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The Health Effects of Rotating Shiftwork in the Oil Sector

A dissertation submitted in partial satisfaction of the requirements for the degree

Doctor of Philosophy in Environmental Health Sciences

by

Katherine Alice McNamara

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ABSTRACT OF THE DISSERTATION

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Professor Wendie A. Robbins, Chair

Despite the improvements in safety since the advent of Process Safety Management regulations in 1992, human factors still play a large role in catastrophic accidents. Worker fatigue is a significant risk in the petroleum industry, where rotating shiftwork is relied upon to staff round the clock production. Using reports of work organization factors that contributed to fatigue from the listening sessions hosted by the California Interagency Taskforce on Refinery Safety in 2013, we developed a survey for rotating shiftworkers in the refining industry. We administered the survey among hourly shift workers in the oil sector represented by the United Steelworkers union. Collecting self-reported data on sleep, mental health, job stress, quality of life, and certain health outcomes associated with shift work, we explored associations between these outcomes and participants' work history, current work schedules and staffing allocations. Our

findings revealed that the 12-hour shift, initially intended as a compressed work week, currently provides limited recovery when rest breaks are interrupted with one or more overtime shifts per week. Sleep durations were also shortest on the 12-hour shift, and averaged more than an hour shorter than previous research on 8-hour rotating shift workers. Recent work schedules reported tended to comply with the American Petroleum Institute's (API) recommended hours of service guidelines, but despite this, more than one half of our study participants reported having trouble staying awake during engaged activities (24% monthly and 27% weekly or more), and sleep disorder prevalence approached 80% in the study population. Those who exceeded the API hours of service guidelines reported greater job demands, shorter sleep durations, and more frequent drowsiness, indicating that they were at greatest risk for fatigue. Mandatory overtime was a stressor, associated with higher job stress, lower staffing coverage, and anxiety (but not additional hours worked). The impacts of mandatory overtime and on-call work were described further in the quality of life data, where participants described the difficulty of keeping personal commitments, resulting in family conflict, social isolation and neglected personal interests; and they expressed a desire for greater control over their time.

The dissertation of Katherine Alice McNamara is approved.

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2018

I dedicate this to my husband Jamie, who encouraged me to undertake this effort and was my constant sounding board throughout it.

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List of Acronyms

ANOVA	Analysis of variance
API	American Petroleum Institute
BLS	Bureau of Labor Statistics
BMI	Body mass index
BP	British Petroleum
Cal-OSHA	California Division of Occupational Safety and Health
DIMS	Disorder of initiating and maintaining sleep
DOES	Disorder of excessive somnolence (narcolepsy)
GAD	General Anxiety Disorder
GERD	Gastroesophageal reflux disease
GII	Gastrointestinal illness
HOS	Hours of Service
IBS	Irritable bowel syndrome
ICSD	International Classification of Sleep Disorders
IIPP	Injury and Illness Prevention Program
LOSH	Labor Occupational Safety and Health Program
MOOC	Management of organizational change
MOT	Mandatory overtime
MSD	Mid sleep on day shift
MSF	Mid sleep on free days
MSN	Mid sleep on night shift
NHANES	National Health and Nutrition Examination Survey

NIOSH	National Institute for Occupational Safety and Health
NTSB	National Transportation Safety Board
OR	Odds ratio
OSHA	Occupational Safety and Health Administration
PHQ	Physicians Health Questionnaire
PSM	Process Safety Management
PSQI	Pittsburgh Sleep Quality Index
QWLQ	Quality of Work Life Questionnaire
R12	Rotating 12-hour shift
RP	Recommended Practice
SCERC	Southern California Education and Research Center
SJL	Social jet lag
SWSD	Shift work sleep disorder
TX	Texas
UCLA	University of California, Los Angeles
USCSB	United States Chemical Safety Board
USW	United Steelworkers
WLC	Work life conflict

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CHAPTER 1

Introduction

Seven years after the accident in Texas City, TX that prompted the development of fatigue risk management guidelines by the American Petroleum Institute[1], an explosion at the Chevron Richmond refinery in California created a plume of smoke that resulted in 15,000 residents seeking medical attention[2]. Subsequent investigations resulted in the formulation of a state-wide Interagency Taskforce on Refinery Safety that produced strengthened Process Safety Management (PSM) and Risk Management Program regulations for California refineries. Although worker fatigue was not identified as a causal factor in the Chevron Richmond incident, listening sessions held by the Interagency Taskforce yielded discussions of the unique work organization factors that interacted with process safety in this high hazard industry[3]. The new PSM for Petroleum Refineries regulations developed by the Taskforce (made effective October 2017) require, for the first time, analysis and management of human factors, naming shift work, employee fatigue, overtime and staffing reductions as potential hazards that must be mitigated as part of a refinery's comprehensive PSM program[4].

In this study, we examined work organization factors in oil refining that could contribute to worker fatigue and impairment, including shift length, schedule configurations, overtime rates, staffing levels, and job demands. We explored associations between these factors and different stressors and health outcomes among the workforce. We also examined characteristics of work life conflict associated with the rotating shift schedules. Surveying voluntary recruits from the oil sector membership of the United Steelworkers union, we collected self-reported data using a 60-item survey that contained questions on health, sleep and mental health outcomes associated with shift work.

Chapter 2 presented sleep deficiencies among the workforce, and explored their associations with schedule characteristics and health outcomes associated with shiftwork. We found that the study population were short duration sleepers; this was aggravated by early start times which both limited available hours for sleeping and appeared to impact sleep quality. There was a high prevalence of sleep disorders in the study population, with individual sleep quality domains that were comparable with severe clinical sleep disorders[5]. Sleep durations among our study participants working 12-hour shifts were an hour or more shorter than averages reported in a meta-analysis of 36 shiftwork studies that only looked at 8-hour shifts[6]. Social jet lag, the difference between mid sleep time on days worked verses days off, was most pronounced during night shift sets. Mid sleep times on days off were approximately two hours earlier than those found in the general population[7], indicating that individual chronotypes may have adapted to the early start times, likely making rotations to the night shift more difficult.

In Chapter 3, we examined the effects of overtime (including mandatory overtime) and staffing levels on worker well being, looking at overtime as a stressor and examining how schedule configurations predicted fatigue. We found that overtime rates were highest for those working 12-hour shifts, likely because the compressed schedule enabled the addition of one or more extra shifts each week. Parenting status was not associated with increased overtime rates, but financial need was. The addition of mandatory overtime to a schedule that routinely requires time away from home added an unpredictability that was reflected in low job satisfaction and poor mental health scores. Those who reported that most of their overtime was mandatory also reported lower scores for management support and job enjoyment. Low staffing levels were associated with high job stress and high mandatory overtime, and staffing availability was lower for safety program functions than for covering vacancies. Thirty percent of the study population

did not meet the hours of service guidelines for fatigue risk management. An increasing number of schedule violations was associated with shorter sleep durations, greater physical exertion and a faster pace of work, all risk factors for fatigue.

In Chapter 4, we examined the dimensions of work life conflict among participants using text analysis from open ended questions. Work life conflict was reported by the majority of the study population, and was primarily characterized as time-based strain[8,9]. Family conflict had the highest prevalence. In addition to nights and weekends away from home, much of the family conflict involved unmet demands of parenting and an unavailability for children's activities. Social isolation and the deterioration of friendships due to work schedules were the second most common complaint, followed by relationship strain. Many cited the structural constraints of their nominal work schedules (long days and routine weekend and holiday work). But the additional impacts of unscheduled extra work (mandatory overtime and on-call duty) were described in detail by participants; where an inability to commit or follow through on social and family obligations resulted in lasting impacts on family and social relationships. Many respondents expressed the desire to maintain their original schedule and to have more control over working hours.

The advent of the extended shift/compressed work week in the petroleum industry coincided with lean staffing business models[10,11], resulting in increasing overtime rates and limiting available recovery time due to mandatory overtime and routine on-call/standby assignments. We found that the 12-hour shift was implicated in poor sleep outcomes, and was identified as a source of fatigue and work life conflict by participants. Mandatory overtime was an additional stressor, exacerbating the existing work life conflict, and correlating with poor mental health outcomes and job stress. Understaffing appeared to be a driver for the mandatory

overtime. About a third of the study population did not meet the hours of service guidelines, which have been criticized as being unprotective. Overall, the potential for fatigue was high in the study population, and those exceeding the hours of service guidelines were at greatest risk. Future research should review the 12-hour shift from a perspective of safety and health, evaluate associations between shift start times and fatigue, and establish health based guidelines for hours of service that consider the existing demands of hours currently worked in the industry.

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CHAPTER 2

Shiftwork organization and its implications for sleep, health and safety

ABSTRACT

Rotating shift work is common in high hazard industries, despite documented associations with sleep deprivation and impairment, and the prevalence of certain morbidities that are uniquely associated with shiftwork. Over the last few decades, work intensification and increasing overtime rates have been broadly documented in the oil industry, where rotating and extended shift schedules are used to staff safety-sensitive operator positions. Since the trend towards extended (12-hour) shifts and reports of increasing overtime, research on the impacts of these work schedules on sleep and health has been limited for this work force. We examined sleep duration and quality among rotating shift workers in the oil industry, and explored associations between work organization, sleep, and health outcomes. We administered a survey on work schedules, sleep, and health outcomes to oil sector members of the United Steelworkers union. Our findings reveal a high prevalence of sleep deficit and disorders; these were associated with health outcomes previously found to be common in shift workers. Early rise and start times were associated with shorter sleep duration and poorer sleep quality. The loss of a swing shift that has previously been shown to provide recovery suggests that the 12-hour shift may limit recovery by reducing available hours for sleep, and also hours for exercise and leisure activity.

INTRODUCTION

Hourly refinery workers commonly work rotating shifts to accommodate a 24/7 production schedule. Since the 1990s, the majority of refineries have staffed their process operations with two 12-hour shifts; these rotate (change from night to day shift) every 2 to 4

days. Prior to this, three rotating 8-hour shifts were common, with slower rotation frequency. Although rapid rotations have been found to be less disruptive in some studies [12,13], there is consensus that rapid rotation adversely affects sleep quality and quantity [6,14]. Actual work schedules have been observed to vary from nominal ones, with frequent overtime shifts limiting the frequency and duration of recovery periods [11,15]. Long hours are associated with short sleep duration [16,17,18]. Comparisons of 8-and 12-hour shifts have been examined most closely in health care, with shorter sleep duration, increased fatigue, decreased performance, and increased errors and injuries reported on the 12-hour shift, particularly in hours 9 to 11 of the shift [19,20]. For industrial workers, short sleep duration, sleep disruptions, and decreased alertness have been documented on extended shift schedules [21,22], although some studies have shown few differences [23]. A comparison of different shift lengths and rotation schedules in transportation found that the 12-hour shift consistently produced the highest fatigue scores [24].

Shiftworkers experience disturbed sleep and increased sleepiness [25–27]. Their rotating schedules require them to work at times that conflict with social and biological circadian rhythms, resulting in a chronic circadian disharmony. The concept of social jet lag (SJL) has been used to illustrate desynchrony among shift workers [7]. SJL is defined as the discrepancy between mid-sleep hours on work days vs. free days (social and biological time).

Shift work may increase risk of fatigue by reducing sleep duration, particularly following night shifts, which are susceptible to noise and light disruptions. Shiftwork sleep disorder (SWSD), clinically defined as the presence of primary insomnia and/or excessive sleepiness in relation to work schedules [28] is associated with certain unique morbidities: gastrointestinal disorders, depression and anxiety, sleep disorders, and fatigue [17,29].

Large individual differences have been observed among shift workers in adapting to work schedules. An ability to adapt to shift work without adverse consequences has been described as shiftwork tolerance [30,31]. Evidence indicates that adaptive abilities range from different coping mechanisms to chronotype flexibility [32] and can also be influenced by externalities such as job stress and social support [33].

Older workers tend to have shorter and more disrupted sleep [34], and circadian rhythm has been shown to advance with age [35]. Aging can also result in slower adjustment to circadian rhythm disruption from shift rotations [36,37], and shorter sleep after night shifts [17,38]. Insomnia from shift work has been shown to increase with age [37]. Some [39,40], but not all [15] studies have demonstrated that aging decreases tolerance to shift work.

For this high-risk population in a safety sensitive industry, the impact of the rotating 12-hour shift concurrent with increasing work intensity has not been well studied. Despite the fact that fatigue has been identified as a root cause in several catastrophic accidents, the fatigue risk management guidelines developed in 2010 for the oil industry are implemented inconsistently (API). In addition to worker fatigue and impairment, acute and chronic health conditions associated with shift work have a high prevalence in this population. As the workforce ages, a better understanding of work organization factors that impair sleep and impact overall health is warranted. Schedule management that is more protective of fatigue risk has the potential to increase job performance, improve process safety and impact long term health.

Our study evaluated recent work schedules among hourly refinery workers and explored associations between work hours and sleep quality and duration. We collected self-reported data, recruiting participants through a roster of oil sector members of the United Steelworkers (USW) union, the largest labor union in the national oil sector. This data was collected as part of

a larger survey administered to evaluate the effects of extended, rotating shifts on employee health and quality of life. For this analysis, we focused on survey data pertaining to work organization and sleep. We compared sleep quality and quantity in the study population to other shift work studies. We examined associations between shift lengths and start times and sleep. Finally, we assessed the prevalence of shiftwork sleep disorder and associated morbidities in the study population.

METHODS

A self-reported health questionnaire was administered to voluntary participants recruited from the oil sector membership of USW's Districts 12 (West Coast states) and 13 (Gulf Coast states) to assess the effects of the rotating shift work schedule. The study design was developed collaboratively between USW and UCLA. The survey tool was developed and pilot tested among two focus groups of refinery employee members of USW Local 675 in Carson, CA. The focus groups provided input on industry specific terminology, work schedule configurations, and schedule management approaches. The study received approval from the UCLA Institutional Review Board.

