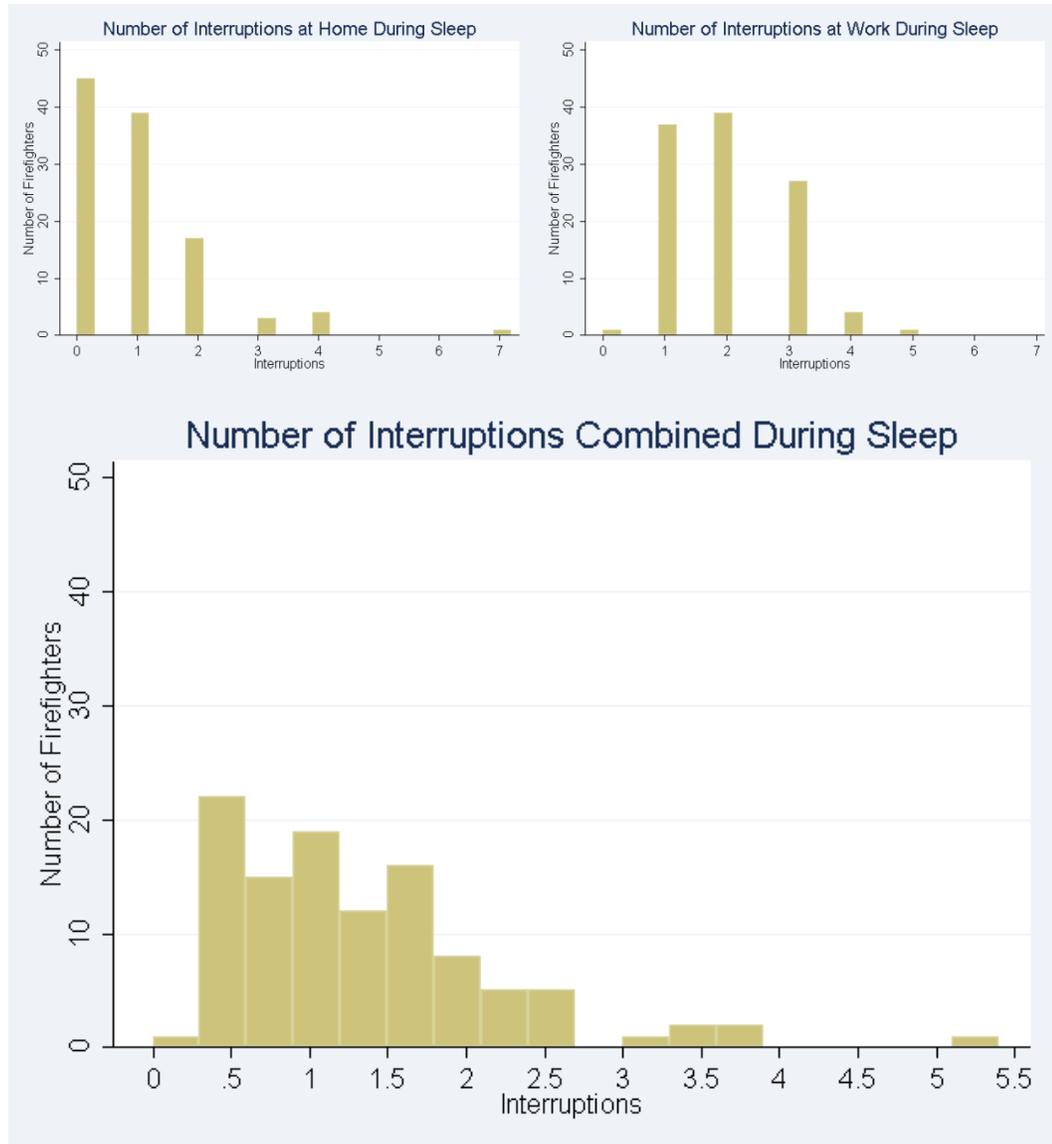
Actual sleep is calculated by subtracting disruptions and sleep latencies from total time in bed. Actual sleep therefore is usually less than total hours in bed. The average hours of actual sleep at home is 7 hours (min 3.25, max 10.25). The average reported number of actual sleep hours at work is 5.2 (min .5, max 8.5). Overall, both actual sleep at home and work averages to 6.4 hours (min 3.1, max 8.1). Figure 3 demonstrates the distribution of actual sleep hours.



**Figure 3. Hours of Actual Sleep**

## *Interruptions*

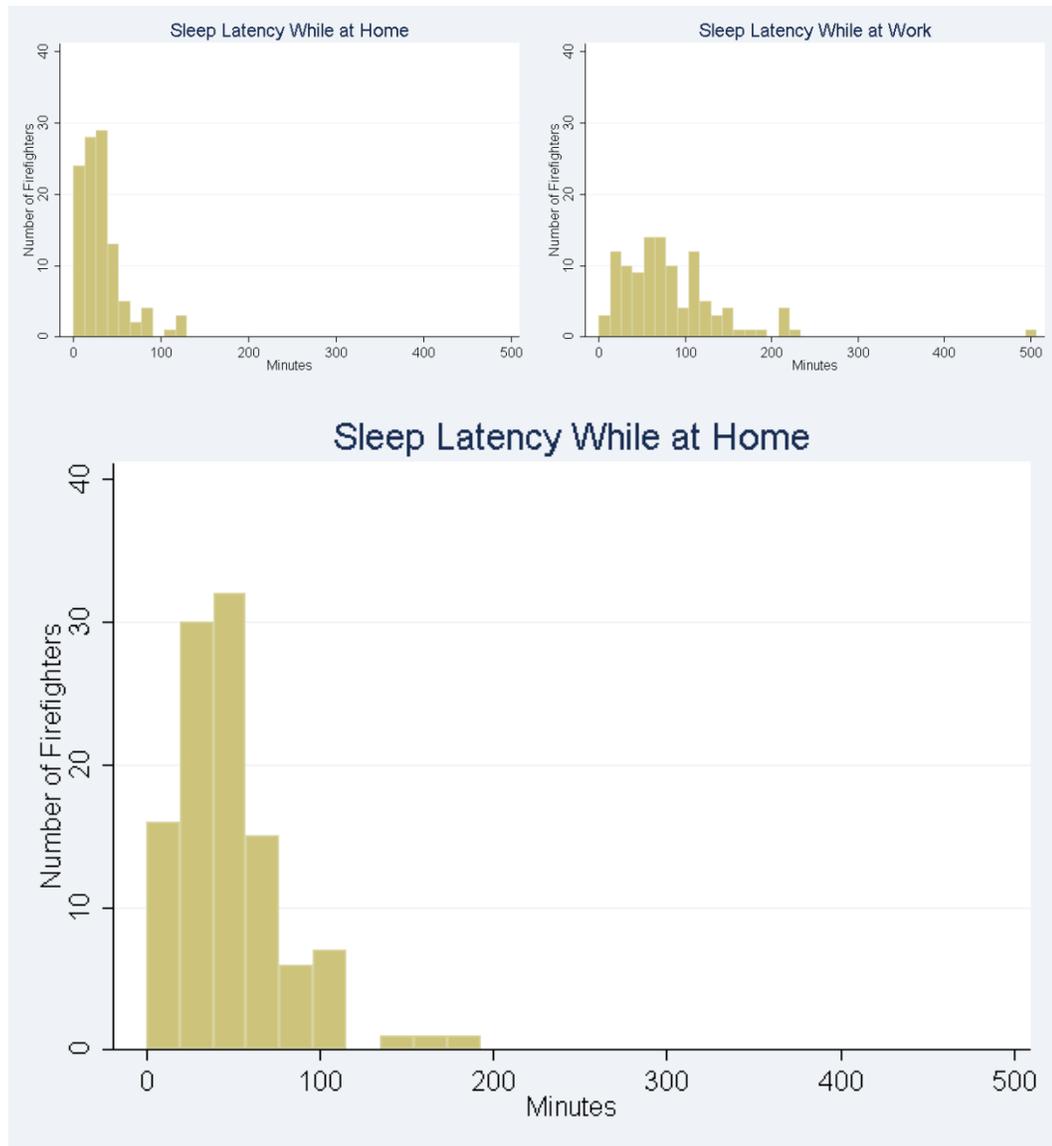
The average number of interruptions at home is 1 (min 1, max 7). The average number of interruptions while at work is 2 (min 0, max 5). The overall average number of interruptions for home and work is 1.3 (min 0, max 5.3). Figure 4 illustrates these patterns.



**Figure 4. Number of Sleep Interruptions**

## *Sleep Latency*

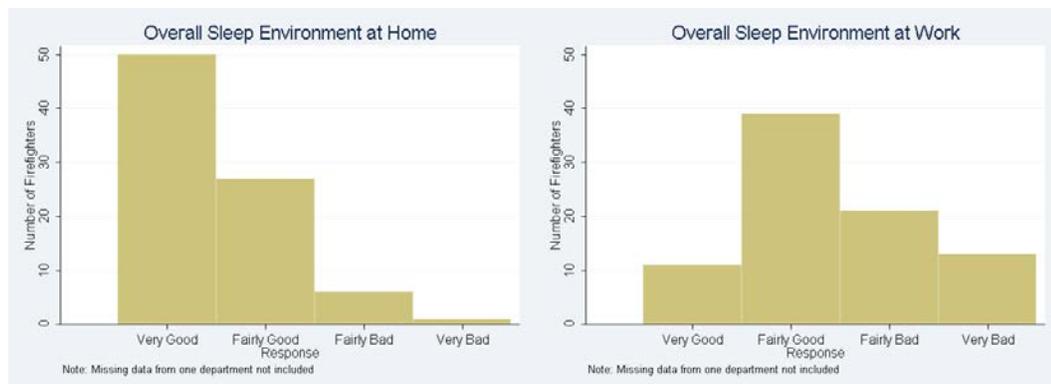
Combining all sleep latencies (the average time attempting to sleep) at home averages 31 minutes (min 0, max 130). The reported average of all sleep latencies while at work is 83 minutes (min 9, max 500). Combining home and work sleep latencies averages 48 minutes (min 10, max 193). Figure 5 depicts the distribution of sleep latencies.



**Figure 5. Duration of Sleep Latency**

## ***Sleep Environment***

Sleep environment refers to structural and non-structural components that, when combined, influence sleep quality. For example, a poorly covered window admitting light into a room is a structural component that can cause poor sleep quality. The average response of sleep environment at home was 0.5 “Very Good” (min 0, max 3). The average response for sleep environment at work was 1.4 “Fairly Good” (min 0, max 3). Figure 6 shows the relationship of sleep environment at home and work.