Recruitment for the study began in September 2014 and the survey was distributed beginning in December 2014. Active or former USW members with current or previous experience in the oil sector (and 25 years of age or older) were invited to participate in the study. UCLA recruited participants by sending an informational flyer about the study to a mailing list of over 10 thousand oil sector members, of which approximately two thirds may have worked rotating shifts. From the initial recruitment mailing about the study, we received 652 requests for surveys, 418 surveys were returned to the research team and 384 of these were complete. Participation in the study was entirely voluntary, and participant identities were not shared with

the USW. Two incentives of $1,000 each were awarded to one participant from each District, randomly selected using a sweepstakes drawing.

Survey

The 60-question survey included questions on the domains of work history, job stress, staffing, physical and mental health, and sleep quality. Data were collected on hours of work in the previous four weeks, including shift type (day, swing or night) and overtime quantity (as additional shifts). During week 1, participants also logged hours slept and hours worked for one week using military time to track schedules through each 24-hour period. The three weeks prior, shifts worked and days off were logged as either day, night, evening/swing, or off. The four week string of days, nights, and off were used to examine schedule patterns and tally hours worked for the 4 week period.

Chronotype was estimated using the mid sleep time on free days (MSF) recorded during week 1, which has been found to be an accurate assessment of chronotype when compared with clinical measurements[7]. MSF was calculated from the mid-point between sleep onset and waking on free days (days off). A method to correct for oversleeping on days off (sleep debt compensation) suggested by Roennenberg et al, based on a standard 5 day work week with 2 free days, was not able to be applied due to the irregularity of individual schedules[41].

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), a 19-item questionnaire that assesses subjective sleep quality over the past month[5]. The PSQI consists of seven component scores that are equally weighted, and when added together create a global PSQI score ranging from 0 to 21 (higher scores representing worse sleep quality). A cut off of five or greater has been shown to be indicative of a clinical sleep disorder. The seven domains range from 0-3 (three being worse) and include subjective sleep quality, sleep latency, sleep

duration, habitual sleep efficiency, sleep disturbances, use of sleeping medications, and daytime dysfunction. Our PSQI scores had a Cronbach's alpha of 0.72.

Health outcomes were measured borrowing questions from the National Health and Nutrition Examination Survey (NHANES). Domains included were metabolic disorders associated with shiftwork (obesity, hypertension, diabetes, cardiovascular disease), and gastrointestinal (GI) discomfort (a self-report of heartburn, acid reflux, indigestion, constipation or diarrhea); or GI illness (a diagnosed condition of peptic ulcer, colitis, Crohn's, irritable bowel syndrome (IBS), or gastroesophageal reflux disorder (GERD)). NHANES questions were also used to collect information on general health behaviors (smoking, alcohol, caffeine consumption, exercise, leisure activity).

A truncated mental health questionnaire was assembled using five questions from the Patient Health Questionnaire (PHQ) 9 [(24)] for depression and three from the Generalized Anxiety Disorder (GAD) 7-item scale [(25)] for anxiety. Questions that would trigger mandatory reporting (i.e. suicide ideation) and those that overlapped between the two questionnaires were removed for the purpose of brevity. A 4-point Likert scale rating was assigned to each symptom based on frequency over the last month: 1=not at all, 2=several days, 3=more than half the days, and 4=nearly every day. A standardized score for depression and another for anxiety were created from the individual PHQ and GAD questions, respectively. These two subscales ranged from 1 to 4, anxiety had a Cronbach's alpha of 0.69, and depression 0.86. An overall mental health score was also created by summing all rankings for a linear variable that ranged from 8 to 32. Higher scores indicated a higher frequency of adverse symptoms (i.e. poorer mental health).

Statistical Analysis

Aspects of the work schedule were assessed to identify associations with sleep outcomes. Descriptive statistics were calculated for all variables of interest. Pearson's correlation coefficients were calculated to assess associations between linear sleep variables (chronotype, sleep duration and quality, rise and start times) and job stress and mental health scores, if normally distributed. A student's t-test was used to compare means of continuous variables between two groups. One-way ANOVA with a Tukey correction was conducted to examine differences in scores between more than two groups. Ordinal logistic regression was used to examine the effect of a continuous predictor variable on the probability of individual Likert scale responses. Rise and start times were tested as a predictor of sleep duration and quality using linear regression. Statistical analyses were generated using SAS 9.4 (copyright 2013, SAS Institute, Inc., Cary, NC).

RESULTS

Study Population Demographics

Characteristics of the study population are summarized in Table 2.1. The majority of study participants were males, working as operators with some college education, and were married with children. Mean age was 50.2 and average years of experience was 21.16. Ninety one point seven percent of the study population was currently working a 12-hour shift, with 85.6% of their work history comprised of rotating shift work, and 68.3% comprised of rotating 12s (R12).

General Sleep Characteristics

The study population are short duration sleepers (defined here as less than 6 hours per night). Those with a history of rotating shift work had shorter sleep duration and poorer (higher)

sleep quality scores. Both sleep quality and quantity were diminished for those who were inexperienced with rotating shiftwork (a threshold of 15 years of experience in shiftwork was applied as reported in Costa, 2003), suggesting that some shiftwork tolerance developed with years of experience. Sleep quantity and quality improved for those not currently working. Sleep duration was inversely associated with shift length, and sleep quality was higher for those on 8-hour shifts compared to 12-hour (but not 10-hour), shifts (Table 2.2).

Sleep Duration

We compared sleep durations reported among study participants to those reported previously in shift work studies. In a meta-analysis of 36 shift work studies (N=4,375), Pilcher et al reported average sleep durations during day, evening (swing), and night shifts for three 8-hour shift rotations, and two rotation frequencies ($\leq$ 4 days = rapid, and $\geq$ 5 days = slow)[6]. Average self-reported sleep durations in these studies were uniformly higher than those reported in our study population, which is primarily (91.7%) working two rotating 12-hour shifts. In contrast to their findings, we found longer sleep durations during rapid rotation schedules, but the differences were not significant (Table 2.3). Pilcher et al calculated an effect size statistic that represented the number of standard deviations from the mean the shiftwork group differed from the mean of the control group. As a result, we were not able to compare the variance we found with the ones included in their analysis.

Increased sleep duration was associated with decreased odds of self-reported drowsiness, OR: 0.61 (0.51, 0.73). Those who reported having trouble staying awake during alert activities (drowsiness) 3 or more times a week (N=36) averaged 4.83 $\pm$ 1.32 hours of sleep per night, and those who reported drowsiness 1-2 times per week (N=57) averaged 5.22 $\pm$ 1.11 hours per night. Increasing drowsiness was significantly associated with decreased sleep quantity (F(3,364): 8.96,

p<.0001) and quality (F(3,377): 36.84, p<.0001), and was common in the study population: more than half of the survey respondents reported having trouble staying awake during engaged activities (24% reporting this monthly but less than once per week, 17.7% 1-2 times per week, and 9.4% three or more times per week).

A significant regression equation was found that explained 14% of the variance in sleep duration based on a possible allocation of hours in the day (R^2: 0.139, F(5,322): 10.39, p<0001). Commute length (β: -0.16, p<.05) and overtime (β: -0.01, p<.001) significantly predicted reduced sleep duration, with shift length having a nearly significant relationship (β: -0.12, p<.10). Exercise (β: 0.17, p<.01) and relaxation activities (β: 0.17, p<.01) significantly predicted increased sleep duration.

Sleep Quality

Participants rated their sleep quality as very bad (9.57%), fairly bad (44.95%), fairly good (41.49%), and very good (3.99%). Seventy eight point two percent of respondents scored in the 'poor' sleep category using the PSQI (global score of 5 or higher); scores in this range have been found to have a sensitivity of 98.7% and a specificity of 84.4% for primary insomnia [(29)]. A comparison of PSQI component scores in our study population with others previously reported revealed that the global scores and all component scores we measured here were in the range of those with clinically diagnosed sleep or depressive disorders, with the exception of daytime dysfunction (Table 2.4). Scores for sleep duration and latency were comparable to those found among patients with primary insomnia, and sleep disturbance scores were higher than those found among patients with major depression and primary insomnia.

Characteristics of those with good (PSQI <5) and poor (PSQI ≥5) sleep scores were examined for our study population (Table 2.5). In comparing the good and poor sleep groups,

significant differences were found for certain lifestyle characteristics (exercise frequency, relaxation time, commute length); work factors (years of work history, staffing availability, ease of taking time off, job stress); and health outcomes (GI illnesses and discomfort, anxiety, depression). Differences in age, caffeine and alcohol consumption, and smoking were not significant.

Chronotype and Desynchrony

The majority of participants were early chronotypes (mean MSF: 2:12 am $\pm$ 1.87 hours). MSFs in our study population were 2-3 hours earlier than those reported elsewhere for the general population (Figure 2.1). No linear relationship was observed between chronotype (as MSF) and sleep quality (r: -0.02, p: 0.76) or duration (r: 0.07, p: 0.30). When chronotypes were stratified into five groups, significant differences were found between groups for sleep duration [F(4,200): 2.41, p: 0.05], but not sleep quality [F(4,208): 1.0, p: 0.41] or drowsiness [F(4,209): 0.72, p: 0.58]. However, MSFs between 2:30 and 4:30 am shared the longest sleep duration with the lowest (best) sleep quality score and the most infrequent drowsiness reported (Table 6), although differences between the latter two were not statistically significant.

The mean absolute difference between mid-sleep on free days and days worked (social jet lag) differed significantly between day (MSD) and night (MSN) shifts, indicating that greater desynchrony occurred during night shift rotations (t: 14.09, p<.0001). The difference between MSF and MSD was 1.79 ($\pm$ 1.66) hours, and the absolute difference between MSF and MSN was 6.80 ($\pm$ 2.34) hours. No associations were found between social jet lag values (for day or night shifts) and sleep duration or quality however (data not reported).

Current Work Schedule and Sleep: Daily Sleep and Work Logs

Shortest sleep duration was reported following shift rotation (4.89 ± 1.41 hours), then during night shift sets (5.04 ± 1.37 hours), then day shift sets (5.34 ± 1.21 hours), then following a day off (7.07 ± 1.60 hours). Significant differences were found between all groups, except between night shift sets and following shift rotation (Figure 2.2). Hours slept for the entire week (days worked and days off) were negatively correlated with total hours worked for that week (r: -0.18, p: 0.0016). Sleep duration decreased through the work set, although the decrease was not statistically significant. Sleep duration increased with each consecutive day off, with some differences significant (Table 2.7).

Day shifts had early start times: they ranged from 3:30 to 8 am for permanent day shifts, with 7 am being the most common start time; and 3 to 7 am for the rotating 12-hour shifts, with 5 am the most common start time. Night shift start times ranged from noon to 9 pm, with 5 pm most common. Rise times prior to day shifts ranged from 2 to 6 am, mean: 3:44 am ± :41. Rise times prior to night shift varied widely (range: 5 am to 5 pm, mean: 12:02 pm ± 2:04). On their day off, participants typically woke up just before 8 am (7:59, ± 119 minutes).

During day shift work sets, sleep duration was longer when rise times and shift start times were later. For the night shift, hours of sleep increased with later rise times, but not later shift start times. An estimate of the additional minutes of sleep gained is provided in Table 2.8. Later rise and start times were a significant predictor of improved (lower) sleep quality scores for both shifts, although explained variance was low.

Associations between sleep and health/well-being

Poor sleep quality and short sleep duration was associated with job stress, and with health and mental health outcomes that are prevalent in shiftworkers (Table 2.9). Significant correlation was found between both sleep quality and quantity and job stress and mental health. Elevated blood pressure correlated with the sleep quantity logged on the previous week. GI disorders were associated with sleep quality and with the previous week's sleep quantity. Correlations between BMI and both PSQI scores and average sleep quantity could be confounded by sleep apnea, which was not assessed in the survey.

Sleep disorders and adverse outcomes

Our survey asked participants if they had ever had an incident at work or while commuting that they attributed to fatigue. One third of the study reported at least one type of incident, and 6.3% had more than one type of incident. 24.6% of respondents reported a near miss at work, 7.6% reported a vehicle accident while commuting, 4.7% a serious error and 3.1% a reportable accident. Elevated PSQI scores were associated with higher frequency of these incidents. For every one-unit increase in PSQI scores, increased odds of an adverse event were observed as follows: near miss OR=1.11 (1.05, 1.18), vehicle accident OR=1.14 (1.03, 1.25), serious error OR=1.12 (0.97, 1.29), reportable accident OR=1.09 (0.97, 1.23).

DISCUSSION

The prevalence of sleep disorders (PSQI global score of 5 or more) was widespread in the study population, and individual component scores were comparable to severe, clinical sleep disorders. Although we did not measure performance in our study, in other studies where attention and function were clinically evaluated in conjunction with PSQI administration,

correlations between function and attention deficits and PSQI components scores have been found. Poor subjective sleep quality has been associated with reduced executive function [42], and short sleep duration has been associated with lower attention span [43]. Sleep latency and habitual sleep efficiency (lying awake while in bed) have been associated with impaired reasoning and attention [44]. We found increased odds of fatigue related incidents as PSQI scores worsened in our study population. Although this association lacks temporal proximity (the PSQI measures sleep quality over the last month, and the incidents were reported for any time in respondents' careers), a history of shiftwork exposure has been found to result in current sleep disorders, even in retirement [45,46]. As a result the PSQI scores obtained could indicate chronic sleep disorders.

Average sleep durations reported here are in the range of those documented in investigations of catastrophic accidents where fatigue has been cited as a cause [47,48]. Weekly (or more frequent) episodes of drowsiness during engaged activities were reported for over one fourth study participants. Our study population reported average sleep durations one or more hours shorter than those reported previously in a meta-analysis of rotating shift work studies that was limited to three 8-hour shift rotations[6]. Although this meta-analysis was not limited to the manufacturing sector, it provides evidence that potentially implicates the 12-hour shift as adversely impacting sleep duration. It is notable that the loss of the swing shift, which averaged the longest sleep duration at 8.03 hours in Pilcher's study, could have resulted in limiting available recovery time and increasing sleep debt in 12-hour shift workers. In addition, we saw decreased frequency of exercise and leisure activities reported for those working 12-hour shifts; these activities were positively correlated with sleep.