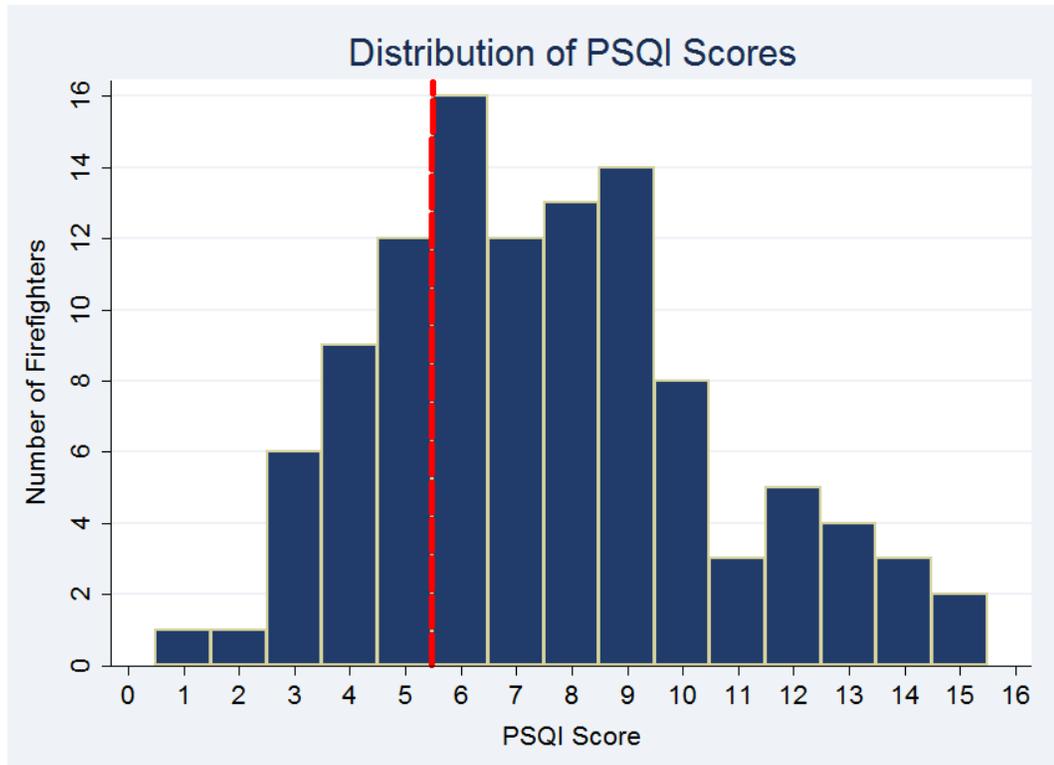


**Figure 6. Overall Sleep Environment**

## **Sleep Quality**

### ***PSQI Scores (raw)***

PSQI scores were calculated using an automatic programming feature in STATA. Figure 7 illustrates the distribution of PSQI scores. Although PSQI scores can range from 0 to 21, the highest score was 15. Considering just the score values, the distribution looks rather normal, though slightly positively skewed. Scores over 5 are considered poor sleep quality (marked by the red vertical line in Figure 7).

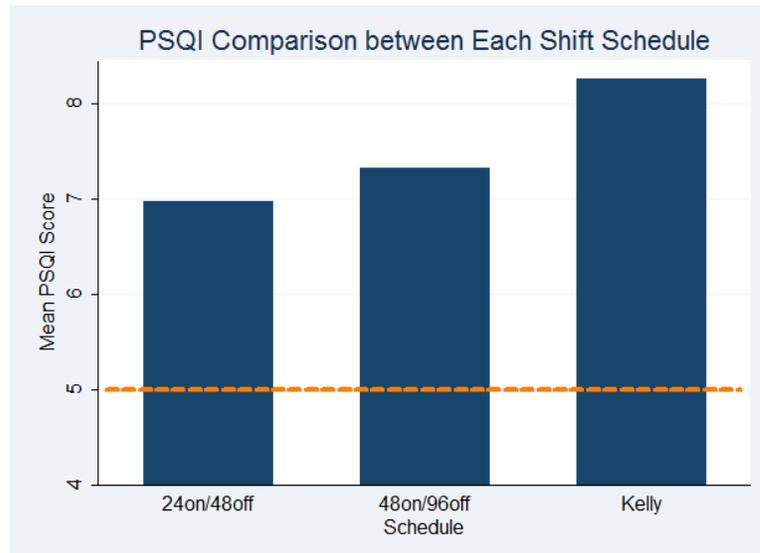


**Figure 7. Distribution of PSQI Scores of Firefighters**

Sleep quality, measured by PSQI scores, for the first and second departments on the 24on/48off shift schedule average 7.2 and 6.8, respectively. The overall PSQI score for the 24on/48off shift schedule averages 7.0. Sleep quality for the first and second departments on the 48on/96off shift schedule average 7.6 and 7, respectively. The overall PSQI score for the 48on/96off shift schedule is 7.3. Sleep quality for the first and second department on the Kelly schedule average 8.2 and 8.4, respectively. The overall PSQI score for the Kelly schedule is 8.3. Table 7 describes the PSQI score for each department. Figure 8 illustrates the overall PSQI averages for each shift schedule on a graph.

**Table 7. Descriptive PSQI Results**

| PSQI Score Measurements                 |               | 24on/48off | 48on/96off | Kelly |
|---|---------------|------------|------------|-------|
| <b>Department One of Shift Schedule</b> | Observation   | 15         | 20         | 23    |
|   | Mean PSQI     | 7.2        | 7.6        | 8.2   |
|   | Standard Dev. | 3.7        | 3.6        | 2.2   |
|   | Variance      | 14.0       | 12.9       | 4.9   |
|   | Skewness      | 0.1        | 0.4        | 0.3   |
|   | Kurtosis      | 1.7        | 2.1        | 2.2   |
| <b>Department Two of Shift Schedule</b> | Observation   | 16         | 18         | 17    |
|   | Mean PSQI     | 6.8        | 7          | 8.4   |
|   | Standard Dev. | 2.3        | 2.7        | 3.6   |
|   | Variance      | 5.3        | 7.5        | 12.9  |
|   | Skewness      | 0.5        | 0.8        | 0.8   |
|   | Kurtosis      | 3.1        | 2.8        | 2.4   |
| <b>Total</b>                            | Observation   | 31         | 38         | 40    |
|   | Mean PSQI     | 7.0        | 7.3        | 8.3   |
|   | Standard Dev. | 3.0        | 3.2        | 2.8   |
|   | Variance      | 9.2        | 10.2       | 8.0   |
|   | Skewness      | 0.3        | 0.4        | 0.8   |
|   | Kurtosis      | 2.3        | 2.5        | 2.9   |



**Figure 8. Mean PSQI Score and Shift Schedule**

***Sleep Quality (Good versus Poor)***

A one-sample mean-comparison analysis determines if reported values are statically and significantly greater than an indicated value. The results of each one-sample mean-comparison analysis indicates that each schedule is statically and significantly greater than the score of 5 (see Table 8). This suggests that most firefighters on each shift schedule suffer from poor sleep quality. Further analysis is summarized in Table 9 for each department, which also resulted in significant results indicating scores from each department are greater than 5.

**Table 8. One-Sample Mean-Comparison per Shift**

| Shift Schedule                | Observations | Mean | Standard Error | Standard Deviation | T-Score | Degrees of Freedom |
|-------------------------------|--------------|------|----------------|--------------------|---------|--------------------|
| 24on/48off                    | 31           | 6.97 | 0.54           | 3.0                | 3.6**   | 30                 |
| 48on/96off                    | 38           | 7.32 | 0.51           | 3.2                | 4.5***  | 37                 |
| Kelly                         | 40           | 8.25 | 0.44           | 2.8                | 7.2***  | 39                 |
| ** $p < .001$ *** $p < .0000$ |              |      |                |                    |         |                    |

**Table 9. One-Sample Mean-Comparison per Department**

| Shift Schedule   | Observations | Mean | Standard Error | Standard Deviation | T-Score  | Degrees of Freedom |
|--|--------------|------|----------------|--------------------|----------|--------------------|
| (1) 24on/48off   | 15           | 7.20 | 0.97           | 3.75               | 2.27*    | 14                 |
| (2) 24on/48off   | 16           | 6.75 | 0.57           | 2.29               | 3.05**   | 15                 |
| (1) 48on/96off   | 20           | 7.60 | 0.81           | 3.60               | 3.23**   | 19                 |
| (2) 48on/96off   | 18           | 7.00 | 0.65           | 2.74               | 3.09**   | 17                 |
| (1) Kelly  | 23           | 8.18 | 0.46           | 2.20               | 6.89**** | 22                 |
| (2) Kelly  | 17           | 8.35 | 0.87           | 3.59               | 3.85***  | 16                 |
| * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$ **** $p < 0.0000$ |              |      |                |                    |          |                    |

Chi-square is a statistical test used to compare observed/reported data with data that would be expected to occur according to the hypothesis. Based on chi-square analysis, of the 109 firefighters, 85 percent of firefighters on the Kelly schedule have poor sleep quality, 68 percent of firefighters on the 48on/96off schedule have poor sleep quality, and 65 percent of firefighters working the 24on/48off shift schedule have poor sleep quality. This relationship between shift schedule and sleep quality is statistically significant,  $\chi^2(2, N = 109) = 4.4918$   $p$  significant  $p < 0.1$  (Table 10).

**Table 10. Chi-Square Results**

| Shift Schedule                |                        | Sleep Quality      |                    | Total  |
|-------------------------------|------------------------|--------------------|--------------------|--------|
|                               |                        | Good Sleep Quality | Poor Sleep Quality |        |
| <b>24on/48off</b>             | Number of Firefighters | 11                 | 20                 | 31     |
|                               | Expected Frequency     | 8.2                | 22.8               | 31.0   |
|                               | Row Percentage         | 35.5               | 64.5               | 100.00 |
| <b>48on/96off</b>             | Number of Firefighters | 12                 | 26                 | 38     |
|                               | Expected Frequency     | 10.1               | 27.9               | 38.0   |
|                               | Row Percentage         | 15.0               | 68.4               | 100.00 |
| <b>Kelly</b>                  | Number of Firefighters | 6                  | 34                 | 40     |
|                               | Expected Frequency     | 10.6               | 29.4               | 40.0   |
|                               | Row Percentage         | 15.0               | 85.0               | 100.00 |
| <b>Total</b>                  | Number of Firefighters | 29                 | 80                 | 109    |
|                               | Expected Frequency     | 29.0               | 80                 | 109.0  |
|                               | Row Percentage         | 26.6               | 73.4               | 100.00 |
| Pearson Chi2(2) = 4.4918 Pr = |                        |                    |                    |        |
| 0.106                         |                        |                    |                    |        |

A Kruskal-Wallis test is similar to an ANOVA except that ANOVA requires interval data for the dependent variable compared to ordinal data. The Kruskal-Wallis analysis determines if the sleep quality for each shift schedules are different among each other. In short, this analysis help determine that sleep quality for each shift schedule is not similar to the other shift schedules.