As documented previously, early rise and start times were seen to have an adverse impact on sleep [12,13,49]. Early shift start times may be responsible for the trend observed in earlier than

average chronotypes, or they may reflect an adaptation of the workforce towards morningness. Previous studies have found morningness to be associated with better sleep quality [5,50], so this trend in our study population could explain a tolerance for shift work (i.e. healthy shift worker effect). When grouped, we found that chronotypes with an MSF within 2:30-4:30 am appeared to have improved sleep quality and quantity. From this we can infer an ideal shift start time to maximize sleep duration and quality by dividing an average work night's sleep of 6 hours across an MSF of 3:30 am, yielding a waking time of 6:30 am. Given that only 5% of shifts started at 7 am or later, current work schedules appear unlikely to accommodate this later rise time. However, any feasible delay in shift start times show promise for increasing sleep duration, which could be meaningful for a workforce that averages less than 5.5 hours per night.

When four week schedules were compared, rapid rotation had longer sleep duration and better sleep quality, but differences were not significant (Table 2.3). However, in the week of daily sleep and work logs showed the shortest sleep duration (4.9 hours) followed a shift rotation. The addition of overtime shifts within standard schedule configurations, and the potential for sleep debt associated with long work sets prevented a more detailed evaluation of schedule patterns and rotation frequency.

Those inexperienced with shiftwork appear to be more impaired in our study population, showing evidence of shift work tolerance among older, experienced employees. A review of the literature indicates that shiftwork tolerance has been more frequently associated with young workers [19,34,49,53,54], than older workers [55,56,57], however age was not analyzed separately from years of work experience in many of these studies.

Both sleep quality and sleep quantity were correlated with health outcomes that have been associated with shift work sleep disorder, including anxiety, depression, GI disorders,

hypertension and weight gain. In other shift work studies, neuroticism, anxiety, and negative affect have been related to lower shift work tolerance [53,58]. The majority of our study were experienced shiftworkers (implying some degree of adaptation), although individual tolerance has been shown to vary widely. The early MSFs we found could predict chronotype inflexibility. We found that those with a good sleep quality shared a combination of healthy behaviors, reduced job stress, and improved health.

Limitations of this study include self-reported data quality, low response rate, and potential for selection bias among survey respondents. Because recruitment materials advertised a health study on rotating shift work, it is likely that interested participants could have been motivated by a personal concern about shift work related health complaints, which could limit generalizability. However, our study population demographics (gender, race, and age) are comparable to available data for this workforce nationally, and our response rates are comparable to other mailed surveys, thus improving generalizability [59–61].

Table 2.1 - Study Population Demographics

Characteristic		N	%
Gender	Male	335	87.24
	Female	49	12.76
Race	White	273	71.65
	Black	44	11.55
	Hispanic/Latino	44	11.55
	Asian/Pacific Islander	13	3.41
	Native American	2	0.52
	Other	5	1.31
Education	HS/GED	80	20.89
	Some college	156	40.73
	AA/Bachelors	136	35.51
	Graduate degree	11	2.87
Age group	25-34	37	9.74
	35-44	67	17.63
	45-54	124	32.63
	55-64	143	37.63
	65-74	9	2.37
Marital status	Married	294	76.96
	Divorced/Separated	42	10.99
	Single	22	5.76
	In a committed relationship	20	5.21
	Widowed	4	1.04
Children	Have no children	61	15.93
	Have children	322	84.07
	Avg. no. of children: 2.27 (± 1.68)		
Job title	Operator	301	79.21
	Technician/Specialist	30	7.89
	Lab Technician	13	3.42
	Maintenance	13	3.42
	Safety	7	1.85
	Other	16	4.21
Avg. years of experience: 21.16 (± 10.7) years			
Avg. overtime rate for entire career: 20.1% (± 13.8)			

Table 2.2 - Sleep duration and sleep quality scores for study participants, grouped by work history, work schedules, and shift

		N	Average hours slept per night	PSQI score
All respondents		381	5.50 ± 1.14	8.96 ± 3.96
Shiftwork history				
Inexperienced	<15 years	139	5.24[1] ± 1.18	9.68[2] ± 4.20
Experienced	>15 years	214	5.61[1] ± 1.07	8.60[2] ± 3.76
None	0 years	27	5.88[1] ± 1.25	8.18[2] ± 3.88
Current schedule				
Employment status	Employed	361	5.48[3] ± 1.12	9.06[4] ± 3.96
	On leave/retired	23	5.82[3] ± 1.37	7.52[4] ± 3.76
Current shift length	8-hour	9	6.33[5] ± 1.00	8.22[6] ± 4.68
	10-hour	20	5.55[5] ± 1.46	10.11[6] ± 3.88
	12-hour	322	5.46[5] ± 1.10	8.97[6] ± 3.95

[1] Differences significant (F(3,361): 4.15, p:0.0065); [2] Differences significant (F(3,374): 2.84, p:0.0377);
[3] Differences not significant (t:1.35, p:0.1769); [4] Differences nearly significant (t: -1.81, p: 0.0717);
[5] Differences nearly significant (F(2,331): 2.70, p:0.0686); [6] Differences not significant (F(2,343): 0.88, p:0.4159).

Table 2.3 - Comparison of average sleep durations between the study population and a meta-analysis of previous shiftwork studies

Schedule type	Study Population			Meta-Analysis Results[1]	
	Hours slept	SD	N	Hours slept	N
Permanent days	5.85	1.57	26	7.00	555
Permanent nights	6.50	0.70	2	6.60	1,604
Rotating	5.45	1.08	314	6.65	8,136
Rotating shift assignment					
Day	5.26[2]	1.16	209	6.62	2,578
Evening				8.03	2,325
Night	4.99[2]	1.36	175	5.85	2,620
Speed of rotation					
Rapid	5.67[3]	1.05	157	6.52[3]	7,337
Slow	5.26[3,4]	1.19	19	6.93	979

[1] Mean sleep durations from Pilcher et al, 2000 were not published with individual variances;
[2] For means of comparison, only R12 schedules were included;
[3] Differences not significant (t:0.52, p:0.60 for hours slept; t:-0.30, p:0.77 for PSQI)
[4] Slow rotation schedules were capped at 20% overtime to represent typical work schedules and estimate a standard work set.

Table 2.4 - Comparison of PSQI global scores and domains between study population and sleep study diagnostic groups

Component	Study population N=359	Sleep Study Diagnostic Groups[1] Controls[2] N=52	Depressives[3] N=34	DIMS[4] N=45	DOES[5] N=17
Sleep quality	1.61 ± 0.71	0.35 ± 0.40	1.88 ± 0.88	1.96 ± 0.93	1.06 ± 0.75
Duration	1.52 ± 0.96	0.29 ± 0.50	1.71 ± 1.14	1.51 ± 1.20	0.47 ± 0.80
Latency	1.42 ± 1.01	0.56 ± 0.73	1.88 ± 1.15	1.42 ± 1.01	0.59 ± 0.87
Habitual sleep efficiency	1.21 ± 1.13	0.10 ± 0.30	1.59 ± 1.18	1.47 ± 1.24	0.29 ± 0.77
Disturbance	1.51 ± 0.62	1.00 ± 0.40	1.47 ± 0.51	1.40 ± 0.62	1.53 ± 0.72
Daytime dysfunction	1.20 ± 0.84	0.35 ± 0.48	1.79 ± 0.69	1.42 ± 0.94	2.24 ± 0.90
Medication	0.75 ± 1.17	0.04 ± 0.28	0.76 ± 1.21	1.20 ± 1.31	0.35 ± 1.00
Global score	9.06 ± 3.96	2.67 ± 1.70	11.09 ± 4.31	10.38 ± 4.57	6.53 ± 2.96

[1] From Buysse et al, 1988; [2] Healthy controls without sleep complaints, mean age: 59.9, 77% male;
[3] Patients diagnosed with major depressive disorder, mean age: 50.9, 73.5% male;
[4] DIMS: disorder of initiating and maintaining sleep (primary insomnia), mean age: 44.8, 35.5% male;
[5] DOES: disorder of excessive somnolence (narcolepsy), mean age: 42.2, 47% male.

Table 2.5 - Characteristics of those with good sleep quality and poor sleep quality

Variable	Good Sleep Quality Mean	SD	Poor Sleep Quality Mean	SD	p-value
Demographics					
Age	51.0	8.91	49.3	9.97	0.1940
Men (frequency)	86.0%		87.6%		0.5051
Non-whites (frequency)	21.2%		30.4%		
Health behaviors					
Caffeinated beverages/day	2.54	1.66	2.55	1.62	0.9583
Alcoholic beverages/day	1.30	1.41	1.11	1.17	0.2578
Smokers (frequency)	7.1%		9.2%		
Number of cigarettes/day	15.5	9.4	11.85	8.01	0.3354
Hours spent relaxing/day	1.99	1.02	1.68	1.05	0.0070
Exercise frequency[1]	2.31	1.17	1.93	0.99	0.0007
Work factors					
Age at career start	29.3	8.46	28.9	8.61	0.7767
Years in industry	23.5	10.7	20.8	10.9	0.0435
% of career on rotating shifts	83.4%	30.4%	86.2%	28.98%	0.4244
% of career on R12 schedule	65.7%	35.2%	69.1%	34.6%	0.3682
Average overtime rate for career	19.6%	14.2%	20.6%	13.8%	0.6084
Hours worked (previous 4 weeks)	187.5	46.5	191.8	47.3	0.4806
Staffing level global score	24.4	4.41	23.0	5.07	0.0310
Mandatory overtime rate	44.9%	38.0%	49.7%	39.1%	0.3474
Difficulty taking time off	2.35	0.91	2.94	0.86	<.0001
Financial need for overtime	26.74% yes		33.22% yes		0.2089
Hours spent commuting/day	1.10	0.74	1.33	0.91	0.0389
General health					
SBP	124.1	9.68	127.8	13.3	0.0686
DBP	77.6	8.40	79.9	10.0	0.1236
BMI	29.3	4.57	30.4	5.06	0.0959
GI symptoms[3]	1.31	1.49	2.12	1.74	0.0003
GI illness (diagnosed)[4]	0.11	0.31	0.27	0.20	0.0014
Mental health					
Job stress global score (10-40)	25.7	4.20	24.1	3.85	0.0008
Depression subscale (0-4)	1.32	0.45	1.99	0.71	<.0001
Anxiety subscale (0-4)	1.20	0.34	1.71	0.67	<.0001

[1] Exercise frequency: 1=not regularly, 2=once/weekly, 3=2-4x/week, 4=5-7x/week

[2] Difficulty taking time off: 1=not at all, 2=not too much, 3=somewhat, 4=very much

[3] GI symptoms: range 0-5, included self report of heartburn, acid reflux, indigestion, constipation or diarrhea

[4] GI illness: range 0-5, included diagnosed condition of peptic ulcer, colitis, Crohn's, IBS, or GERD

Table 2.6 - Chronotype groups and hours slept, sleep quality, drowsiness

Chronotype (MSF)	N	Hours Slept[1]	PSQI score[2]	Drowsiness[2, 3]
Before 12 am	19	4.78 ± 1.06	10.63 ± 3.89	1.32 ± 1.10
12 – 2:29 am	105	5.50 ± 0.98	9.14 ± 3.90	0.93 ± 1.04
2:30-4:29 am	69	5.62 ± 1.03	8.74 ± 4.13	0.88 ± 1.05
4:30-6:29 am	15	5.60 ± 1.24	8.87 ± 3.60	1.00 ± 0.93
6:30 and later	5	5.40 ± 1.52	10.40 ± 3.58	1.20 ± 1.30

[1] Differences near significant (F(4,200): 2.41, p:0.0502)
[2] Differences not significant: PSQI (F(4,208): 1.00, p:0.4086); drowsiness (F(4.209):0.72; p:0.5778)
[3] Drowsiness scale: 0=not in the last month, 1=less than 1x/week, 2=1-2x/week, 3=3 or more x/week.