The results of the Kruskal-Wallis analysis indicates that sleep quality significantly differs across the schedules,  $\chi^2(2, 106) = 4.451, p = 0.1080$ . A statically significant finding at 0.1 warrants further analysis in a post-hoc comparison<sup>7</sup>. That analysis yields two significant relationships: first, between the 24on/48off schedule compared to the Kelly schedule ( $p = 0.0465$ ), and second, between the 48on/96off schedule compared to the Kelly schedule ( $p = 0.0844$ ). The variance between the 24on/48off and 48on/96off schedule is not significant (see Table 11).

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<sup>7</sup> The initial Kruskal-Wallis analysis can only identify that a difference exists, but cannot report between which schedules. Therefore, a post-hoc Kruskal-Wallis determines which schedules are different.

**Table 11. Kruskal Wallis Post-Hoc Results**

| Scheduled                 | $\chi^2$ with Ties |
|---------------------------|--------------------|
| 24on/48off VS 48on /96off | 0.734              |
| 24on/48off VS Kelly       | 3.967**            |
| 48on/96off VS Kelly       | 2.979*             |
| * $p < 0.1$ ** $p < 0.05$ |                    |

The results from the one-sample mean comparison, chi-square, and Kruskal-Wallis analyses suggests that (1) poor sleep quality exists in the fire service and (2) a difference in sleep quality exist among fire department shift schedules. Therefore, the null hypothesis that a relationship between shift schedule and sleep quality does not exist can be rejected.

The last set of analyses included logistic regression and predicted probabilities between the three shift schedules, which identifies the probabilities of having poor sleep quality when firefighters associate to a particular shift schedule. In addition, the analyses can also be interrupted to indicate the probabilities of having poor sleep quality when firefighters switch from one shift schedule to another.

The logistic regression analysis with predicted probabilities included two dichotomous control variables: children and second job<sup>8</sup>. While holding the control variables constant at their median<sup>9</sup>, the 24on/48off schedule has a .73 predicted probability of poor sleep, but is not significant. The 48on/96off schedule is associated with a .76 predicted probability of poor sleep, but is also not significant. Results illustrate a significant .86 predicted probability of poor sleep for firefighters on the Kelly schedule (see Table 12).

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<sup>8</sup> A correlation of the control variables and sleep quality indicated that only children and second jobs are statistically significant. Therefore, the other variables were omitted from the logistic regression with predicted probabilities analyses.

<sup>9</sup> Since the two control variables were ordinal dichotomous data, each variable was held at its median because it is the most representative value of the variable.

**Table 12. Predicted Probabilities Compared to all Schedules**

| Schedule          | Coefficient | Std Err. | Observations | LR chi <sup>2</sup> | P-value |
|-------------------|-------------|----------|--------------|---------------------|---------|
| <b>24on/48off</b> | -0.5128     | 0.4795   | 109          | 8.09                | 0.04    |
| <b>48on/96off</b> | -0.2973     | 0.4634   | 109          | 7.37                | 0.06    |
| <b>Kelly</b>      | 0.8888*     | 0.5282   | 109          | 10.02               | 0.02    |
| * <i>P</i> < 0.1  |             |          |              |                     |         |

In addition to predicted probabilities for each individual schedule, probabilities can be derived from comparing the 24on/48off and 48on/96off schedule to the Kelly schedule (see Table 13). While holding children and second jobs constant, the 24on/48off schedule has a .71 predicted probability of poor sleep compared to the Kelly schedule. This comparison is significant at the 0.01 level. The 48on/96off schedule has a .75 predicted probability of poor sleep compared to the Kelly schedule, but is not significant.

**Table 13. Predicted Probabilities Compared to Kelly Schedule**

| Schedule          | Coefficient | Std Err. | Observations | LR chi <sup>2</sup> | P-value |
|-------------------|-------------|----------|--------------|---------------------|---------|
| <b>24on/48off</b> | -0.9778*    | 0.6000   | 109          | 10.11               | 0.04    |
| <b>48on/96off</b> | -0.8143     | 0.5820   | 109          |                     |         |
| * <i>P</i> < 0.1  |             |          |              |                     |         |

## CHAPTER V

### DISCUSSION

#### **Introduction**

The purpose of this research was twofold: (1) to provide an exploratory investigation of the incidence of sleep quality in the fire service and (2) to determine potential variation in sleep quality across three popular shift schedules.

#### **Major Findings**

Based on a sample of 109 firefighters from six regional fire departments, 80 (73 percent) firefighters had poor sleep quality. Initial results illustrate that this occurrence is statistically significant that the mean PSQI scores from each schedule is greater 5, indicating poor sleep quality. Further analysis reveals that the mean PSQI scores of each department is significantly greater than 5.

In addition to the one-sample mean-comparison, an analysis using chi-square yields expected frequencies and percentages of poor sleep quality for each shift schedule. Out of 31 firefighters from the 24on/48off schedule, 20 (64.5 percent) firefighters have poor sleep quality. 26 firefighters working the 48on/96off schedule have poor sleep quality, out of 38 (68.4 percent). Lastly, of the 40 firefighters working the Kelly schedule, 34 (85 percent) firefighters had poor sleep quality. Overall, the results of the chi-square analyses are statistically significant. Among the 109 firefighters who participated in this study, almost three-quarters have poor sleep quality.

These initial results, in part, provide evidence that suggests that a sleep quality problem does in fact exist. It is evident that poor sleep quality is common in all departments. How this affects the physical and mental health of firefighters remains to be investigated. More discussion on health risks is provided later in this chapter.

The null hypothesis that a relationship between shift schedule and sleep quality does not exist is rejected. The Kruskal-Wallis test measured significant differences among the three shift schedules and found a significant difference between the Kelly and the other two schedules but not between the 24on/48off and 48on/96off schedules. A post-hoc analysis determined differences between comparisons of shift schedules. The difference between 24on/48off and 48on/96off is relatively small in comparison to the differences between 24on/48off to Kelly and 48on/96off to Kelly, which are significant at the 0.05 and 0.1 levels, respectively.

Theoretically, sleep quality should vary according to shift schedule and should result in significant differences. Although the difference between 24on/48off and 48on/96off schedule is not significant, it is possible to speculate that the lack of difference is due to other characteristic of the shift schedule design. Perhaps receiving four days off can be an adequate duration to recovery. In fact, Åkerstedt et al. (2000) suggested that two days are usually required for irregular working hours, and depending on the workload, three to four days could be necessary. In general, as shift systems become irregular (e.g., not traditional working week 8 a.m. to 5 p.m.) and of longer work durations, more resting and recovery time is required to counterbalance adverse shift effects. Still, as evident in the mean PSQI scores in figure 8, a slight difference exists between the 24on/48off and 48on/96off schedule. Even with four consecutive days of rest, sleep quality levels are poorer compared to the 24on/48off schedule. Therefore, perhaps duration of work time could be considered an equal, if not a more influence, than duration of leisure time.

Since the results suggest that sleep quality varies according to shift schedule, logistic regression with predicted probabilities can identify the probability of having poor sleep quality with each shift schedule. The first step in the logistic model is to run three separate analyses for each shift schedule, where sleep quality was the dependent variable, and shift schedule, firefighters with second jobs, and firefighters with children as the independent variables. The two control variables, second job and children, were kept constant at their medians. This ensures that the analyses are dependent on shift schedule alone. As reported in Table 12, the predicted probability of having poor sleep quality is .73 if one's shift schedule is 24on/48off and increases to .76 if one's shift schedule is 48on/96off; however, the predicted probabilities were not significantly different. The only shift schedule that produced significant results was the Kelly schedules which increases the predicted probability of having poor sleep quality to .87.

The results of the chi-square expected frequencies and percentages of having poor sleep quality per shift schedule validate these probabilities. The percentage of firefighters calculated to have poor sleep quality is 85 percent. This supports the proposition that poor sleep quality is more frequent among those working under the Kelly schedule.

The second step in the logistic model is to run predicted probabilities comparing two shift schedules against each other. The variable Kelly schedule was omitted because the logistic model cannot compute scores of the three dichotomous independent variables when the sums of the variables equal '1' (due to collinearity). In addition, because previous statistical analyses indicated a non-significant difference between 24on/48off and 48on/96off schedule, omitting the Kelly forced the logistic model to compare the 24on/48off and 48on/96off schedule against the Kelly schedule only. As reported in Table 13, firefighters had a 0.71 probability of having poor sleep quality, compare with the Kelly schedule. This prediction was significant at the 0.1 level. The probability increased for firefighters working the 48on/96off schedule to 0.75, but was not significant.

Analyzing the results of the logistic regression and the percentages produced by chi-square suggests that shift schedule can be ordered. Firefighters are more likely to have better sleep quality on the 24on/48off shift schedule compared Kelly schedule. Theoretically, the 48on/96off schedule should fall between the 24on/48off and Kelly schedule, but the results were not significant. According to Figure 8, however, mean PSQI score of the 48on/96off schedule is between the other two schedules. Although the relationship was found not be statistically significant, the literature supports the location of the 48on/96off lying between the other two schedules.

### **Design of a Shift System**

The design of a shift system can influence sleep habits. The results from the chi-square analyses support this claim. However, other characteristics of a shift system can impact sleep habits and quality as well.

For example, suppose a fire department transitioned to a traditional scheduling system consisting of three 8-hour shifts. Firefighters would not be allowed to sleep because they work for only 8 hours on a shift. Firefighters' sleep quality may return to a 'normal' state because the design of the system allows for recovery at a more frequent interval. For every 8 hours of work, one receives 16 hours of leisure time. The motivation to seek additional employments may decrease since the leisure time would be less compared to a 24-hour shift schedule. Time designated for recovery would be spent actually recovering, not working. This example is meant only to illustrate that shift design components can affect sleep quality.

Knauth (1993:16) describes several aspects to consider in designing a scheduling system, including consecutive shifts, length of each shift, start and finish times, duration and placement of time off, direction of shift rotation, regularity of shift systems, flexibility of systems, and use of part-time/full-time workers. In addition, he mentions several political legitimacy concerns including legislation, unions, collective agreements, economic aims, labor markets, working conditions,

stakeholders, and physiological, psychological, and social recommendations. These political, social, and technical components can affect a system and the workers. One change can result in a domino effect, which may later on affect sleep quality and human health. For example, cutting employees because of budget constraints may increase the workload of others, which will affect the required amount of time needed for recovery. The following section discusses the structural design of these three shift schedules and how the distribution of work/off durations impact sleep quality. Reference Tables 3, 4, and 5 in Chapter two for a diagram of the shift schedules.

### **Sleep Debt**

If a shift schedule results in insufficient recovery, then it is appropriate to define the deficiency of recovery as “sleep debt.” Using the PSQI threshold of 5, sleep debt can refer to scores above that threshold. For example, using the 24on/48off shift schedule, Åkerstedt et al. (2000) would agree that the sleep debt is zero hours.

### ***24on/48off Schedule***

The structure of the 24on/48off design allows two days of recovery after each 24-hour shift. According to Åkerstedt et al. (2000) and Kechlund and Åkerstedt (1995), two days off should be sufficient after working 24 hours. This claim is supported by these statistical PSQI results indicating that the 24on/48off is the best of the three work schedules. However, if two days off is ample time to restore rest, then why did the 24on/48off schedule have a mean PSQI score of 7, which is greater than the good/poor sleep quality threshold of 5? According to Åkerstedt, this schedule should have PSQI scores somewhere below 5, consistent with studies of other occupations consisting of more traditional work schedules. Perhaps other phenomena influenced the results.

### ***48on/96off Schedule***

The structure of the 48on/96off schedule requires personnel to work 48 hours before receiving time off. Although the ratio of working and non-working days is 1:2, the schedule should reflect noticeable differences in sleep quality because of the duration of the workshift at 48 hours. To hypothesize that a schedule of work/non-work ratio set at 2:1 will produce equal results is inappropriate and ignores the literature regarding shift design and recovery. Therefore, some other feature in PSQI prevents statistical significance. Possibilities include other interruptions during work or resting times, and other characteristics not captured in this survey. One speculation is that some firefighters do not receive adequate resting time on this schedule due to family obligations and second jobs that prevent rest. Another speculation is that some phenomena occur during the distribution of work hours. It is plausible that while some fire departments and fire stations receive large call volumes, others receive far fewer. Perhaps, workload (e.g., call volume) has an effect on system design. Firefighters attend frequent training and perform daily duties, but the distribution and frequency of these aspects could vary.

As previously mentioned, sleep debt can be a contributing external factor that influences sleep quality. The structure of the 48on/96off schedule does not allow firefighters to recover two days after working 24 hours. They work an additional 24 hours consecutively compared to the 24on/48off schedule. Therefore, sleep debt in each shift cycle (i.e., tour) is calculated at 24 hours.

### ***Kelly Schedule***

The structure of the Kelly schedule is quite different from the 24on/48off and 48on/96off schedules. Using Åkerstedt (2000) and Kechlund and Åkerstedt (1995) as a foundation for recovery time, firefighters on the Kelly schedule are required to work off and on for five days before receiving at least two days of rest. Firefighters lose 24 hours of recovery in the first interval (time from the start of one shift to the start of the next shift) of the shift cycle. Since firefighters experience two

complete intervals during a cycle, sleep debt for one cycle is 48 hours. This is clearly confirmed in Figure 8 with the highest mean PSQI score of 8.3. The results of the logistic regression and predicted probabilities also support this claim, indicating that the Kelly system was significantly worse compared to the other two schedules at the 0.01 level. Firefighters on the Kelly schedule have a 0.87 probability of having poor sleep quality. The Kelly structure is a clear example why a 1:2 work/rest ratio does not explain sleep quality. Since all three shift schedules have the same ratio but different mean PSQI scores indicates that other factors influence sleep habits.

## **Other Results**

### *Second Jobs*

Currently, no peer-reviewed literature explores how second jobs impact firefighters. Murphy et al. (1999) reports that 25 to 50 percent of firefighters have a second job, but do not indicate how they calculated these percentages. One could hypothesize that the duration of continued time off a firefighter receives could be a motivating factor to seek additional employment either in emergency services or in different occupations. The survey developed for this study included two questions that asked whether a firefighter had a second job and the average total weekly hours of the second job. During discussions after participants completed the surveys, a probing technique was used to elicit information about their second job.

Of the 109 respondents, 70 (64 percent) of firefighters had a second job. This finding provides a current updates Murphy et al. (1999) Most revealed that employment was within emergency services, mainly an EMS company. The minimum and maximum reported number of additional weekly working hours for second jobs was 4 hours and 100 hours, respectively. The mean number of hours was 27. Although second jobs was not the focus of this study, an interesting pattern arose with their use. A Pearson's correlation coefficient was computed to determine if second jobs had an impact on sleep quality. The results indicate a positive but weak relationship between the two

variables,  $r = 0.2436$ ,  $p = 0.0107$ . This means that those who have second jobs are likely to have poorer sleep quality compared to firefighters without second jobs.

### ***Recovery***

Recovery time should increase when weekly working hours increase. In fact, Åkerstedt et al. (2000) find that those working more than 84 hours in a week may require three to four days of recovery to return sleepiness to baseline levels. Although the mean weekly output for those who have second jobs was 27 hours, one needs to consider the number of hours the firefighting job requires. According to the Fair Labor Standards Act, 29 USC §207(k), emergency services personnel are allowed to average 53 hours a week before receiving compensation for overtime. Adding in 53 hours to second jobs, the minimum now becomes 57 hours and the maximum becomes 155 hours, with an average weekly work hours totaling 80.<sup>10</sup> For some, and assuming that the reported hours are correct, three to four days may be needed to recovery. Amount of time needed for recovery also depends on workload, a discussion, which is not the primary focus of this study.

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<sup>10</sup> Considering an average working week at a fire department, it is difficult to believe that someone actually works another job for 100 additional hours. Only 168 hours exist in a week. Working 153 hours only leaves 15 hours of 'free' time, which is unrealistic to obtain over extended periods, especially since all questions in the survey was related to an average week over the past month. Therefore, errors occurred in the data collection. While it is not necessary the fault of the firefighter, the survey question could have been confusing or misleading, a fault of the researcher. On the survey, two questions related to second jobs. The first question stated, "Do you work a second job?" This question does not seem to be confusing since it provided a "Yes" or "No" response choice. The second question, however, could be subject to different interpretations. The questions states, "If yes, how many hours (on average) do you work per week?" Two possible interpretations are possible. First, it can be interpreted as how many 'additional' hours one works per week. Looking at the described statistics of this question, any numerical response lower than 53 could suggest that a firefighter interpreted the question as 'additional' working hours, assuming that firefighter is working and averages 53 hours during the main job. However, seven respondents reported estimates exceeding 53 hours, which suggests that they interpreted the question as either 'additional' working hours or 'total' hours from both jobs. Therefore, this study cannot rely on responses to this question because of poor construction. In addition, this study did not consider overtime, vacation, sick leave, and other deduction/additions in hours worked. This may be why the preliminary analyses of the number of hours was not significantly related to sleep quality. However, whether one had a job was significant. Regardless, empirical evidence suggests that a large percentage of firefighters may be pursuing second jobs, which no doubt affects sleep quality.

## *Children*

Another variable that could influence sleep quality is having children at home. Young children, especially, may require attention during the night, which would affect sleep quality. However, the results of a Pearson's correlation demonstrate that the relationship was slightly negative,  $r = -0.0921$ ,  $p = 0.3408$ . However, despite this result, this variable was included in the logistic regression model discussed above.

## **A Future without Change**

Although firefighters report better sleep quality on the 24on/48off schedule as compared to the Kelly schedule, all schedules in this study had mean PSQI scores above the threshold. Several health risks can arise from sleep deprivation, as poor sleep quality and sleep debt increases.

## *Health Effects of Sleep Deprivation*

Researchers have studied various effects of sleep on the human body. The brain, eating habits, gastrointestinal, cardiovascular system, diabetes, stress, fatigue, immune system, and mortality are all current fields of interest (Costa 1996; Joffe 2006; Luyster et al. 2012; Yaggi, Araujo, and McKinlay 2006). As noted in Chapter Two, the acute effects of sleep deprivation cause decrements in alertness, physiological performances, cognitive thinking, and reaction speed. The focus of this section turns to long-term, chronic implications of sleep deprivation.

Sleep durations have decreased from 8.5 hours in 1960 to less than 6 hours in 2004 while obesity has increased (Knutson and Van Cauter 2008). Leptin and ghrelin are two hormones that affect gastrointestinal function. Leptin, produced by adipose tissue, promotes satiety. As leptin levels decrease, an individual's appetite increases. During a laboratory experiment, individuals who were sleep deprived saw their leptin levels decrease, resulting in an increase in appetite (Costa 1996; Knutson and Van Cauter 2008; Luyster et al. 2012). Ghrelin, released from the stomach, is

responsible for stimulating hunger. Higher levels of ghrelin stimulate the appetite. As firefighters continue to receive insufficient sleep, hormonal imbalances increase. This leads to feelings of hunger, which causes an increase in food intake and increases risk of obesity.

Chronic sleep deprivation also increases the risk of adverse effects on metabolic and endocrine regulations. Knutson and Van Cauter (2008) compared studies relating to gastrointestinal health effects. They suggest that chronic sleep deprivation disrupts glucose regulation and leads to excessive eating. Laboratory results of glucose tolerance from sleep-deprived individuals were lower compared to fully rested individuals (Spiegel, Leproult, and Van Cauter 1999). Over time, this may increase the risk of type 2 diabetes (Knutson and Van Cauter 2008; Luyster et al. 2012; Spiegel, Leproult, and Van Cauter 1999; Yaggi et al. 2006).

Little consensus exists on how sleep deprivation affects the cardiovascular system (Costa 1996). Shift work has attracted the attention of most researchers looking for causal connection relating to cardiovascular health (Åkerstedt et al. 1984; Gottlieb et al. 2006). They suggest that longer work hours and lack of sleep may result in cardiovascular disease, hypertension, and myocardial infarctions (Åkerstedt et al. 1984; Costa 1996; Fung et al. 2011; Luyster et al. 2012).

Another impact of sleep deprivation is on the immune system. Some researchers suggest that sleep restores antioxidants in the liver and heart (Joffe 2006; Luyster et al. 2012). Majde and Krueger (2005) and Mohren et al. (2002) find that chronic sleep deprivation may increase the risk of infection. Others conclude that such studies are inconclusive because it is difficult to isolate sleep as an independent variable (Majde and Krueger 2005).

Overall, the chronic effects resulted from poor sleep quality can be severe and life threatening. Fire departments and decision makers can intervene to provide good sleeping environments to promote good sleeping habits.

## **Treatments**

Different treatments can help to improve sleep quality in the fire service, including modified shift systems, allocating sleeping periods and naps, better alerting equipment, individual sleeping rooms, better beds, and structural enhancements.

### ***Modified Shift Schedule***

Takeyama et al. (2009) studied how a modified shift schedule affects ambulance paramedics. The participants in this study worked normal 24-hour shifts every other day. During this study, researchers modified the 24-hour workday to allocate uninterrupted sleeping periods. If an emergency occurred, a different group would respond. After the 42-day study, researchers concluded that the modified system reduced the occurrences of fatigue as well as adverse effects on physiological functions. Although, they did not examine the modified schedule on firefighters, an earlier study stated that ambulance paramedics experienced a larger workload than firefighters (Takeyama et al. 2001). Dutton et al. (1978) found greater stress levels in paramedics than among firefighters. Since paramedics experience higher workloads and stress, it is possible that researchers could translate these findings to fire departments. The use of a modified shift schedule could be beneficial to firefighters as well and reduce the number of sleep related injuries.