Table 2.7 - Mean hours slept following consecutive shifts worked and days off

Hours slept following:	N	Mean	SD
First shift (w1)	186	5.27	1.38
Second shift (w2)	186	5.23	1.29
Third shift (w3)	186	5.20	1.38
First day off (o1)	169	$6.86_{o2*, o3**}$	1.77
Second day off (o2)	161	7.11_{o1*}	1.71
Third day off (o3)	61	7.31_{o1**}	1.64

Within rows, means with subscripts are significantly different from the group noted
*Differences significant at p<.05. ** Differences significant at p<.01

Table 2.8 - Simple linear regression of sleep duration and rise / start times

		Sleep duration				Sleep quality (PSQI global)			
Variable	Minutes	β	SE	R^2	p	β	SE	R^2	p
AM rise time	27.8	0.46	0.10	0.09	<.0001	-0.657	0.33	0.02	0.044
Day shift start	18.8	0.31	0.10	0.04	0.0016	-0.805	0.31	0.02	<.0001
PM rise time	15.4	0.26	0.05	0.14	<.0001	-0.184	0.13	0.01	<.0001
Night shift start	1.4	0.02	0.11	0.003	0.83	-0.693	0.29	0.03	0.018

Table 2.9 - Correlation between health outcomes and sleep quality and quantity (as self-reported monthly average and from daily logs)

Variable	Sleep Quality	Sleep Quantity	
	PSQI score	How many hours do you sleep on average?	Mean hours slept recorded on 1 week sleep log
Job Stress	0.31***	-0.19***	-0.157**
Mental health (global score)	0.60***	-0.32***	-0.19***
Anxiety subscore	0.58***	-0.30***	-0.19**
Depression subscore	0.54***	-0.30***	-0.18**
SBP	0.06	-0.032	-0.176*
DBP	0.15*	-0.095	-0.201**
GI irritation[1]	0.28***	-0.13**	-0.13*
GI illnesses (diagnosed)[2]	0.17**	-0.06	-0.18**
Antacids used per month	0.18*	-0.04	-0.19*
BMI	0.17***	-0.06*	-0.09

Pearson's correlation coefficients significant as noted: *p<.05, **p<.01, ***p<.001

[1] GI symptoms: range 0-5, included self report of heartburn, acid reflux, indigestion, constipation or diarrhea

[2] GI illness: range 0-5, included diagnosed condition of peptic ulcer, colitis, Crohn's, IBS, or GERD

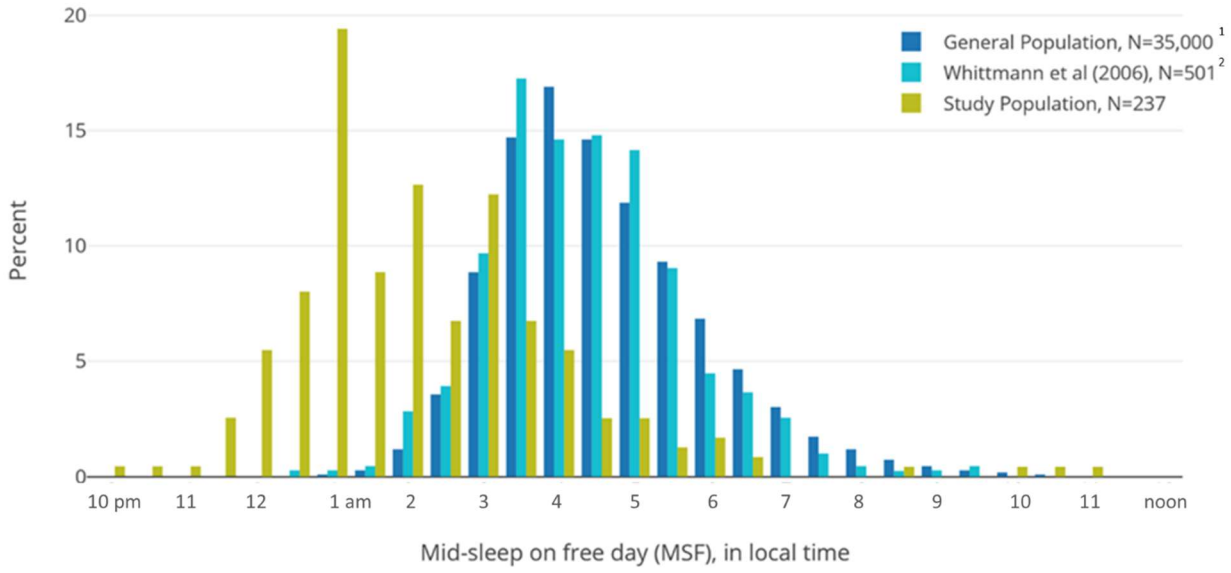

Figure 2.1 - Distribution of chronotypes in the study population (green) compared to the general population (blue and aqua) as reported by Whittmann et al (2006). MSF values reported in local time.

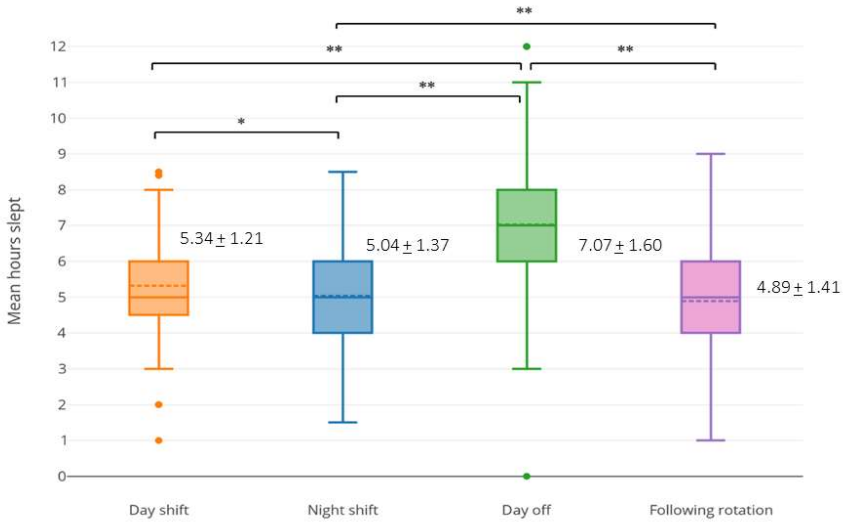

Figure 2.2 - Mean hours of sleep reported during day and night shift sets, during days off, and immediately following a shift rotation. Differences between means were tested using a Student's t test, significance is noted as follows: * p<.05, ** p<.01.

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CHAPTER 3

Fatigue risk management in an era of lean staffing and routine use of overtime

ABSTRACT

Worker fatigue has been identified as a risk among rotating shift workers, and becomes a safety concern in high hazard industries. We conducted an exploratory study of work-related fatigue among hourly oil refinery workers, looking at associations between staffing levels and job stress to identify associations between fatigue and hours of work among hourly refinery workers. We analyzed self-reported data from a mailed survey, recruiting participants from the oil sector membership of the United Steelworkers (USW) union. We found that mandatory overtime was associated with job stress, low job satisfaction, anxiety, and reduced coverage for safety program areas. Non-compliance with industry recommendations for fatigue risk management was associated with increased risk of fatigue, shorter sleep duration, greater job demands and poorer mental health. Among this study population of rotating shift workers, overtime is common. Mandatory overtime is an additional job stressor that is associated with job stress, and with staffing levels that reveal impacts to safety programs. Risk of fatigue is greatest among those who exceed recommended hours of service guidelines.

INTRODUCTION

A significant number of catastrophic industrial accidents, including Three Mile Island, Union Carbide Bhopal, Chernobyl, and Exxon Valdez, occurred at night, and increased accidents and worker impairment have been associated with night shifts [1, 2]. Frequent overtime has also been shown to increase the likelihood of an accident at work [3-5]. Research comparing fatigue impairment to alcohol intoxication found that two hours of sleep loss produced the same

performance limitations as a blood alcohol content of .045 percent[6]. Increased feelings of sleepiness and a decrease in performance on vigilance (monitoring) tasks have been identified in subjects with sleep debt[7, 8].

Refinery operators play a critical role in process safety in a high hazard industry, yet they work one of the most demanding schedules in manufacturing, comprised of both extended and rapidly rotating shifts. Because refineries staff to maintain operations 24 hours per day, 7 days per week, continuous coverage of nights, weekends, and holidays is needed. Shift rotation has become the industry norm in an effort to spread the distribution of off-hours work most equitably. Further, rapid rotation allows process operators to have more regular contact with management, improving communication and allowing for continuity [9]. In comparison to other industries, where workers rotate from night to day shift once monthly or quarterly [9-11], hourly refinery workers (operators and some maintenance personnel, both considered safety-sensitive positions) rotate every 2 to 4 days. This rapid shift rotation results in frequent circadian rhythm disruption and is associated with chronic sleep disturbance.

In the 1990s, most refineries in the US transitioned from three 8-hour shifts per day to two 12-hour shifts per day for their positions that worked rotating shifts. This coincided with increasing rates of overtime and reports of understaffing [9, 12-13]. Despite widespread acknowledgement that fatigue is associated with accidents and ill health, there is no occupational exposure limit for hours of duty in the US, even though the US Department of Transportation has implemented federal hours of service regulations for aviation, highway, and rail [14]. The American Petroleum Institute (API) issued guidelines for fatigue risk management systems in 2010[15], following a catastrophic accident where fatigue was identified as a causal factor by the investigating US Chemical Safety Board (CSB). These were later described as having

"significant shortcomings" and were labeled an "unacceptable response" by the CSB (CSB comments to OSHA RFI on PSM, 2014).

During this incident at a BP refinery in Texas City, TX in 2005, faulty equipment was improperly brought back online by an Operator who had worked 29 consecutive 12-hour shifts and reported an average of 5 hours of sleep each night [16]. In response to this event, the API issued Recommended Practice 755 Fatigue Risk Management Systems for Personnel in the Refining and Petrochemical Industries (RP 755). It contains hours of service guidelines that establish minimum rest breaks and maximum work sets for 8-, 10- and 12-hour shifts. These hours of service limits were designed as 'triggers at which additional fatigue risk evaluations will be performed', rather than recommendations for routine work schedules, and specifies: 'consistently working at the limits shown is not sustainable and may lead to chronic sleep debt' (RP 755 Section 4.8). For the 12-hour shifts, the hours of service (HOS) guidelines set limits at 7 continuous shifts during normal operations, and 14 continuous shifts during shut downs. Minimum time off between work sets must be at least 36 hours for up to 3 shifts, and 48 hours for 4 or more night shifts (or 84 hours of day or night) before returning to work (Table 3.1). Implementation of these guidelines remains inconsistent in the industry, with 20% of oil and petrochemical facilities reporting no hours of service limits, 31% setting limits at 5-7 consecutive work days, and 18% allowing greater than 14 consecutive work days in a recent benchmarking study[9]. Other components of RP755 include individual risk assessment and mitigation recommendations for fatigued employees, and the inclusion of fatigue as a potential root cause to be investigated following incidents. According to RP755, incident investigations should collect information on schedule patterns, numbers of consecutive shifts worked, number of hours awake and hours slept in the previous 24 hours.

RP755 may be limited in its effectiveness because it is remains a mere guidance document. Although Federal OSHA has acknowledged that extended or unusual work shifts may lead to increased fatigue, stress, and lack of concentration and thus to an increased risk of operator error, injuries and/or accidents, federal Process Safety Management (PSM) regulations do not explicitly address fatigue. However, Cal-OSHA's recently published PSM for Petroleum Refineries regulations contains specific language on controlling the hazards of fatigue [17]. Touted as a landmark workplace safety and health regulation, this standard for specifically for refineries includes a new requirement for management of organization change (MOOC) that specifies that changes in shift duration or a reduction in staffing levels should be incorporated into hazard analysis to ensure that they do not adversely affect process safety[15]. The initial statement of reasons for the proposed regulations specifies "Requiring a Human Factors analysis throughout the MOOC process is necessary to ensure that the employer effectively identifies and addresses organizational changes that have the potential to worsen various pressures on employees, such as fatigue, time pressure, inadequate training levels, mandatory overtime, and the understandability and effectiveness of operating and maintenance procedures" [18]. It also identifies staffing levels, employee fatigue, shift work and overtime as risk factors to be included in required human factors analyses for all incident investigations.

The relationship of overtime to injury has been reported for many industry sectors, with injury risks increasing as hours increase [10, 20-21]. Job demands associated with overtime can include increased work pace, increased quantity of work, and higher emotional load [19]. Extended shifts and overtime have been found to increase exposure to job demands and limit rest and recovery time [10, 14]. High demand schedules are also associated with fatigue [20]. Overtime

alone may not require increased recovery time, but the combination of high job strain and increased work quantity have been associated with a need for additional recovery time [19, 22].

Unscheduled overtime adds unpredictability to the demands of the rapidly rotating shift schedule. Elective overtime shifts can be appealing to hourly employees, who receive time and a half pay for additional shifts taken. However, mandatory overtime (forced overtime that deviates from the predetermined work schedule) can increase work-life conflict for employees that already have scheduled work during half or more of their evenings and weekends. Unscheduled overtime also disrupts the recommended work rest schedules and contributes to greater risk of fatigue, further disrupting sleep patterns and increasing the potential for health problems and stress [11, 14]. Continuous use of overtime to fill necessary positions and cover unscheduled absenteeism can result in chronic understaffing. Employees who routinely fill vacant positions with overtime shifts can become accustomed to greater earnings than their base pay.

Our study evaluated recent work schedules among hourly refinery workers and looked for associations between work hours and perceived staffing levels, job stress, fatigue, sleep quality and mental health. We collected self-reported data, recruiting participants through a roster of oil sector members of the United Steelworkers (USW) union, the largest labor union in the national oil sector. Based on feedback from focus groups, we included rates of mandatory overtime in the survey as a possible stressor. This data was collected as part of a larger survey administered to evaluate the effects of extended, rotating shifts on employee health and quality of life. For this analysis, we focused on survey results pertaining to overtime management and staffing levels and their relationships to employee well-being, safety climate, and fatigue risk. We investigated the following issues: 1) how does work organization interact with job stress, employee morale,

and safety culture? 2) how does the organization of work hours interact with employee fatigue? 3) are the hours of service guidelines being followed, and if not, are they predictors for fatigue?

METHODS

A self-reported health questionnaire was administered to voluntary participants recruited from the oil sector membership of USW's Districts 12 (West Coast states) and 13 (Gulf Coast states) to assess the effects of the rotating shift work schedule. The study design was developed collaboratively between USW and UCLA. The survey tool was developed and pilot tested among two focus groups of refinery employee members of USW Local 675 in Carson, CA. The focus groups provided input on industry specific terminology, work schedule configurations, and schedule management approaches. The study received approval for human test subject research from the UCLA Institutional Review Board.

Study Design

Recruitment for the study began in September 2014 and the survey was distributed beginning in December 2014. Active or former USW members with current or previous experience in the oil sector (and 25 years of age or older) were invited to participate in the study. UCLA recruited participants by sending an informational flyer about the study to a mailing list of over 10 thousand oil sector members, of which approximately two thirds may have worked rotating shifts. From the initial recruitment mailing about the study, we received 652 requests for surveys, 418 surveys were returned to the research team and 384 of these were complete. Active recruitment ended in January 2015 and the majority of surveys were received by April 2015. Participation in the study was entirely voluntary, and participant identities were not shared

with the USW. Two incentives of $1,000 each were awarded to one participant from each District, randomly selected using a sweepstakes drawing.