### ***Naps***

Researchers find that the use of naps helps restore performance (Fallis, McMillan, and Edwards 2011; Hirose 2005; Pilcher et al. 2005). A prophylactic nap taken to avoid sleep deprivation can sustain alertness and performance throughout the nightshift (Bonnet 1991; Gillberg 1984; Sakai and Kogi 1986; Sasaki, Kikuchi, and Shindo 1994; as cited in Takeyama, Tomohide, and Itani 2005). A nighttime nap is taken during a nightshift and can prevent disturbance to circadian rhythms (Purnell, Feuer, and Herbison 2002; Saito and Sasaki 1996; Matsumoto and Hanada 1994; Bonnefond et al. 2001; as cited in Takeyama, Tomohide, and Itani 2005). Kogi (2001) identifies

five rules to follow in a nap strategy: encourage napping, promote longer 60 to 90-minute naps, consider the timing so all workers are able to participate within the effective nadir of sleepiness, provide an environment for quality sleep, and plan naps to improve shift conditions (as cited in Takeyama, Tomohide, and Itani 2005).

If firefighters use naps to recover, they must understand that napping is not a substitute for quality sleep (Dinges 1987). Waking up in deep sleep cause lower levels of alertness and sleep inertia. Smith-Coggins et al. (2006) find that a 40-minute nap improves performance, but memory response worsened. Naps should therefore be timed to avoid waking from deeper stages of sleep.

### ***Structural Enhancements***

The recommendations below that were made by the firefighters are additional factors that could affect sleep quality. Factors include individual sleeping rooms and better doors, walls, lighting system, alerting system, temperature control, and better bedding material.

**Individual Sleeping Rooms.** Joffe (2006) described the importance of a napping environment. He suggested that individualized rooms be designed to enhance quality of sleep. Single-occupant sleeping rooms should have low to no lighting and be soundproofed. Although Joffe focuses on physicians, his advice can be applicable toward the fire service. Several firefighters argued for individual rooms. During each visit to a fire department, firefighters provided a tour around their sleep quarters; no two departments had identical room setups.

**Doors.** Some fire stations had solid hardwood doors, some had no doors (e.g., office cubical appearance), and some had quilts that covered the doorway (e.g., shower curtain appearance). Hardwood doors would prevent most noise from entering the room, followed by quilts and open doorways.

**Walls.** The type of walls used in the rooms varied. Some stations had cinderblock walls, some had walls constructed of gypsum board, and others had plaster walls. Cinderblock walls limit most noise from other rooms, but is more expensive than gypsum board. Although, wall color may seem a minor characteristic, some departments offered a color, whereas others used only white. Though color may seem to relate more to appearance than sleep quality, appearance influences mood, which can affect quality of sleep.

**Windows.** Although departments cannot control exterior lights and noises, departments can limit light and noise entering the room. Some stations had triple pane windows, while others had dated, single pane windows. Installing blinds or curtains can reduce light and noise. Yet, some stations failed to cover windows; firefighters took action by covering cracks and openings with paper and tape. In addition, depending on the season, some windows leaked air and caused fluctuations in room temperature.

**Lighting.** Takeyama et al. (2005) identifies the use of sudden alarms and lights as a source stress. Firefighters from several fire stations complained about lighting in rooms and hallways. Some stations had a separate lighting system for alarms, which would turn on in rooms and hallways. The activation of lights during the night can be bothersome especially since most stations use Troffer light fixtures. Lighting systems that use red lights that slowly become brighter to wake firefighters reduces sudden shock to the body. In fact, some firefighters admitted to unscrewing bulbs or tampering with the light switch to reduce sudden shock or non-relevant interruption (e.g., alarm meant for another company or grew within same station). In addition to design, placement is a concern. Several stations place Troffer light fixtures directly above the bed.

**Alerting System.** Alerting systems varied widely. Some systems alert only particular stations. One station had a system that could be programmed to alert individual rooms (each bedroom had a control panel that a firefighter could program according to company, crew, or truck assigned to

respond). Another department used an open system in which every station was forced to hear radio traffic 24/7. Finally, one department required the battalion chief to receive calls from the dispatcher and then personally dispatch individual stations or crews. Most firefighters prefer a system that can be individually programmed in each room.

Alert sounding devices also differed. Most departments operate on an electrical alerting system, in which an electronic tone is broadcast over a loudspeaker. However, some departments use fire alarm bells (similar to the type seen in older schools). These bells are loud; if activated during sleep, they startle firefighters.

**Temperature.** The inability to adjust the temperature was an issue at some departments. Some were restricted to a constant temperature while others were limited to a narrow range. Other departments allowed unrestricted access to adjust temperature. Even in cases where firefighters managed the station's temperature, the structure of the building was not efficient in maintaining a constant temperature in every room. To compensate for temperature imbalance, some firefighters use fans. However, the use of fans can disturb sleep quality for others in the same or nearby rooms. Nevertheless, firefighters preferred unrestricted access to manage the temperature.

**Beds.** Bedding is an important component of sleeping. Usually, firefighters share rooms with firefighters from other shifts. Fire departments cannot provide the resources to give each firefighter a personal room, yet it is important to supply proper mattresses. For example, one firefighter claimed that it was uncomfortable to sleep on a mattress because the mattress had conformed to someone else's body. Providing proper bedding is important to sleep quality.

## CHAPTER V

### IMPLICATIONS

#### **Research Results Overview**

This study expanded sleep research to the fire service by investigating shift schedules. It uncovered unknown anomalies with firefighter sleep patterns. Seventy-three percent of firefighters have poor sleep quality. Significant relationships emerged according to fire department shift schedules. Firefighters on the 24on/48off schedule have better sleep quality compared to the Kelly schedule. Overall, firefighters on the 24on/48off have better sleep quality compared to all shifts, this difference is not statistically significant. The design of a shift system encompasses a plethora of characteristics that can affect sleep quality. Inferences can also be drawn from collected data on the widespread use of second jobs. Sixty-four percent of firefighters in this study have a second job, and is a significant contributing factor toward poor sleep quality. Having second jobs can increase a firefighter's sleep debt and require more time to recover. The effects of children influencing sleep quality is not significant and of an opposite direction depicted from that association reported in the literature.

#### **Interpretation and Impact**

Poor sleep quality can increase the likelihood of becoming sleep deprived. Since the human body requires sleep to restore function, sleep deprivation can affect various systems, which can have a detrimental effect on human health. Treatments should be aimed at the source of the problem.

Although the fire service cannot prevent all emergency interruptions during the night, departments can incorporate structural and non-structural enhancements to increase sleep quality. Decision makers can also create policies that allocate sleeping periods for firefighters.

The results of the study suggest that many firefighters may be unaware of the importance of sleep quality and physiological need. The direct implications on human health in the fire service has yet to be explored, but considering the medical inferences deduced from the literature regarding the medical field (nurses, residents, coal miners) and the transportation industry (highway and aviation), firefighters can be equally susceptible to health complications from poor sleep habits.

### **Limitations of Study**

Since this study is exploratory, research had to be extrapolated from other disciplines to the fire service. The complexity of studying sleep presents challenges and involves many other human inferences external to what was measured in this study. Furthermore, the use of the PSQI instrument presents developmental challenges because the survey is designed for individuals that receive one bout of sleep.

This study is a regional case study. The limitations of a case study is generalizing and transferring results to the entire population of career firefighters. Since a systematic or random stratified sample could not be attained, results are specific to the sample selected in this design. Clearly, it is better to generalize study results to all career firefighters and departments in the US, but a comprehensive list of department shift schedules does not exist, and thus would require significant expense to obtain this information. A larger sample and more variance in firefighter sleep patterns from different fire departments would add greater validity to research in this area of inquiry.

## **Recommendations for Future Research**

In this study, sleep quality was operationalized by a self-reported, subjective survey. Future research should develop or incorporate objective measures aimed at measuring sleep quality. The use of sleep monitoring equipment can provide researchers with valid and reliable data, not subject to self-interoperation.

Future research should also incorporate other variables related to sleep not discussed in this study. Examples include structural elements, a complex look into the effects of additional employments, firefighter workload, and personal medical issues.

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## APPENDICES

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Appendix A: Original PSQI

Subject's Initials \_\_\_\_\_ ID# \_\_\_\_\_ Date \_\_\_\_\_ Time \_\_\_\_\_ AM  
PM

**PITTSBURGH SLEEP QUALITY INDEX**

**INSTRUCTIONS:**

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1. During the past month, what time have you usually gone to bed at night?

BED TIME \_\_\_\_\_

2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?

NUMBER OF MINUTES \_\_\_\_\_

3. During the past month, what time have you usually gotten up in the morning?

GETTING UP TIME \_\_\_\_\_

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)

HOURS OF SLEEP PER NIGHT \_\_\_\_\_

***For each of the remaining questions, check the one best response. Please answer all questions.***

5. During the past month, how often have you had trouble sleeping because you . . .

- a) Cannot get to sleep within 30 minutes

Not during the past month \_\_\_\_\_ Less than once a week \_\_\_\_\_ Once or twice a week \_\_\_\_\_ Three or more times a week \_\_\_\_\_

- b) Wake up in the middle of the night or early morning

Not during the past month \_\_\_\_\_ Less than once a week \_\_\_\_\_ Once or twice a week \_\_\_\_\_ Three or more times a week \_\_\_\_\_

- c) Have to get up to use the bathroom

Not during the past month \_\_\_\_\_ Less than once a week \_\_\_\_\_ Once or twice a week \_\_\_\_\_ Three or more times a week \_\_\_\_\_

d) Cannot breathe comfortably

|                                    |                                |                               |                                     |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
| Not during the<br>past month _____ | Less than<br>once a week _____ | Once or twice<br>a week _____ | Three or more<br>times a week _____ |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|

e) Cough or snore loudly

|                                    |                                |                               |                                     |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
| Not during the<br>past month _____ | Less than<br>once a week _____ | Once or twice<br>a week _____ | Three or more<br>times a week _____ |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|

f) Feel too cold

|                                    |                                |                               |                                     |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
| Not during the<br>past month _____ | Less than<br>once a week _____ | Once or twice<br>a week _____ | Three or more<br>times a week _____ |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|

g) Feel too hot

|                                    |                                |                               |                                     |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
| Not during the<br>past month _____ | Less than<br>once a week _____ | Once or twice<br>a week _____ | Three or more<br>times a week _____ |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|

h) Had bad dreams

|                                    |                                |                               |                                     |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
| Not during the<br>past month _____ | Less than<br>once a week _____ | Once or twice<br>a week _____ | Three or more<br>times a week _____ |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|

i) Have pain

|                                    |                                |                               |                                     |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
| Not during the<br>past month _____ | Less than<br>once a week _____ | Once or twice<br>a week _____ | Three or more<br>times a week _____ |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|

j) Other reason(s), please describe \_\_\_\_\_

---

How often during the past month have you had trouble sleeping because of this?

|                                    |                                |                               |                                     |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
| Not during the<br>past month _____ | Less than<br>once a week _____ | Once or twice<br>a week _____ | Three or more<br>times a week _____ |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|

6. During the past month, how would you rate your sleep quality overall?

Very good \_\_\_\_\_

Fairly good \_\_\_\_\_

Fairly bad \_\_\_\_\_

Very bad \_\_\_\_\_

7. During the past month, how often have you taken medicine to help you sleep (prescribed or "over the counter")?

Not during the past month \_\_\_\_\_ Less than once a week \_\_\_\_\_ Once or twice a week \_\_\_\_\_ Three or more times a week \_\_\_\_\_