Survey

The entire survey consisted of 70 questions and was available online or on paper. The survey included questions on the domains of work history, job stress, staffing, physical and mental health, and sleep quality. Data were collected on hours of work in the previous four weeks, including shift type and overtime quantity. Participants were asked to estimate what percent of their overtime was mandatory and what percent was voluntary, with responses given in two percentages that added up to 100. Participants were asked about a history of incidents that they attributed to fatigue at any time in their career. Data was collected on four adverse outcomes: a reportable incident, a serious error, a near miss, or a car accident while commuting. Participants were only able to select yes or no for each of these four types of incidents which were summed for a maximum of four per individual.

Questions on job stress were compiled from the National Institute for Occupational Safety and Health Quality of Work Life Questionnaire (QWLQ) [23]. Ten questions were selected from the QWLQ to characterize work demands (pace of work, physical exertion) and rewards (social support, advancement opportunity, stimulation, recognition, decision latitude, and overall job satisfaction). Responses were formatted as a 4-point Likert scale rating of 1 = not at all true, 2 = not very true, 3 = somewhat true, and 4 = very true. The ten job stress variables were analyzed individually, and also summed to create an overall job stress score that was calculated from answers to all questions, which ranged from 10 to 40 (Cronbach's alpha: 0.66). Negative answers were reversed so that a higher score indicated more support and lower job stress.

Staffing questions were developed by the researchers in consultation with USW. Questions were included to measure available coverage for various planned and unplanned absences, including areas related to safety program implementation. The survey collected data on eight staffing parameters that included: coverage availability for absences related to vacation, sick time, training, or drills; availability of personnel for contractor oversight, emergency response activities, and responding to process upsets/outages; and safe coverage of normal operations (alpha: 0.83). A 4-point Likert scale rating was assigned: 1 = never, 2 = rarely, 3 = sometimes, and 4 = often. Staffing parameters were analyzed individually and also summed to create an overall staffing score, which ranged from 8 to 32. Higher scores indicated greater reported staffing coverage.

A truncated mental health questionnaire was assembled using five questions from the Patient Health Questionnaire (PHQ) 9 [(24)] for depression and three from the Generalized Anxiety Disorder (GAD) 7-item scale [(25)] for anxiety. Questions that would trigger mandatory reporting and those that overlapped between the two questionnaires were removed for the purpose of brevity. A 4-point Likert scale rating was assigned to each symptom based on frequency over the last month: 1 = not at all, 2 = several days, 3 = more than half the days, and 4 = nearly every day. An average score for depression and another for anxiety were created from the individual PHQ and GAD questions, respectively. These two subscales ranged from 1 to 4, anxiety had an alpha of 0.69, and depression 0.86. An overall mental health score was also created by summing all rankings for a linear variable that ranged from 8 to 32. Higher scores indicated a higher frequency of adverse symptoms (i.e. poorer mental health).

Data on sleep quantity and quality were collected and scored using the Pittsburgh Sleep Quality Index (PSQI) [(26)]. The PSQI is a 19 item questionnaire that evaluates sleep habits over

the last month (alpha: 0.72). Variables are grouped into seven domains: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, daytime dysfunction, sleep fragmentation, and use of sleep aid medications. These domains are scored and combined to provide a global sleep quality index score. The possible scores range from 0–21, with greater than five indicative of impaired sleep quality.

Statistical Methods

Descriptive statistics were calculated for all variables of interest. Pearson's correlation coefficients were calculated to assess associations between total scores for job stress, staffing, sleep quality, and mental health, whose global scores were normally distributed. Characteristics of overtime users were assessed using student's t-test for continuous variables and one-way analysis of variance (ANOVA) for Likert scale responses. Plots of mandatory overtime rates (0-100%) revealed a tri-modal distribution, with peaks at high (80% or more) and low (20% or less) rates of mandatory overtime, and a third node around 50%. In order to examine the effect of mandatory overtime on outcomes, respondents were grouped into three categories: those who reported that 80% or more of their overtime was mandatory, those who reported that 20% or less was mandatory (i.e. 80% or more of their overtime was elective), and all others. One-way ANOVA with a Tukey correction was conducted to examine differences in scores between the high, moderate, and low mandatory overtime groups in individual job stress parameters and staffing levels.

Deviations from the API RP 755 hours of service guidelines were measured by reviewing work schedules reported for the previous four weeks. Schedules without a minimum 48 hours of time off following four consecutive night shifts or 84 hours of any shift (day or night) during the 4 weeks monitored were flagged as having a time off deviation. Schedules where the maximum

work set recommendation (of seven 12-hour shifts, nine 10-hour shifts, or ten 8-hour shifts) was exceeded were flagged as having a work set deviation. Total numbers of work set and time off deviations were summed for each participant's schedule for the previous 4 weeks. The total count of hours of service guidelines deviations were tested as a predictor of fatigue, job stress, and mental health outcomes, using linear and ordinal logistic regression. Staffing levels were also tested as a predictor of schedule violations. Statistical analyses were generated using SAS 9.4 (copyright 2013, SAS Institute, Inc., Cary, NC).

RESULTS

Demographics for the study population are summarized in Table 3.2. Our study demographics were comparable to previously published cohorts from the oil refining industry for gender, race and age [9, 27-28]. 81.4% of the study population worked in refining, 7.0% in petrochemical and 6.2% in chemical production; the remainder (2.6%) worked in on shore and off shore extraction and distribution. Study participants resided in 11 states and worked at 18 different oil companies.

Hours of Work

Although 88.6% of respondents were working rotating 12-hour (R12) shifts at the time the survey was administered, their work histories reflected a mixture of schedule types and shift lengths. The average number of years spent on the R12 schedule was 13.4 $\pm$ 8.6; this schedule also represented the largest proportion of all participants' work history (68% $\pm$ 35% of total years worked). Previous schedules worked also included three 8-hour shift rotations (both backward [night → swing →day] and forward rotating [day →swing →night] schedules), and also permanent day, swing, and night shifts. Only 5% of study participants had no history of

working rotating shifts. The R12 schedule was the most common and the longest duration schedule worked for the majority of participants: participants worked more years on this shift than all others combined (Table 3.3).

Participants worked a range of overtime rates throughout their careers; these rates varied across schedule type as shown below. The R12 shift reflected the largest proportion of overtime, with a career average of 23% overtime for that shift schedule. Non-rotating day, swing and night shifts had substantially lower overtime rates than the three rotating shift schedules. Average overtime rates reported over the duration of their careers were 20% $\pm$ 14% across all shifts.

During the four week period monitored, overtime (defined as hours in excess of 160) reported for study participants averaged 42.9 hours or approximately one shift per week (a 26.8% overtime rate). Approximately 10% of participants working extended (12-hr) shifts worked some overtime hours at the end of their shift (ranging from 1-5 hours). When asked what percent of their overtime (on average) was voluntary, 13.4% reported that it was all voluntary, 21.2% reported that it was all mandatory, and 13.9% reported that it was half and half. A Pearson's correlation indicated that high mandatory overtime rates were associated with high job stress (r: 0.23, $p < .0001$), low staffing levels (r: 0.22, $p < .0001$), and poor mental health (r: 0.12, p: 0.0378). Strong correlation was observed between low staffing levels and high job stress (r: 0.48, $p < .0001$).

Characteristics of overtime users were examined, with no significant differences in mean overtime hours observed between gender [t(355): -1.57, p: 0.12], parental status [t(354): 0.25, p: 0.80], or whether or not participants lived alone [t(352): 0.72, p: 0.48]. Marital status was also not found to have an effect on overtime [F(6, 357): 0.52, p: 0.80]. Participants were asked if their base pay was enough to cover their household expenses; higher monthly overtime averages

were found among those who answered no (47.5 $\pm$ 25.7 hours per month) compared to those who answered yes (37.9 $\pm$ 27.6) [t(354): 3.11, p: 0.002]. No linear relationships were found between average monthly overtime rates and years of experience (r: -0.057, p: 0.26), or numbers of children (r: 0.003, p: 0.95), although age showed a weak inverse correlation (r: -0.09, p: 0.07). Participants who reported that their base pay was not enough to cover their household expenses also had larger average family sizes (2.63 $\pm$ 2.29 children) compared to those who said it was (2.14 $\pm$ 1.94 children), t(353): 2.53, p: 0.012). Numbers of children was also positively associated with difficulty taking personal time off (r: 0.11, p: 0.032). A significant relationship was observed between increasing mandatory overtime rates and difficulty taking time off for personal matters [F(3,365): 15.69, p<.0001], revealing the potential for work-life conflict from overtime.

Mandatory Overtime as a Stressor

Participants that reported a high rate of mandatory overtime (80% or more of their overtime was mandatory) reported a more negative perception of fair treatment, safety climate, job enjoyment, and resource availability compared to those who were primarily able to elect their overtime shifts (Table 3.4). Those with high mandatory overtime (MOT) rates also had lower perceptions of promotional opportunity and decision latitude, although differences were not statistically significant. No significant trends were observed between mean scores for pace of work, learning on the job, physical exertion, or the competence of coworkers. Within the high MOT group, the lowest mean scores reported were for promotional opportunity and job enjoyment (these approached 'rarely'); scores for the remaining variables approached 'sometimes' (except for learning opportunities, which scored almost a point higher than all others).

Frequency of reported anxiety and depression symptoms were higher for the high MOT group, but differences were not significant. Notably, there were not significant differences in hours worked between the high and low MOT groups during the 4 week period monitored (the moderate group, however, worked the equivalent of one additional shift). Average hours slept per night decreased as mandatory overtime increased, but differences were not significant.

Mandatory Overtime and Personnel Availability

Unsurprisingly, high mandatory overtime rates were a consistent indicator of low personnel availability: every staffing variable measured was lower for the high MOT group (Table 3.4), with significant differences found for 7 of the 8 variables measured (safe coverage of operations, responding to incidents/emergencies, covering vacation leave, responding to process upsets, conducting drills, performing quality control/contractor oversight, and covering sick leave). The most significant mean differences between the groups was found for the safe coverage of operations measure ($F(2,345)$: 10.13, $p<.0001$). Other impacts to safety program areas were reflected in the personnel coverage reported by the high MOT group, with staffing levels that approached 'rarely' for two measures (quality control/contractor oversight and drills), and were midway between 'rarely' and 'sometimes' for three measures (training, incident/emergency response, and responding to process upsets). In comparison, these scores approached 'sometimes' for the high voluntary overtime users.

Trends in Coverage for Safety Program Functions

Irrespective of overtime (or MOT) rates, greater coverage was reported among all respondents for personal time off (sick and vacation leave) than for emergency response and training activities. Availability for emergency response and training activities was collected

from the following five questions: 'At my work, minimum staffing levels are maintained to allow for: a) Training, b) Emergency drills, c) Overseeing the work of inexperienced employees or contractors, d) Responding to incidents/ emergencies, e) Handling process upsets/outages'. Scores for sick and vacation leave coverage were combined and an average taken. The mean score for sick and vacation leave coverage across the entire study population was 3.49 $\pm$ 0.59, midway between 'sometimes' and 'always'; whereas the mean score for emergency response and training coverage was 2.65 $\pm$ 0.82, between 'rarely' and 'sometimes' (differences significant at t(360): 18.66, p: <.0001) (Figure 3.1). Interestingly the mean score for a general variable pertaining to safe staffing levels ('At my work, there are an adequate number of trained and qualified workers available to safely cover operations') was fairly positive (3.09 $\pm$ 0.78, slightly above the 'sometimes' rating). But the lower scores reported for the five emergency response and training activities reveal that practical implementation of some elements of safety/preparedness programs may be limited by understaffing, despite a general perception of safe operating conditions.

Deviations from the Hours of Service Guidelines

More than one fourth of participants (28.12%) had one or more deviations from the RP755 hours of service guidelines during the 4-week period monitored. For those who reported their work schedules for the previous four weeks (N=349), mean numbers of schedule deviations per person were 0.73 $\pm$ 1.47, and ranged from 0 – 7. To assess the impact of schedule severity, total numbers of deviations from the HOS guidelines were summed for each participant during the period that work schedules were logged, and analyzed as a linear variable. Simple linear regression was used to determine whether increasing numbers of schedule violations predicted sleep disturbance, job stress, or mental health outcomes. A significant regression equation was

found for sleep duration (average hours slept per night), and mental health scores (both anxiety and depression symptoms), although explained variance was low (Table 3.5). Each additional schedule violation was associated with a five minute decrease in sleep duration, and a 0.07 and 0.06 point increase in anxiety and depression symptom frequency, respectively (scale 0-4). Unsurprisingly, a strong association was found between schedule violations and hours worked, with each additional schedule violation associated with approximately 20 additional hours worked. A near significant association was found between increasing HOS violations and increased (worse) PSQI global scores. Interestingly, no association was found between job stress scores and HOS deviations.

A similar analysis was conducted to see if staffing levels predicted hours of service violations, in an effort to see if understaffing drove non-compliance. Contrary to our hypothesis, a weak positive association was observed between hours of service violations and increased personnel coverage (β: 0.03, $p<.05$). However, an examination of overtime rates revealed increasing rates of voluntary overtime among those with non-compliant schedules, although variance was high and differences were not significant when grouped ($F(2, 343):0.30$, $p:0.75$). Voluntary overtime users could also explain the lack of a significant association between hours of service violations and job stress.

Ordinal logistic regression was used to generate proportional odds ratios for the job stress and sleep disturbance measures that showed a significant correlation with HOS deviations (Table 3.6). Significant odds ratios (ORs) were generated for both physical exertion and a fast pace of work, with nearly significant ($p<.10$) ORs for sleepiness during engaged activities and increased job enjoyment. Each additional schedule violation resulted in a 20% increased odds for a high score for physical exertion (verses any of the three lower scores), assuming that all other

variables are held constant. Increased odds of high score for pace of work score were 16%. Interestingly, odds of a high score for job enjoyment increased by ~13%, indicating that high job satisfaction is linked to increased hours of work, and more hours of service deviations. Odds of a higher score for sleepiness were ~12%. These tests satisfied the assumption of proportional odds, indicating that the same odds ratios were maintained between the lower score categories. Remaining odds ratios generated were not significant, and revealed both positive and negative associations.