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

Not during the past month \_\_\_\_\_ Less than once a week \_\_\_\_\_ Once or twice a week \_\_\_\_\_ Three or more times a week \_\_\_\_\_

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

No problem at all \_\_\_\_\_

Only a very slight problem \_\_\_\_\_

Somewhat of a problem \_\_\_\_\_

A very big problem \_\_\_\_\_

10. Do you have a bed partner or room mate?

No bed partner or room mate \_\_\_\_\_

Partner/room mate in other room \_\_\_\_\_

Partner in same room, but not same bed \_\_\_\_\_

Partner in same bed \_\_\_\_\_

If you have a room mate or bed partner, ask him/her how often in the past month you have had . . .

a) Loud snoring

Not during the past month \_\_\_\_\_ Less than once a week \_\_\_\_\_ Once or twice a week \_\_\_\_\_ Three or more times a week \_\_\_\_\_

b) Long pauses between breaths while asleep

Not during the past month \_\_\_\_\_ Less than once a week \_\_\_\_\_ Once or twice a week \_\_\_\_\_ Three or more times a week \_\_\_\_\_

c) Legs twitching or jerking while you sleep

Not during the past month \_\_\_\_\_ Less than once a week \_\_\_\_\_ Once or twice a week \_\_\_\_\_ Three or more times a week \_\_\_\_\_

d) Episodes of disorientation or confusion during sleep

|                                    |                                |                               |                                     |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
| Not during the<br>past month _____ | Less than<br>once a week _____ | Once or twice<br>a week _____ | Three or more<br>times a week _____ |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|

e) Other restlessness while you sleep; please describe \_\_\_\_\_

---

|                                    |                                |                               |                                     |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|
| Not during the<br>past month _____ | Less than<br>once a week _____ | Once or twice<br>a week _____ | Three or more<br>times a week _____ |
|------------------------------------|--------------------------------|-------------------------------|-------------------------------------|

## Appendix B: Original PSQI Scoring

### Pittsburgh Sleep Quality Index (PSQI)

#### Form Administration Instructions, References, and Scoring

##### Form Administration Instructions

The range of values for questions 5 through 10 are all 0 to 3.

Questions 1 through 9 are not allowed to be missing except as noted below. If these questions are missing then any scores calculated using missing questions are also missing. Thus it is important to make sure that all questions 1 through 9 have been answered.

In the event that a range is given for an answer (for example, '30 to 60' is written as the answer to Q2, minutes to fall asleep), split the difference and enter 45.

##### Reference

Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ: The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research* 28:193-213, 1989.

##### Scores – reportable in publications

On May 20, 2005, on the instruction of Dr. Daniel J. Buysse, the scoring of the PSQI was changed to set the score for Q5J to 0 if either the comment or the value was missing. This may reduce the DISTB score by 1 point and the PSQI Total Score by 1 point.

##### **PSQIDURAT**

##### **DURATION OF SLEEP**

IF  $Q4 \geq 7$ , THEN set value to 0

IF  $Q4 < 7$  and  $\geq 6$ , THEN set value to 1

IF  $Q4 < 6$  and  $\geq 5$ , THEN set value to 2

IF  $Q4 < 5$ , THEN set value to 3

Minimum Score = 0 (better); Maximum Score = 3 (worse)

##### **PSQIDISTB**

##### **SLEEP DISTURBANCE**

IF  $Q5b + Q5c + Q5d + Q5e + Q5f + Q5g + Q5h + Q5i + Q5j$  (IF Q5JCOM is null or Q5j is null, set the value of Q5j to 0) = 0, THEN set value to 0

IF  $Q5b + Q5c + Q5d + Q5e + Q5f + Q5g + Q5h + Q5i + Q5j$  (IF Q5JCOM is null or Q5j is null, set the value of Q5j to 0)  $\geq 1$  and  $\leq 9$ , THEN set value to 1

IF  $Q5b + Q5c + Q5d + Q5e + Q5f + Q5g + Q5h + Q5i + Q5j$  (IF Q5JCOM is null or Q5j is null, set the value of Q5j to 0)  $> 9$  and  $\leq 18$ , THEN set value to 2

IF  $Q5b + Q5c + Q5d + Q5e + Q5f + Q5g + Q5h + Q5i + Q5j$  (IF Q5JCOM is null or Q5j is null, set the value of Q5j to 0)  $> 18$ , THEN set value to 3

Minimum Score = 0 (better); Maximum Score = 3 (worse)

##### **PSQILATEN**

##### **SLEEP LATENCY**

**First, recode Q2 into Q2new thusly:**

IF  $Q2 \geq 0$  and  $\leq 15$ , THEN set value of Q2new to 0

IF  $Q2 > 15$  and  $\leq 30$ , THEN set value of Q2new to 1

IF  $Q2 > 30$  and  $\leq 60$ , THEN set value of Q2new to 2

IF Q2 > 60, THEN set value of Q2new to 3

**Next**

IF Q5a + Q2new = 0, THEN set value to 0

IF Q5a + Q2new  $\geq 1$  and  $\leq 2$ , THEN set value to 1

IF Q5a + Q2new  $\geq 3$  and  $\leq 4$ , THEN set value to 2

IF Q5a + Q2new  $\geq 5$  and  $\leq 6$ , THEN set value to 3

Minimum Score = 0 (better); Maximum Score = 3 (worse)

**PSQIDAYDYS**

**DAY DYSFUNCTION DUE TO SLEEPINESS**

IF Q8 + Q9 = 0, THEN set value to 0

IF Q8 + Q9  $\geq 1$  and  $\leq 2$ , THEN set value to 1

IF Q8 + Q9  $\geq 3$  and  $\leq 4$ , THEN set value to 2

IF Q8 + Q9  $\geq 5$  and  $\leq 6$ , THEN set value to 3

Minimum Score = 0 (better); Maximum Score = 3 (worse)

**PSQIHSE**

**SLEEP EFFICIENCY**

Diffsec = Difference in seconds between day and time of day Q1 and day Q3

Diffhour = Absolute value of diffsec / 3600

newtib = IF diffhour > 24, then newtib = diffhour - 24

IF diffhour  $\leq 24$ , THEN newtib = diffhour

(NOTE, THE ABOVE JUST CALCULATES THE HOURS BETWEEN GNT (Q1) AND GMT (Q3))

tmphse = (Q4 / newtib) \* 100

IF tmphse  $\geq 85$ , THEN set value to 0

IF tmphse < 85 and  $\geq 75$ , THEN set value to 1

IF tmphse < 75 and  $\geq 65$ , THEN set value to 2

IF tmphse < 65, THEN set value to 3

Minimum Score = 0 (better); Maximum Score = 3 (worse)

**PSQISLPQUAL**

**OVERALL SLEEP QUALITY**

Q6

Minimum Score = 0 (better); Maximum Score = 3 (worse)

**PSQIMEDS**

**NEED MEDS TO SLEEP**

Q7

Minimum Score = 0 (better); Maximum Score = 3 (worse)

**PSQI**

**TOTAL**

DURAT + DISTB + LATEN + DAYDYS + HSE + SLPQUAL + MEDS

Minimum Score = 0 (better); Maximum Score = 21 (worse)

Interpretation: TOTAL  $\leq 5$  associated with good sleep quality

TOTAL > 5 associated with poor sleep quality

## Appendix C: Modified PSQI Scoring

### PITTSBURGH SLEEP QUALITY INDEX (PSQI)

#### FORM ADMINISTRATION INSTRUCTIONS, REFERENCES, AND SCORING

##### Form Administration Instructions

The range of values for questions 11 through 15 are all 0 to 3.

Questions 1 through 15 are not allowed to be missing except as noted below. If these questions are missing then any scores calculated using missing questions are also missing. Thus, it is important to make sure that all questions 1 through 15 have been answered.

In the event that a range is giving for an answer (for example, '30 to 60' is written as the answer to Q4, minutes to fall asleep), split the difference and enter 45.

##### Reference

Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ: The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research* 28:193-213, 1989.

##### Scores – Reportable in Publications

On May 20, 2005, on the instruction of Dr. Daniel J. Buysse, the scoring of the PSQI was changed to set the score for Q11X to 0 if either the comment or the value was missing. This may reduce the DISTB score by 1 point and the PSQI Total Score by 1 point.

##### **PSQIDURAT:**

###### **Duration of Sleep**

If  $((Q7 \times 2) + Q2) / 3 \geq 7$ , then set value to 0

If  $((Q7 \times 2) + Q2) / 3 < 7$  and  $\geq 6$ , then set value to 1

If  $((Q7 \times 2) + Q2) / 3 < 6$  and  $\geq 5$ , then set value to 2

If  $((Q7 \times 2) + Q2) / 3 < 5$ , then set value to 3

Minimum Score = 0 (better); Maximum Score = 3 (worse)

##### **PSQIDISTB:**

###### **SLEEP DISTURBANCE**

If  $Q11II + Q11III + Q11IV + Q11V + Q11VI + Q11VII + Q11VIII + Q11IX + Q11X = 0$ , then set value to 0.

If  $Q11II + Q11III + Q11IV + Q11V + Q11VI + Q11VII + Q11VIII + Q11IX + Q11X \geq 1$  and  $\leq 9$ , then set value to 1.

If  $Q11II + Q11III + Q11IV + Q11V + Q11VI + Q11VII + Q11VIII + Q11IX + Q11X > 9$  and  $\leq 18$ , then set value to 2.

If  $Q11II + Q11III + Q11IV + Q11V + Q11VI + Q11VII + Q11VIII + Q11IX + Q11X > 18$ , then set value to 3.

Minimum Score = 0 (better); Maximum Score = 3 (worse)

##### **PSQILATEN:**

###### **SLEEP LATENCY**

**First, recode Q3, Q4, Q5, Q8, Q9, Q10 thusly:**

If  $(((((Q8 \times Q10) + Q9) \times 2) + ((Q3 \times Q5) + Q4)) / 3) \geq 0$  and  $\leq 15$ , then set value of temp-latency to 0.

If  $(((((Q8 \times Q10) + Q9) \times 2) + ((Q3 \times Q5) + Q4)) / 3) > 15$  and  $\leq 30$ , then set value of temp-latency to 1.

If  $(((((Q8 \times Q10) + Q9) \times 2) + ((Q3 \times Q5) + Q4)) / 3) > 30$  and  $\leq 60$ , then set value of temp-latency to 2.

If  $(((((Q8 \times Q10) + Q9) \times 2) + ((Q3 \times Q5) + Q4)) / 3) > 60$ , then set value of temp-latency to 3.

**Next**

IF Q11I + temp-latency = 0, then set value to 0  
IF Q11I + temp-latency  $\geq 1$  and  $\leq 2$ , then set value to 1  
IF Q11I + temp-latency  $\geq 3$  and  $\leq 4$ , then set value to 2  
IF Q11I + temp-latency  $\geq 5$  and  $\leq 6$ , then set value to 3  
Minimum Score = 0 (better); Maximum Score = 3 (worse)

**PSQIDAYDYS: DAY DYSFUNCTION DUE TO SLEEPINESS**

If Q14 + Q15 = 0, then set value to 0  
If Q14 + Q15  $\geq 1$  and  $\leq 2$ , then set value to 1  
If Q14 + Q15  $\geq 3$  and  $\leq 4$ , then set value to 2  
If Q14 + Q15  $\geq 5$  and  $\leq 6$ , then set value to 3  
Minimum Score = 0 (better); Maximum Score = 3 (worse)

**PSQIHSE: SLEEP EFFICIENCY**

If  $(((((Q7 \times 2) + Q2) / 3) / (((Q6 \times 2) + Q1) / 3)) \times 100) \geq 85$ , then set value to 0  
If  $(((((Q7 \times 2) + Q2) / 3) / (((Q6 \times 2) + Q1) / 3)) \times 100) < 85$  and  $\geq 75$ , then set value to 0  
If  $(((((Q7 \times 2) + Q2) / 3) / (((Q6 \times 2) + Q1) / 3)) \times 100) < 75$  and  $\geq 65$ , then set value to 2  
If  $(((((Q7 \times 2) + Q2) / 3) / (((Q6 \times 2) + Q1) / 3)) \times 100) < 65$ , then set value to 0  
Minimum Score = 0 (better); Maximum Score = 3 (worse)

**PSQISLPQUAL: OVERALL SLEEP QUALITY**

Q12  
Minimum Score = 0 (better); Maximum Score = 3 (worse)

**PSQIMEDS: NEED MEDS TO SLEEP**

Q13  
Minimum Score = 0 (better); Maximum Score = 3 (worse)

**PSQI: TOTAL**

DURAT + DISTB + LATEN + DAYDYS + HSE + SLPQUAL + MEDS  
Minimum Score = 0 (better); Maximum Score = 21 (worse)  
Interpretation: TOTAL  $\leq 5$  associated with good sleep quality  
TOTAL  $> 5$  associated with poor sleep quality

## Appendix D: Explanation of Modifications

### Duration of Sleep (PSQIDURAT)

Originally, the PSQI calculated PSQIDURAT from one question, Q4: “During the past month, how many hours of actual sleep did you get a night? (This may be different than the number of hours you spend in bed.)” This question is complicated to answer because the use of this instrument is to assess cumulative sleep quality of firefighters, which requires both an assessment of home and work. Therefore, the original question is divided into two questions representing home and work.

For all three shift schedules (24on/48off, Kelly, 48on/96off), the home:work ratio is 2:1. Firefighters from the selected shift schedules work one out of three days at the fire department. The arrangement of home verses work is a function of the shift schedule. Not all shift schedules have the same recovery schedule because each shift has a different shift cycle and work duration. Since recovery time varies and is a function on the duration of work, Only measuring the sleep quality of firefighters while on shift excludes the recovery that is occurring off shift as a function of the shift schedule. Therefore, to adequately measure and compare sleep quality among fire department shift schedules, measurements of sleep quality from both home and work must be obtained.

The calculation of PSQIDURAT is to multiply home hours by two, add work hours, and then dividing by three for an average number of hours asleep.

$$\text{Original Q4} = (((Q7 \times 2) + Q2) / 3)$$

Once the duration of sleep is calculated using the new method, values of 0, 1, 2, or 3 are assigned using the original scoring method:

PSQIDURAT: Duration of Sleep

If  $((Q7 \times 2) + Q2) / 3 \geq 7$ , then set value to 0

If  $((Q7 \times 2) + Q2) / 3 < 7$  and  $\geq 6$ , then set value to 1

If  $((Q7 \times 2) + Q2) / 3 < 6$  and  $\geq 5$ , then set value to 2

If  $((Q7 \times 2) + Q2) / 3 < 5$ , then set value to 3

Minimum Score = 0 (better); Maximum Score = 3 (worse)

### Sleep Latency (PSQILATEN)

PSQILATEN is calculated in a two-step process. The first step calculates sleep latency, which required modification. The second step, which does not require modification, adds values from the first step with Q11I for an overall PSQILATEN score shown below.

Originally, the first step calculates sleep latency (i.e., the time from attempting to fall asleep to actual sleep) by asking one question, Q2: “During the past month, how long (in minutes) has it usually taken you to fall asleep each night?” Again, this question tailors to individuals with one sleep bout. Firefighters are likely to have several bouts in one night at the fire department due to responding to emergencies. Therefore, three questions are need to answer the first step: Q4 & Q9: how long it takes to fall asleep the first attempt; Q5 & Q10, if sleep was interrupted, how long did it take to fall back asleep; Q3 & Q8, the average number of interruption while sleeping each night. Questions 4, 5, and 3 represented sleep latency at work, while questions 9, 10, and 8 represented home.

To calculate sleep latency for home or work requires adding the initial sleep latency to the after-interruption sleep latencies.

$$\text{Home latency} = ((Q8 \times Q10) + Q9)$$

$$\text{Work Latency} = ((Q3 \times Q5) + Q4)$$

To calculate an overall average sleep latency for both home and work requires multiplying home twice, adding work, and dividing by three, since the home:work ration is 2:1.

$$\text{Original Q2} = (((((Q8 \times Q10) + Q9) \times 2) + ((Q3 \times Q5) + Q4)) / 3)$$

Once the average sleep latency is calculated using the new method, values of 0, 1, 2, or 3 are assigned using the original scoring method. The second step, which does not require modification adds the value from step one with Q11I. Therefore, PSQILATEN is calculated:

**PSQILATEN: SLEEP LATENCY**

**First Step**, recode Q3, Q4, Q5, Q8, Q9, Q10 thusly:

If ((((((Q8 X Q10) + Q9) X 2) + ((Q3 X Q5) + Q4)) / 3)  $\geq$  0 and  $\leq$  15, then set value of temp-latency to 0.

If ((((((Q8 X Q10) + Q9) X 2) + ((Q3 X Q5) + Q4)) / 3)  $>$  15 and  $\leq$  30, then set value of temp-latency to 1.

If ((((((Q8 X Q10) + Q9) X 2) + ((Q3 X Q5) + Q4)) / 3)  $>$  30 and  $\leq$  60, then set value of temp-latency to 2.

If ((((((Q8 X Q10) + Q9) X 2) + ((Q3 X Q5) + Q4)) / 3)  $>$  60, then set value of temp-latency to 3.

**Second Step**, add step one (temp-latency) with Q11I thusly:

IF Q11I + temp-latency = 0, then set value to 0

IF Q11I + temp-latency  $\geq$  1 and  $\leq$  2, then set value to 1

IF Q11I + temp-latency  $\geq$  3 and  $\leq$  4, then set value to 2

IF Q11I + temp-latency  $\geq$  5 and  $\leq$  6, then set value to 3

Minimum Score = 0 (better); Maximum Score = 3 (worse)

**Sleep Efficiency (PSQIHSE)**

Sleep efficiency is the percentage of actual sleep compared to total time in bed. A firefighter who sleeps significantly fewer hours compared to the time they spent in bed will have a lower percentage, thereby reflecting poorer sleep efficiency.

Originally, the PSQI scoring of sleep efficiency is a three-step process. The first step determines the total time in bed (sleeping and attempting to sleep) by calculating the difference of Q1: “During the past, what time have you usually gone to bed at night?” and Q3: “During the past month, what time have you usually gotten up in the morning?” The second step divides Q4: “During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)” with the total time in bed (first step). This division produces a decimal number for sleep efficiency. To obtain a percentage, the third step is to multiply the decimal by 100.

Calculating the PSQIHSE using the original method (the difference of the time a firefighter went to bed to when they awoke) is inappropriate because firefighters may receive emergency calls during the night. This would not accurately reflect the actual number total hours in bed. Therefore, the Modified PSQI directly asks the total time in bed (Q1 & Q6) and number of actual sleep hours (Q2 & Q7), for both work and home. Participants received careful direction on how to calculate hours for Q1, Q6, Q2, and Q7.

To calculate an overall sleep efficiency for both home and work requires multiplying home twice, adding work, and then dividing by three, since the home:work ratio is 2:1. Multiplying by 100 yields percentages.

Once sleep efficiency is calculated using the new method, values of 0, 1, 2, or 3 are assigned using the original scoring method:

**PSQIHSE: SLEEP EFFICIENCY**

If ((((((Q7 X 2) + Q2) / 3) / (((Q6 X 2) + Q1) / 3)) X 100)  $\geq$  85, then set value to 0

If ((((((Q7 X 2) + Q2) / 3) / (((Q6 X 2) + Q1) / 3)) X 100)  $<$  85 and  $\geq$  75, then set value to 0

If ((((((Q7 X 2) + Q2) / 3) / (((Q6 X 2) + Q1) / 3)) X 100)  $<$  75 and  $\geq$  65, then set value to 2

If ((((((Q7 X 2) + Q2) / 3) / (((Q6 X 2) + Q1) / 3)) X 100)  $<$  65, then set value to 0

Minimum Score = 0 (better); Maximum Score = 3 (worse)

**Other Modifications to PSQI (minor)**

Originally, Q5b-j included the following: “During the past month, how often have you had trouble sleeping because you...”

Q5 (b) “Wake up in the middle of the night or early morning”

Q5 (c) “Have to get up to use the bathroom”

Q5 (d) “Cannot breathe comfortably”

- Q5 (e) "Cough or snore loudly"
- Q5 (f) "Feel to cold"
- Q5 (g) "Feel to hot"
- Q5 (h) "Had bad dreams"
- Q5 (i) "Have pain"
- Q5 (j) "Other reason(s), please describe"

The modified PSQI Q11III-X includes the following: "During the past month, how many days in an average week have you had trouble sleeping because you:"

- Q11 (II) "Have to get up to use the bathroom?"
- Q11 (III) "Cannot breathe comfortably?"
- Q11 (IV) "Hear loud noises?"
- Q11 (V) "Feel to cold or too hot?"
- Q11 (VI) "Have bad dreams?"
- Q11 (VII) "Have pain?"
- Q11 (VIII) "Are restless due to excitement?"
- Q11 (IX) "Are restless due to stress"?
- Q11 (X) "Other reason (please describe):"

A comparison of the original and modified questions highlights four changes. First, deletion of 5b was justified because the fire service is naturally subject to the possibility of night interruptions. This question would theoretical influence sleep quality on all participants. To reduce the effects of spurious relationship, this question was deleted from the PSQI calculation. Although not directly calculated in the dependent variable (PSQI), original Q5b was added to the survey (Q3 & Q8) stating, "How many interruptions did you experience while sleeping each night/day? (An example of an interruption would be responding to a call.)" Incorporating this question into the survey represents an independent variable.