DISCUSSION

In a population of rotating shift workers in a high hazard industry, we found that overtime was common, and overtime rates were highest for those working 12 or more hours at a time. Mandatory overtime was associated with increased job stress, low staffing availability, and greater anxiety; it was not associated with greater hours worked. These findings indicate that losing control over scheduled time off was a stressor independent of the additional workload or added hours away from home. The ability to exert control over work activities has previously been found to be associated with greater job satisfaction and well-being [22, 29, 31]. Similarly we found that job enjoyment dropped by a third of a Likert point moving from the high voluntary to the high mandatory overtime group, indicating that the combination of unpredictable and compulsory extra work hours could contribute to diminished job enjoyment. Diminished perceptions of management support were revealed in the lower safety culture, fairness, and resources scores reported for those with high mandatory overtime rates. Increased job control has been found to buffer the effect of work/family conflict [22], but we did not see significant differences in job decision latitude scores measured. Overall our findings indicate that

decreasing the proportion of mandatory overtime is a potential management tool that could help alleviate work life conflict and improve job satisfaction among this workforce.

We found strong associations between low staffing availability and high mandatory overtime rates: seven out of eight staffing measures decreased significantly as mandatory overtime increased. Furthermore lower personnel availability appeared to impact the capacity to respond to an emergency or process upset more severely than the ability to cover staffing vacancies from sick and vacation time. Our results indicate that where mandatory overtime rates were high, adequate coverage was reportedly rare for emergency drills and quality control/oversight, and ranged between rarely and sometimes for training, emergency response, and responding to outages/process upsets. This reveals potential weaknesses in the functionality of critical process safety programs that could stem from understaffing. Although declining staffing levels have been reported for the oil industry by the Bureau of Labor Statistics and other industry research groups [9, 12-13] over the last decade, details regarding the impact of staffing on specific safety program areas is rare, making this snapshot of industry conditions unique. Our findings provide an unusual glimpse at management activities that could limit response capabilities during a process safety incident. Further, a lack personnel availability was associated with increased job stress, revealing another dimension of understaffing that impacts employee well-being. Looking at job enjoyment scores separately, we saw them decrease as mandatory overtime increased (χ^2: 18.74, p:0.095), and increase as global staffing levels increased (χ^2: 66.45, p<.0001).

We found that at least one deviation from the hours of service guidelines for fatigue risk management was reported by more than one fourth of the study population in their previous 4 weeks of work. As deviations from the hours of service guidelines increased, inadequate

recovery time and work related fatigue were indicated by shorter sleep duration, increased frequency of dozing off, longer work hours, and greater physical exertion and pace of work. These findings indicate that exceeding the hours of service limits could be an important leading indicator for fatigue risk and adverse outcomes related to fatigue impairment. Higher frequency of anxiety and depression symptoms reported this group also suggests a greater need for recovery.

We anticipated seeing associations between low staffing levels and deviations from the hours of service guidelines, but did not. This suggests that staffing availability was not necessarily a driver behind non-compliance with the RP755 guidelines. Further, no correlation was observed between mandatory overtime rates and HOS violations (r:-0.02, p: 0.7066), indicating that schedule violations may not be driven by management priorities. Additional analyses could reveal subsets within these groups that elect voluntary overtime shifts, or report individual characteristics of job stress or satisfaction.

Previous efforts to manage fatigue risk in other industries have focused on hours of service, recognizing associations between working hours, overtime, fatigue and sleep quantity [5, 8, 11, 14]. But in contrast to prescriptive hours of service guidelines, the PSM model is a performance-based standard, in that effective results are the criteria for compliance. This gives employers flexibility in designing a safety program to best prevent or minimize adverse outcomes for their unique workplace and workforce. Under the Federal PSM standard, the hazard analysis requirement is limited to physical and chemical process parameters, such as preventing a run-away reaction in a process unit. And despite the improvements in process safety since PSM was implemented in 1992, organizational and human factors are still frequently identified as causes of catastrophic accidents [13].

To this end, the newly issued PSM regulations for Petroleum Refineries approved by the Cal-OSHA Standards Board specify that a human factors analysis address hazards from shift work, employee fatigue, overtime and staffing reductions. The requirement to conduct this analysis proactively as part of the Management of Organizational Change shows promise in identifying and controlling leading indicators of work related fatigue. Fatigue hazards must also be evaluated during accident investigations (along with risks from shift work, overtime, and staffing levels); following this, employers must document that they are corrected and controlled. This approach is supported by parallel requirements in California's Injury and Illness Prevention Program [33] for hazard identification and control, and implementing corrective actions following incidents. Thus the IIPP framework provides additional mechanisms for managing fatigue risk. Effective implementation of this new standard, in conjunction with a thorough IIPP has the potential to impact fatigue in the workplace and reduce incident rates caused by human factors.

Limitations of this study include self-reported data, low response rate, and potential for selection bias among survey respondents. Because recruitment materials advertised a health study on rotating shift work, it is likely that interested participants could have been motivated by a personal concern about shift work related health complaints. However, the analyses discussed in this paper focus on associations found between psychosocial stressors and schedule demands, which may be less dependent on health status. As a result we anticipate that the potential selection bias for health complaints, if present, may not have as strong effect an on the results discussed in this paper. Conversely, the issue of elective overtime is a sensitive one, and many eligible participants may have declined to participate because they favor having the option of elective overtime. However, our data indicates the proportion of those who reported use of elective overtime shifts and those who reported mandatory overtime shifts was roughly equal.

Table 3.1 - Summary of API Recommended Practice for Fatigue Risk Management No. 755 Hours of Service Guidelines

Operational Situation	12-Hour Shift	10-Hour Shift	8-Hour Shift
Maximum Consecutive Shifts (day or night) in a work set			
a) Normal Operations	7 shifts	9 shifts	10 shifts
b) Outages	14 shifts	14 shifts	19 shifts
Minimum time off after a work set			
a) Normal Operations	36 hours	36 hours	36 hours
Work set of 4 or more night shifts	48 hours	48 hours	48 hours
After 84 hours or more regardless of day or night	48 hours	48 hours	48 hours
b) Outages	36 hours	36 hours	36 hours

Table 3.2 - Demographics for Study Population

Characteristic		N	%
Gender	Male	335	12.76
	Female	49	87.24
Race	White	273	71.65
	Black	44	11.55
	Hispanic/Latino	44	11.55
	Asian/Pacific Islander	13	3.41
	Native American	2	0.52
	Other	5	1.31
Education	HS/GED	80	20.89
	Some college	156	40.73
	AA/Bachelors	136	35.51
	Graduate degree	11	2.87
Age group	25-34	37	9.74
	35-44	67	17.63
	45-54	124	32.63
	55-64	143	37.63
	65-74	9	2.37
Marital status	Married	294	76.96
	Divorced/Separated	42	10.99
	Single	22	5.76
	In a committed relationship	1	0.26
	Widowed	35	9.19
Children	Don't have children	61	15.93
	Have children	322	84.07
	Avg. no. of children: 2.27 ($\pm$ 1.68)		
Job title	Operator	301	79.21
	Technician/Specialist	30	7.89
	Lab Technician	13	3.42
	Maintenance	13	3.42
	Safety	7	1.85
	Other	16	4.21
Avg. years of experience: 21.16 ($\pm$ 10.7) years			
Avg. overtime rate for entire career: 20.1% ($\pm$ 13.8%)			

Table 3.3 - Cumulative years worked on each shift schedule, with mean overtime rates reported

Shift/schedule	N	Years worked	Mean over-time rate[1]	SE overtime rate
Rotating 12-hr shift	341	5,090	0.23[2]	0.14
8-hr shift, forward rotation	101	886	0.16**	0.15
8-hr shift, backward rotation	64	516	0.19	0.15
Day shift (non-rotating)	131	1,305	0.13***	0.16
Swing shift (non-rotating)	30	139	0.08***	0.13
Night shift (non-rotating)	30	154	0.09***	0.14

[1]Differences between groups significant (F(5,691): 14.75, p<.0001)

[2]Mean overtime rate for the R12 shift differed from the other shift schedules as noted:
** = p<.001, *** = p<.0001.

Table 3.4 - Comparison of mean job stress, staffing, and mental health scores grouped by mandatory overtime percentages (a. low=20% or less, b. moderate=21-79%, and c. high=80% or more)

Variable	Percent Mandatory Overtime Group a. ≤20% N=127	b. 21-79% N=102	c. ≥80% N=119	*F* *df* (2,345)	Eta[2]
Job Stress measures:[1]					
Employees are treated fairly	3.09 (0.78)$_c$	2.97 (0.74)$_c$	2.71 (0.85)$_{ab}$	7.11***	0.04
Safety is a management priority	3.24 (0.82)$_c$	3.09 (0.74)	2.87 (0.91)$_a$	6.19***	0.03
Enjoy going to work	2.55 (0.91)$_c$	2.51 (0.88)	2.25 (0.84)$_a$	4.00*	0.02
Help and resources are available	3.02 (0.86)$_c$	2.89 (0.74)	2.72 (0.82)$_a$	3.96*	0.02
Promotional opportunities exist	2.28 (0.99)	2.31 (0.88)	2.05 (0.88)	2.84	0.02
Pace of work is fast	2.72 (0.83)	2.92 (0.76)	2.90 (0.69)	2.42	0.01
I have decision latitude	2.73 (0.82)	2.61 (0.81)	2.52 (0.89)	2.01	0.01
Learning opportunities exist	3.28 (0.79)	3.39 (0.69)	3.40 (0.65)	1.04	0.01
Coworkers are competent	3.00 (0.68)	2.88 (0.70)	2.94 (0.62)	0.86	0.005
Work is physically demanding	2.73 (0.75)	2.80 (0.69)	2.75 (0.83)	0.26	0.002
Mental Health:[2]					
Anxiety symptoms	1.50 (0.53)	1.63 (0.70)	1.67 (0.72)	2.29	0.01
Depression symptoms	1.76 (0.65)	1.88 (0.77)	1.93 (0.73)	1.93	0.01
Staffing availability for:[3]					
Safe coverage of operations	3.22 (0.77)$_c$	3.25 (0.70)$_c$	2.84 (0.80)$_{ab}$	10.13***	0.06
Emergency response activities	2.96 (0.96)$_c$	2.88 (0.90)$_c$	2.51 (1.08)$_{ab}$	7.14***	0.04
Vacation absences	3.77 (0.48)$_c$	3.69 (0.49)$_c$	3.52 (0.68)$_{ab}$	6.60**	0.04
Responding to process upsets	2.90 (0.94)$_c$	2.89 (0.88)$_c$	2.52 (1.02)$_{ab}$	6.33**	0.04
Sick time absences	3.50 (0.75)$_c$	3.41 (0.72)	3.20 (0.90)$_a$	4.55*	0.03
Performing drills	2.73 (0.99)$_c$	2.57 (1.00)	2.35 (1.04)$_a$	4.35*	0.02
QC/Contractor oversight	2.67 (0.99)$_c$	2.56 (0.88)$_c$	2.31 (1.01)$_{ab}$	4.31*	0.02
Training absences	2.76 (0.94)	2.65 (0.97)	2.49 (0.98)	2.46	0.01
Hours worked	189.2 (45.3)	197.7 (46.7)	187.8 (50.6)	1.38	0.01
Hours slept	5.56 (1.17)	5.43 (1.06)	5.41 (1.12)	0.64	0.00

* = p≤.05, **= p<0.01, *** = p≤.001. Standard deviations appear in parentheses. Within rows, means with subscripts are significantly different from the group noted at the p≤.05 level based on Tukey's Studentized Range test for paired comparisons. [1]Job stress scale: 1: not at all true, 2: not very true, 3: somewhat true, 4: very true. [2]Anxiety and depression: average of all symptoms reported, scale: 1: Not at all, 2: Several days/mo., 3: More than half/mo., 4: nearly every day. [3]Staffing scale: 1: never, 2: rarely, 3: sometimes, 4: often.

Table 3.5 - Simple linear regression of hours of service guideline deviations on sleep, stress and mental health

Dependent variable	B	SE(B)	t	p(t)	R^2
Mental Health (global)	0.49	0.18	2.64	0.009	0.020
Anxiety symptoms	0.07	0.023	3.10	0.003	0.026
Depression symptoms	0.06	0.026	2.14	0.033	0.010
Hours slept	-0.09	0.04	-2.13	0.034	0.014
PSQI score (global)	0.23	0.14	1.62	0.107	0.008
Job stress (global score)	0.02	0.15	0.15	0.883	0.001
Hours worked	19.99	1.17	17.07	<.0001	0.461

Table 3.6 - Ordinal logistic regression to predict the risk of stress and sleep disruption from hours of service guideline deviations

Variable	OR	95% CI	Wald test	p-value
Work is physically demanding	1.20	1.04, 1.38	6.353	0.0117
Pace of work is fast	1.16	1.03, 1.27	6.029	0.0141
I enjoy going to work	1.13	0.99, 1.29	3.208	0.0733
I doze during waking hours	1.12	0.98, 1.28	2.970	0.0848
Learning opportunities exist	1.13	0.98, 1.30	2.629	0.1049
Promotional opportunities exist	1.09	0.95, 1.24	1.581	0.2087
My overall sleep quality is poor	1.05	0.92, 1.20	0.493	0.4826
Employees are treated fairly	0.97	0.84, 1.11	0.236	0.6274
I have decision latitude	0.97	0.85, 1.11	0.197	0.6569
Help and resources are available	0.97	0.85, 1.11	0.195	0.6587
My coworkers are competent	1.02	0.88, 1.18	0.047	0.8281
Safety is a management priority	0.99	0.87, 1.14	0.007	0.9349

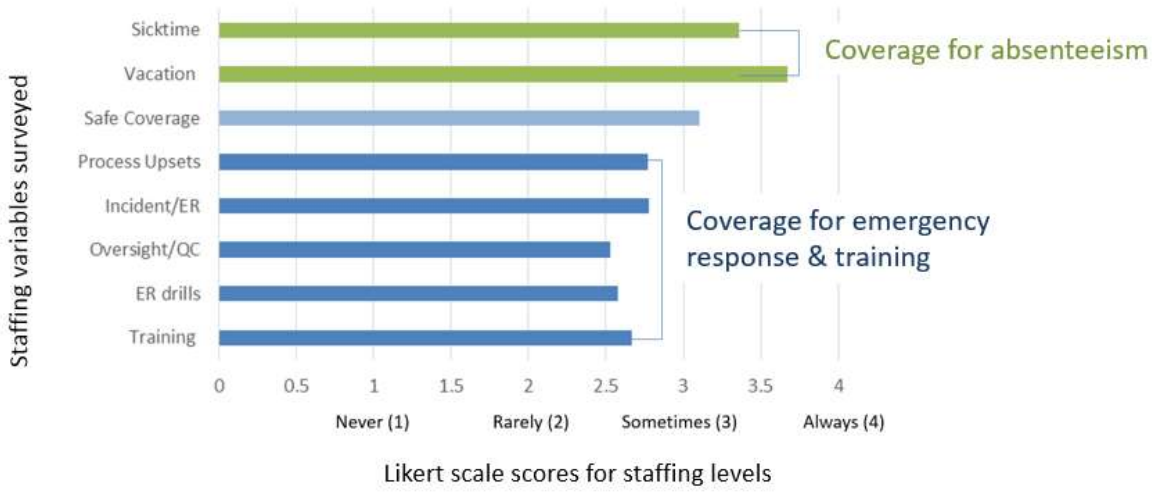

Figure 3.1 - Mean scores for staffing variables for the study population (N=384). Staffing variables were grouped as pertaining to absenteeism (for sick and vacation coverage [in green]) and pertaining to emergency response and training (in blue).

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CHAPTER 4

Characteristics of work life conflict among rotating shiftworkers

ABSTRACT

Work life conflict is a common complaint among shiftworkers, who routinely work when their family and friends are off. We characterized dimensions of work life conflict among rotating shiftworkers in the oil industry, and assessed the presence of stressors and coping mechanisms to alleviate strain. Much of the research in work life conflict is in the professional sector, primarily among working women. Comparatively little is known about the impact of shiftwork schedules on male industrial workers. As part of a larger study on the health effects of shift work, we asked rotating shiftworkers to describe how their personal life was impacted by their work schedules, and to suggest improvements to improve work life conflict. We found that work family conflict had the highest prevalence among respondents, and that losing the ability to control their time off further compromised their roles in the domestic sphere.

INTRODUCTION

Hourly process workers in the oil industry work around the clock, primarily in rotating shift assignments. The industry widely transitioned to extended (12-hour) shifts in the mid-1990s, and typically uses rapid rotation schedule configurations that change from day to night shift every two to four days. This compressed work schedule was originally designed to result in roughly 14 shifts worked per month, but in reality varies from that. Work intensification and increasing overtime rates, broadly documented in the oil industry [11,62,15], add overtime shifts that eliminate scheduled days off and diminish available recovery time from the compressed work week.

Because 24/7 operations require regular night and weekend work as well as staffing over holidays, attempts are made to distribute the off-hours work fairly. Rapidly rotating shift schedules are complex; the short work sets result in different days worked and days off from week to week. Days off migrate across the weekend in a schedule pattern that repeats every 4 to 7 weeks, resulting in one or two weekends off per month. Schedule patterns are disrupted by the addition of overtime shifts, which can be made compulsory based on staffing availability, making schedule patterns difficult to discern for family and friends. It is also common for workers to be placed on call (standby) on days off. The erratic nature of these schedules, in addition to the demands of long days, night work, and frequent circadian rhythm disruption from shift rotation, can combine to create intense job demands. An example of some common rotating shift schedules in the oil industry are provided in Figure 4.1, shown as intended (nominally) and with the addition of three additional shifts (~21% overtime--the average quantity of overtime reported for our study population).

The goal of this study was to assess characteristics of work life conflict among rotating shiftworkers, and to examine associated stressors and coping mechanisms. We collected self-reported data, recruiting participants through a roster of oil sector members of the United Steelworkers (USW) union, the largest labor union in the national oil sector. This data was collected as part of a larger survey administered to evaluate the effects of extended, rotating shifts on employee health and quality of life. For the current analysis, we focused on responses to open ended questions on quality of life and work schedule.

Work life conflict (WLC) describes incompatible demands of work and non-work roles, such that participation in one role is compromised by participation in the other [8]. Increased stress at home or work can result, with effects ranging from health and mental health impacts, to

absenteeism and low job satisfaction. WLC can result in burnout, anxiety, depression, and substance abuse[63]. Three domains have been identified in WLC research: time-based, strain-based and behavior-based conflict [8,9]. Time-based strain is particularly relevant to shiftworkers.

Time-based WLC occurs when work hours interfere or inhibits participation in non-work roles. Long work hours, overtime, commute length, schedule inflexibility and shiftwork have all been positively associated with time-based work life conflict [64,65–67]. Insufficient autonomy and inadequate control over work schedules and workload were found to be leading causes of turnover and job dissatisfaction in nursing[68]. Strain-based conflict arises when strain in one role affects the performance in another role. Job stressors can be drivers for strain (anxiety, fatigue, depression, apathy, or irritability), causing spillover of negative emotions into home life. Other job stressors, such as role ambiguity, conflict, low support, physical and mental demands, can contribute to strain-based conflict. Autonomy and skill variety have been shown to buffer these effects to some degree. Behavior-based conflict occurs when specific behaviors required in one role are incompatible with behavioral expectation in another role, such as detached, authoritarian behavior at work that conflicts with the expectation for a more open and accessible behavior at home (Table 4.1).

Various buffers to work life conflict have been identified. An inverse relationship was found between WLC and perceived control among nurses[69], and a lack of control has been associated with increased WLC in other industries[70]. Co-worker support has been found to reduce work life conflict[63],[71]. One study on shiftworkers found that both supervisor and co-worker support influenced psychological wellbeing indirectly via control over work schedules and diminished work life conflict [70]. Stress and shiftwork research have both established associations between social support at work and both physical and psychological health [72],[73].

Work life conflict is bidirectional, meaning that strain can occur in either the work or the domestic sphere. Spillover describes the process by which an employee's experience in one domain affects their experience in another domain, and can be positive or negative. For example, family strain can spillover into the work environment and create distractions or absenteeism. Work life balance is defined as satisfaction and good functioning at work and at home, with a minimum of role conflict[74]. Work life enrichment is a form of positive spillover, defined as a process whereby involvement in one domain establishes benefits and/or resources which then may improve performance or involvement in another domain[75].

METHODS

Survey

A self-reported health questionnaire was administered to voluntary participants recruited from the oil sector membership of USW's Districts 12 (West Coast states) and 13 (Gulf Coast states) to assess the effects of the rotating shift work schedule. The study design was developed collaboratively between USW and UCLA. The survey tool was developed and pilot tested among two focus groups of refinery employee members of USW Local 675 in Carson, CA. The focus groups provided input on industry specific terminology, work schedule configurations, and schedule management approaches. The study received approval from the UCLA Institutional Review Board.

Recruitment for the study began in September 2014 and the survey was distributed beginning in December 2014. Active or former USW members with current or previous experience in the oil sector (and 25 years of age or older) were invited to participate in the study. UCLA recruited participants by sending an informational flyer about the study to a mailing list

of over 10 thousand oil sector members, of which approximately two thirds may have worked rotating shifts. Both paper and electronic surveys were available. From the initial recruitment mailing about the study, we received 652 requests for surveys, 418 surveys were returned to the research team and 384 of these were complete. Participation in the study was entirely voluntary, and participant identities were not shared with the USW. Two incentives of $1,000 each were awarded to one participant from each District, randomly selected using a sweepstakes drawing.

Three open ended questions pertaining to work life balance and schedule configurations were at the end of a 60-item questionnaire on health, mental health, and work schedules. The full survey included questions on the domains of work history, job stress, staffing, physical and mental health, and sleep quality. Data were collected on hours of work in the previous four weeks, including shift type (day, swing or night) and overtime quantity (as additional shifts). The three open ended questions were: 1. How has your work schedule impacted your personal life, and your social or family obligations? 2. What would your ideal work schedule be? 3. Do you have any suggestions for improving scheduling issues that would benefit you and your coworkers? There was no limit to the amount of text allowed in the responses.

Data Analysis

Responses to all three questions for each respondent were assessed for work life balance as enriched, neutral, mostly conflict, and all conflict. Text responses were reviewed using an inductive (ground-up) coding scheme developed to construct themes. These themes were then grouped and organized into code families. Code families were categorized according to domains established in work life conflict literature. Quotations were coded using Atlas.ti version 7.5.18

(date, Scientific Software Development GmBH, Berlin). Data were queried to assess their prevalence and co-occurrence with other themes using Atlas.ti analytical tools.

RESULTS

Demographics

Of the 384 participants who completed the survey, 354 (92.2%) provided responses to the open-ended questions. Table 4.1 summarizes demographics for this subset of the study population, which are comparable to the demographics of the greater pool of questionnaire respondents.

Work-life Interface

Comments were generally positive (describing work life enrichment) for 4.24% of the respondents, neutral (describing work-life balance) for 7.34%, mostly negative (describing more conflict than enrichment) for 11.30%, and all negative for 76.55%.

Work life conflict

General domains of work life conflict reported are depicted in Figure 4.2. The most frequent type of work life conflict mentioned was family conflict, affecting 61.0% of the study population. Some participants further specified conflicts with their spouse/partner (18.4%), children (18.1%), or diminished contact with extended family (30.8%)--mostly in the context of an inability to attend family gatherings (commonly mentioned were holidays, birthdays, weddings, and funerals). Social life impacts were described by more than a third of the study population (36.7%). Social impacts could be grouped into three general categories: 24/7 work schedule conflicts (working when others normally socialize), loss of scheduled days off and an inability to make plans, and fatigue-related withdrawal. Additional dimensions of work life conflict are listed in Table 4.2, along with the number and frequency of mentions (with the

exception of fatigue related withdrawal, which is listed as one of the dimensions of fatigue in Table 4.3). Impacts to participants' personal lives were coded separately, grouped here into a general 'self' category that affected 21.2% of the study population. Some domains in this category were tallied from general statements ("I have no personal life"); others were inferred from mentions of activities, hobbies, or self care that were neglected or abandoned due to work schedules.

Time-based conflict was the dominant characteristic among these responses, as the nominal schedule alone requires regular time away from home on evenings, weekends and holidays. Overtime shifts (or on-call/standby status) that eliminated previously scheduled days off and required plans to be cancelled was frequently cited as an additional stressor.

Work family conflict

"Missed out on family events" was the most common statement included in the work family conflict domain, mentioned by nearly a third (30.8%) of participants. In some cases, these statements were elaborated on further as working during holidays (17.5%), birthdays (7.3%), funerals (2%), weddings (1.4%), anniversaries (0.8%), and births (0.6%). 2% of participants reported having to cancel a planned family vacation. 2.8% specified the difficulty of seeing extended family: "My social and family obligations are hit and miss. By this I mean that I miss out on a lot of family functions and time with my fiance, elderly mother, sister and daughter and two grandsons". More commonly, the daily activities of home life were missed or time away from home was cited (17.2%).

Conflict with Parenting Role

Fifteen percent mentioned missing out on children's activities (primarily sporting events, but also music recitals, parent teacher meetings, etc.), and 4.5% reported missing school events. An inability to participate in parental activities requiring routine commitment (i.e. coaching a sports team) was expressed by several participants: "Can't enroll them in any sports because its more of a burden on wife." Another typical statement was:

> "Has caused me to miss almost everything my kids do. Work on weekends, holidays, and nites causes conflict with everything. Missed my kid's games, birthdays, Christmas. Very bad impact on personal life, social life and family events."

These statements were accompanied by regret in some cases, with several stating they missed out on their children growing up.

> "I've missed a lot of family things, parties, dinners, holidays, kids sports! You just can't get those things back."

> "It severely affected my life years ago when I did work shift work, by my not being around my family at special occasions, or even their daily lives at special moments. It has had a great deal to do with the lack of relationships that I have with them now."

In other cases, an inavailability for day to day parenting was described. One example given was not being able to help with their children's homework. Another stated: "Have had my children leave messages, literally crying, because they miss me". Others cited the long work days as interfering with home life: "I have not seen my kids or wife at all in the last few months except on the days I have off. I get home from work and they leave for school and work and they get back home and I've already left for work."

Conflicts with childcare during work hours were described by 2% of participants: "Another huge challenge is finding quality baby sitters. It is asking a lot for someone to be available to keep your kids before dawn." Others mentioned work schedules complicating custody issues or the adding to the difficulty of single parenting:

> "As a single mother I am constantly being impacted by work schedule. With forced overtime at an all time high due to insufficient staffing my children suffer due to my inability to be at home for family time. I have to hire a caregiver to do what I cannot do because I am forced to be at work. That is no way for children to be raised. I am told at work it is not an issue because we are being monetarily compensated."

Two percent of participants acknowledged a conflicted parental role, but reconciled it with the benefits of providing for their family:

> "You name it and this schedule screws it up. However, it is the nature of the business. Everything in life is a trade off. The fact that we make a pretty good wage with our base pay and the available OT, allows my wife to not have to work full time and care for the kids. There are many others who do not work as much OT but their spouses work full time. Either way, time spent with family by one parent or both is reduced due to the schedule."