Another modification to questions 5b-j was to combine 5f and 5g into one question. The relevance in the difference of hot versus cold is not captured in the meaning of the question. There is no theoretical reason for asserting that cold affects sleep differently than hot. The impact is the same: sleep disturbance. In addition, dividing hot and cold into two questions treats them as if they had different effects on sleep.

Since the PSQI is calculated using on a fixed set of paramants, by deleting Q5b and combining 5f and g, a PSQI score cannot be calculated. This created the need develop two replacement questions: Q11 VIII "Are restless due to excitement?" and Q11 IX "Are restless due to stress?" These two questions were selected based on advice from the focus group. The group noted that firefighters sometimes have difficulty falling asleep or returning to sleep because of excitement or stress. Excitement can be the result of coming back from an emergency wide awake and full of energy or adrenaline. Stress can be the result of anticipating a call or the result of a sudden emergency call.

The modified survey was administered to a fire department as a field pretest to discover errors and obtain feedback on survey design and construction. The group of firefighters offered several valuable comments on readability. Therefore, minor changes to the survey were performed to improve readability and consistence in the use of verb tense. The modified survey allowed easy interpretation of the questions by participants and more reliable interpretations of responses needed for interpreting components of the PSQI.

## Appendix E: Thesis Questionnaire

### NATIONAL SURVEY OF FIREFIGHTER SLEEP QUALITY IN CAREER FIRE DEPARTMENTS

This survey includes 24 questions that inquire into the quality of sleep that firefighters in career fire departments obtain on average during the past month. In addition, 11 questions are included about you that will help us interpret the sleep survey responses.

To be eligible to complete this survey, each respondent must satisfy the following criteria:

1. Work full time as a paid professional (career) firefighter
2. Work on a particular shift schedule continuously for at least three months
3. Work in that shift schedule currently

#### Sleep Quality Questions

The following questions relate to your usual sleep habits during the past month **only**. Your answers should indicate the most accurate reply for **most** of days and nights in the past month. Please answer **all** questions.

#### *Sleep At Work*

1. What is the total time you spent in bed each night/day? (This includes only the amount of time actually sleeping and time spent trying to go to sleep.)  
\_\_\_\_\_Hours
2. How many hours of actual sleep did you get each night/day?  
\_\_\_\_\_Hours
3. How many interruptions did you experience while sleeping each night/day? (An example of an interruption would be responding to a call.)  
\_\_\_\_\_ Interruptions
4. How long has it usually taken you to fall asleep, on average?  
\_\_\_\_\_ Minutes
5. If your sleep was interrupted, how long did it take, on average, for you to fall asleep once back in bed?  
\_\_\_\_\_ Minutes

#### *Sleep At Home*

6. What is the total time you spent in bed each night/day? (This includes only the amount of time actually sleeping and time spent trying to go to sleep.)  
\_\_\_\_\_Hours
7. How many hours of actual sleep did you get each night/day?  
\_\_\_\_\_Hours
8. How many interruptions did you experience while sleeping each night/day?  
\_\_\_\_\_ Interruptions
9. How long did it take for you to fall asleep, on average?  
\_\_\_\_\_Minutes
10. If your sleep was interrupted, how long did it take, on average, for you to fall asleep once back in bed?  
\_\_\_\_\_Minutes

***For each of the remaining questions, check the one best response.***

11. During the **past month**, how many days in an average week have you had trouble sleeping because you:

I. Cannot get to sleep within 30 minutes?

- A. No days in any week during the past month
- B. Less than one day a week on average
- C. One or two days a week on average
- D. Three or more days a week on average

II. Have to get up to use the bathroom?

- A. No days in any week during the past month
- B. Less than one day a week on average
- C. One or two days a week on average
- D. Three or more days a week on average

III. Cannot breathe comfortably?

- A. No days in any week during the past month
- B. Less than one day a week on average
- C. One or two days a week on average
- D. Three or more days a week on average

IV. Hear loud noises?

- A. No days in any week during the past month
- B. Less than one day a week on average
- C. One or two days a week on average
- D. Three or more days a week on average

V. Feel too cold or too hot?

- A. No days in any week during the past month
- B. Less than one day a week on average
- C. One or two days a week on average
- D. Three or more days a week on average

VI. Have bad dreams?

- A. No days in any week during the past month
- B. Less than one day a week on average
- C. One or two days a week on average
- D. Three or more days a week on average

VII. Have pain?

- A. No days in any week during the past month
- B. Less than one day a week on average
- C. One or two days a week on average
- D. Three or more days a week on average

VIII. Are restless due to excitement?

- A. No days in any week during the past month
- B. Less than one day a week on average
- C. One or two days a week on average
- D. Three or more days a week on average

IX. Are restless due to stress?

- A. No days in any week during the past month
- B. Less than one day a week on average
- C. One or two days a week on average
- D. Three or more days a week on average

X. Other reason (please describe): \_\_\_\_\_

How often during the past month have you had trouble sleeping because of this reason?

- A. No days in any week during the past month
- B. Less than one day a week on average
- C. One or two days a week on average
- D. Three or more days a week on average

12. During the past month, how would you rate your sleep quality overall?

- A. Very good
- B. Fairly good
- C. Fairly bad
- D. Very bad

13. During the past month, how many days in an average week have you taken medicine (either prescribed or over-the-counter) to help you sleep?

- A. No days in any week during the past month
- B. Less than one day a week on average
- C. One or two days a week on average
- D. Three or more days a week on average

14. During the past month, how many days in an average week have you had trouble staying awake while driving, eating meals, or engaging in social activity?
- A. No days in any week during the past month
  - B. Less than one day a week on average
  - C. One or two days a week on average
  - D. Three or more days a week on average
15. During the past month, how much of a problem has it been for you to keep up enough energy to get things done?
- A. No problem at all
  - B. Only a very slight problem
  - C. Somewhat of a problem
  - D. A very big problem
16. Do you have a bed partner or roommate most days?
- A. No bed partner or roommate
  - B. Partner/roommate in another room
  - C. Partner in same room, but not same bed
  - D. Partner in same bed

**Please continue to the next page**

**Questions about You**

1. What is your gender?  
 Male       Female
2. In what year were you born?  
\_\_\_\_\_
3. How many years have you worked in the fire service?  
\_\_\_\_\_ Years
4. What is your current marital status?  
 Married       Single
5. Do you have children living with you now?  
 Yes       No
6. Do you work a second job?  
 Yes       No  
If yes, how many hours (on average) do you work per week?  
\_\_\_\_\_ Hours per week
7. How many years have you been working on your current shift schedule? If less than a year, enter "0" for the number of years and state the number of months.  
\_\_\_\_\_ Years      \_\_\_\_\_ Months
8. On average, how many hours per shift are you free to sleep if you wanted to?  
\_\_\_\_\_ Hours
9. Do you suffer from a sleep-related disorder such as apnea?  
 Yes       No  
If yes, do you use any prescribed equipment at work?  
 Yes       No       Not prescribed any equipment
10. What types of calls does your station respond to?  
A. Fire  
B. EMS  
C. Both fire and ems
11. What is your current rank in the department?  
A. Firefighter  
B. Lieutenant  
C. Captain  
D. Battalion chief  
E. Other (please identify): \_\_\_\_\_

## Appendix F: IRB and Consent Form

### Oklahoma State University Institutional Review Board

Date: Thursday, February 06, 2014

IRB Application No AS1410

Proposal Title: Firefighter Sleep Quality

Reviewed and  
Processed as: Exempt

Status Recommended by Reviewer(s): Approved

Protocol Expires: 2/5/2017

Principal  
Investigator(s):

Joel M Billings  
5724 Dwight Ave  
Waterford, MI 48327

William J Focht  
228 Murray  
Stillwater, OK 74078

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The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

The reviewer(s) had these comments:  
Approval letters from each Fire Department must be submitted to the IRB prior to each site visit.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnnett Watkins in 219 Cordell North(phone: 405-744-5700, dawnnett.watkins@okstate.edu).

Sincerely,



Shelia Kennison, Chair  
Institutional Review Board

**INFORMED CONSENT  
OKLAHOMA STATE UNIVERSITY**



**Title:** Firefighter Sleep Quality

**Investigator(s):** Joel M. Billings –Department of Political Science, Graduate Student  
Dr. Will Focht – Department of Political Science, Associate Professor

**Purpose:** The purpose of the research study is to investigate firefighter sleep quality.

**What to Expect:** You will complete one survey consisting of 21 questions that inquire into the quality of sleep that firefighters in career fire departments obtain on average. In addition, 11 questions are included about firefighters that will help us interpret sleep survey responses. It should take about ten minutes to complete the questionnaire.

**Risks:** There are no risks associated with this project that are greater than those ordinarily encountered in daily life.

**Benefits of Participation:** There are no expected benefits to the participant from participating in this study.

**Compensation:** There will be no compensation for your participation in this study.

**Confidentiality:** The records of this study will be kept private. Any results will discuss group findings and not include information that can be used to identify you. In addition, no identifiable information will be collected that would link you to the survey. Research records will be stored on a password protected computer in a locked office and only researchers and individuals responsible for research oversight will have access to the records. Data will be destroyed three years after the study has been completed.

**Contacts:** You may contact the researcher at the following address and phone number, should you desire to discuss your participation in the study and/or request information about the results of the study: Dr. Will Focht, will.focht@okstate.edu 228 Murray Hall, Department of Political Science Oklahoma State University, Stillwater, OK 74078, 405-744-1097. If you have questions about your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu.

**Participant Rights:** I understand that my participation is voluntary, that there is no penalty for refusal to participate, and that I am free to withdraw my consent and participation in this project at any time, without penalty.

**Consent Documentation:**

I have been fully informed about the procedures listed here. I am aware of what I will be asked to do and of the benefits of my participation. I also understand the following statements:

I affirm that I am 18 years of age or older. I have read and fully understand this consent form. I sign it freely and voluntarily. A copy of this form will be given to me. I hereby give permission for my participation in this study.

\_\_\_\_\_  
Signature of Participant

\_\_\_\_\_  
Date

I certify that I have personally explained this document before requesting that the participant sign it.

\_\_\_\_\_  
Signature of Researcher

\_\_\_\_\_  
Date

VITA

Joel Matthew Billings

Candidate for the Degree of

Master of Science

Thesis: THE EFFECTS OF FIRE DEPARTMENT SHIFT SCHEDULES ON SLEEP  
QUALITY

Major Field: Fire and Emergency Management Administration

Biographical:

Education:

Completed the requirements for the Master of Science in Fire and Emergency  
Management Administration at Oklahoma State University, Stillwater,  
Oklahoma in July, 2014.

Completed the requirements for the Bachelor of Science in Fire Science at Lake  
Superior State University, Sault Sainte Marie, Michigan in 2011.

Experience:

Graduate Teaching/Research Assistant (2012-2014)

Graduate and Professional Student Government Association Departmental  
Representative.

Volunteer Firefighter and Emergency Medical Technician-Basic (2008-  
2014)

Professional Memberships:

International Association of Emergency Managers–Student Chapter  
Treasure