However, in some cases the provider role appeared to add additional strain:

> "Yes, I feel the obligation to provide for my family means working more hours. I also believe this is a normal feeling. I miss my immediate family often. I also feel my children are having to miss out on sporting or other activities like birthday parties because I'm not there to help my wife, and she is way too overwhelmed to do it all. On a normal work day I'm up at 2AM and I don't return until close to 6PM. That's 16 hours away from home. My

wife doesn't work right now due to kid's needs. My boys range in age from 1 and a half to 10 years old. I feel like I work way too much, and yet it's still not enough."

Others elaborated further on the burden placed on their families (4.5%) or on their spouse (3.7%):

"My family has to plan their lives around my job and it's taken a toll. Though they are troopers, I feel it is unfair to them. It always seems that I'm always making up for lost time in every aspect of my life. Whether its time with my kids, with my wife, with my chores around the house…I'm always having to catch up. I have no time to volunteer for anything."

However, a few (1.4%) described their work schedule as providing additional family time: "Now I have more day off during the week so I got to do more things with my kids (sports, school trips)."

Social Isolation

More than a third of participants described work conflict with friendships or the lack of a social life. 11.9% of respondents expressed missing their friends. Part of the isolation described appeared to be structural, a result of the shift schedule: "I feel isolated a lot of the time. Working weekends and off when everyone is working"; or: "Have to do leisure activities alone because family and friends are working during the week". Others discussed the difficulty created by the irregular schedule: "Because it is difficult for day people to understand shift work, I think it makes normal social interactions more difficult and therefore makes regular friendships harder to maintain". Difficulty maintaining friendships was described by 5.4% of participants. Two primary reasons were cited for diminished social contact: having to cancel or turn down invitations due to work, and their irregular sleep patterns:

"What's also hard is trying to make plans to do stuff because I never know for sure I am going to be off on my weekends then I don't tend to make plans because I hate being a flake. I am losing friendships more and more because I am not available, but most of my family also knows and understands thankfully."

"I can't tell you how many times people would tell me they didn't call my house because they thought I might be sleeping."

Fatigue was also cited when describing an inability to engage socially; this is discussed further in the section on stressors.

Personal Life Conflict

Twenty one point six percent of respondents mentioned impacts to their personal life. 6.5% indicated the work days were too long to do anything else, and 5.6% made a general statement that they 'had no personal life'. A lack of time for specific interests (fishing, sports, hobbies) was described by 5.1% of participants. Others described an inability to attend church (1.4%), do volunteer work (0.8%), or engage in self care or enrichment activities (0.6%):

"In addition, attempts to give back to my community by doing volunteer work has been curtailed, as I frequently have to reschedule on cancel previous commitments."

"I have a rotating shift so I have no regular social life. As a 12 stepper with over 25 years of recovery, my meeting attendance has dropped to two meetings a month, from three a week."

Relationship Conflict

Relationship conflict was mentioned by 18.4% of participants, and stemmed primarily from time-based conflict. Work schedules were cited as a source of strain with spouses and

partners, and also as putting an unfair burden on them, relative to childcare or domestic responsibilities:

> "I have a great wife, been married 42 years, I believe it is hard on her, to keep up the family with shift work and schedule and rest of the family."

Limited quality time together was mentioned by 2.8%, with about half citing night work as problematic. Others described a fundamental incongruity with their spouse's schedule:

> "I might want to go out on Tuesday night, but my wife has to work the next day so even just enjoying a movie and dinner takes some planning."

> "My personal life is strange to say the least. I've a girlfriend who lives 10 blocks from me but we only see each other maybe 10 times a month due to work schedules".

A number of participants (3.7%) cited their work hours as a factor in their divorce:

> "Cause of failure in my first marriage, which ended in divorce when my wife left me because of forced overtime. Causes a lot of stress and miscommunication in my current marriage."

> "I believe the excessive overtime I have had to work in the past 8 years contributed to my divorce."

Some described the challenge of caring for spouses with ill health or disability:

> "In the past month my spouse had surgery or important doctor visits that I could not be there for due to my work sick leave policy and the lack of extra personnel on shift to allow me the time off."

> "I never have time off to attend family gatherings. My disabled wife is always left at home by herself. I am never able to be home for holidays. I have no social life, I'm always working. Due to the rotating shifts, I am always tired."

At the time of the survey, 11.3% of respondents were divorced and 5% were single. Among these responses (N=54), there were 5 mentions of the difficulty of dating, nearly 10%. One stated: "It has made dating very difficult, as well as any lasting relationships hard"; another: "I don't date because my schedule is so erratic."

Health/Mental Health

Health and mental health outcomes that were mentioned in relation to work life conflict are summarized in Table 4.3. Mentions of fatigue and exhaustion were included in this category, as the majority of comments associated it with a state of withdrawal or overload. Overload, characterized here as a form of fatigue, was expressed by 6.8% of participants. Some described an all work existence, with an inability to perform in other roles when away from work:

> "I don't have a personal life anymore. I am asked to work all the time, and even when I am not at work I am so tired from lack of sleep and stress that I have no energy to do anything. I have three young kids and I don't even get to spend holidays with them or take them on vacation. I am miserable but the money is good and we rely on it so I am stuck working here."

Social withdrawal that resulted from tiredness was a common observation: "I get out of work too tired to be in the mood to do anything. I have no time to make friends or bond with family. I now merely tolerate people instead of actively trying to establish relationships." One respondent

stated: “The social outings which do come up are either impossible to attend, or I'm simply too exhausted.”

Fatigue was cited by 4.5% as contributing to decreased participation or enjoyment in non-work activities. It was also associated with a feeling of insurmountable demands on free time.

> “I worked so much that I no longer enjoy doing activities on my days off that I used to enjoy-- yard work, washing the cars--I see them as more work now.”
>
> “I'm always tired and this irritates my husband. I can't seem to get anything done except catch up on the minimum house work when I'm off. I can only enjoy a few of the social obligations because I'm tired. I just don't ever feel good unless I'm been able to sleep 12 hours for 2 days after I've gotten off of shift.”

Others (3.1%) described a state of confusion or disorientation:

> “Social life is non-existent, no time to do anything, and it’s hard for friends to keep up with the work schedule constantly changing. It’s all I can do to spend enough time with my wife on the days I can. I try to take advantage of family time, but it feels like I'm living in a fog. Like time doesn't matter and the numbers on the clock are just that…numbers on a clock.”

Nine percent of respondents mentioned a mood state that they associated with work life conflict, with depressive feelings being the most common (“I am miserable”), followed by anxiety and irritability (“I get agitated more quickly”). One stated:

> “I couldn't come close to explaining everything that has changed since I started shift work. I have anxiety problems now and take Celexa for it. I have to take prescription sleeping meds daily so I can get a few hours of sleep. I'm not the happy, outgoing guy I once was. I'm only 32 years old.”

An inability to engage was also expressed by several respondents: “don't enjoy being around people anymore or doing things”, or “I live a recluse lifestyle”.

Four point five percent cited a health complaint that they associated with work; primarily weight gain, but also various chronic diseases:

> “My schedule doesn't match up with anyone else I know or care about. Since getting DM2 [Diabetes mellitus type 2], I've been depressed and have lost interest in most things. I don't know how I'm going to survive another 7 years until retirement. At work the prospect of a promotion or straight daylights job are bleak. I think my current work schedule has really taken a toll on my health both physically and emotionally. It seems especially difficult to get the DM2 in check. I'm really worried that I won't see retirement.”

Stressors

Some stressors were voluntarily mentioned in discussions of work life balance, these were organized into two groups: work organization factors and psychosocial stressors (Table 4.4).

Work organization

Structural work organization factors primarily involved staffing and overtime allocation. Low staffing was most common job demand mentioned (9.9%), then mandatory overtime (7.3%), overtime in general (5.6%) and the on-call/standby role (4.2). Impacts from staffing shortages was described various ways: maintaining an experienced crew (5.4%), covering absences (training and sick/vacation leave) (3.1%), and providing backup during emergencies (0.5%) or turnarounds (0.5%). 13% of individuals mentioned the need to hire.

"Yes because the way we work and people off sick and vacation we do not have enough qualified people to make a strong crew at times, and management really don't care about the situation. They say being [that] everyone has passed a test they are qualified. But we have many new people that are young and do not have the experience needed if the unit would have an upset. And the short-handed we are right now my head operator and myself will work 18 hours on Thanksgiving so that will effect time with my family greatly...And I am looking at the same thing for Christmas..."

"The work schedule is easy to plan around with outside obligations. It is the not knowing if I will be off on the scheduled off days that make my work schedule negatively impact my life. The company chooses not to adequately man posts or use wage earners to fill supervisor's jobs, creating unscheduled, forced overtime. The only guarantee I have to being off is to call in sick or use my vacation days."

Psychosocial job stressors included an inability to plan (10.7%), a desire to maintain the nominal schedule (10.2%), a lack of consideration for shiftworkers by management (6.1%) and a desire for more control over their schedule (4.5%). This lack of understanding that was cited among family and friends also pertained to managers and administration (who work days): "In 30 years I have never seen a training class scheduled for a normal 40 hour a week employee scheduled on their day off (Saturday/ Sunday)." Another stated: "When was the last time you seen a benefits enrollment seminar at 3:00AM?".

Family Demands

Some respondents expressed family responsibilities that took up their available free time time: "Feel worn down quite often and when I'm off work I sleep a lot. So I'm limited when I'm

off to the hours I have to spend doing the things I need to do around my home. It is quite frustrating." Some indicated domestic responsibilities that interfered with recovery:

> "I have no problem going to sleep. My problem is not enough time to sleep. This could be attributed to 'Honey dos', balancing family finance, ect. Keeping up with your family obligations is hard due to the nature of 12 hour rotating shifts."

Others expressed diminished time for their personal life after family demands: "Personally I have sacrificed personal life for necessity to provide".

Work Life Balance

Seven point nine percent of the population commented favorably on their work schedule, with only one qualifying it by saying: "I don't mind our schedule just wish there was less over time". A larger proportion of permanent day shift workers were found in the positive comments (20% of these were day shift workers), followed by neutral comments (11.5% day shift), then slightly negative (10% day shift) and all negative (4.4% day shift) comments. Most of the day shift workers also worked shorter (8- or 10-hour) shifts. Benefits described included free time (3.1%), doing errands during the week (2%), providing support for their family (2%), having extra family time (1.4%), having a personal life (1.1%), and being able to exercise (0.3%).

> "My work schedule allows me to spend more time with my family and more time enjoying my hobbies. My exercise is usually better working shift work. I rarely miss some social or family obligations. We have a great schedule, its called the Five Four."

Several participants described the pleasure of being on the day shift, either on a temporary or permanent basis, after a history of rotating shiftwork:

"I have been on a day schedule for the 7 years and it has been a blessing. I have a social life again, I can exercise regularly, not rely on caffeine to stay awake, less irritable, better and more sex. Be home for holidays, birthdays and stay at a decent weight."

"Currently, I am on a 4/10 schedule, straight dayshift, which I really enjoy, and has really helped my quality of life. I am now able to attend most, if not all the family functions, nor am I fatigued or exhausted by the time I return home. I can actually spend quality time with my kids, instead of having to take a nap at mid-day due to an upcoming nightshift, or from lack of sleep from the previous nightshifts. Being constantly in a state of sleep debt or deprivation begins to weigh very heavily upon the mind!"

Others described various coping mechanisms to buffer the effects of the schedule. The most significant was an accommodating family or spouse, cited among 7.6%, followed by careful planning (2.3%): "We always work around my schedule, we always have a backup plan for holidays and outings.". Others described a culture of shiftwork in their family (1.1%):

"I grew up in a household where my dad shifted for 40 years so it was something I was used to seeing and my philosophy was 'get your mind right' and go to work and I had a very understanding wife/family when it came to family situations that I could not attend."

Some discussed strategies among co-workers to distribute last minute overtime shifts, sometimes with the consent of managers: "Right now we are told to find our own coverage, i.e. work something out with a coworker, don't bother the company." Using sick or vacation time to assure a day off was another coping mechanism: "The only guarantee I have to being off is to call in sick or use my vacation days."

DISCUSSION

We found that among survey respondents, the majority described work life conflict rather than balance or enrichment. Themes of WLC found primarily fell under time-based conflict, where work primarily interfered with family, but also friends, relationships, and self-care. These conflicts could be grouped under three themes: working during times others are normally off, the long work days requiring additional time away from home, and unscheduled work during planned time off (Table 4.6). Structurally inherent in shift work is the imposition of work hours onto what is normally family or social time. But we found that family and personal life conflict already present from shift work schedules was exacerbated by last minute schedule changes and unscheduled overtime shifts. The ability to exert control over work activities has previously been found to buffer the effect of work/family interference [76,69] and has been associated with greater job satisfaction and well-being [76,77]. Nearly a fourth of our study population mentioned lacking (or desiring more) control over their work schedule.

The majority of our study population were men and also fathers, and spoke often of their responsibility to provide for their families. Because much of the published research on work life balance focuses on professional women following childbirth and their pursuit of part time or flexible schedules, it is important to recognize this distinction among our study population. A phenomenon of 'pragmatic workers' identified by Emslie & Hunt (2009) considers male blue collar workers in their study of gender balance in work and home life[78]. They observed that manual workers who acknowledged the practical and financial benefit of work were better at establishing boundaries between work and home life. A boundary to protect the domestic sphere has been seen as critical in maintaining familial identities and concepts of self-worth[79], However, the inability expressed by many of our study participants to engage in meaningful activities

outside of work demonstrates the potential erosion of their personal identities outside of the workplace and a deterioration of this boundary.

Further, the lack of control they experienced at work became reinforced in their domestic life. The fact that the family also could not make commitments, or were subjected to cancellations when plans were made, brings the powerlessness of the worker into their domestic sphere. Damaging autonomy in their personal lives could create role conflict in the breadwinner identity and potentially offset the benefits provided to the family by their jobs. In comparison, professional working mothers have been seen to exert some choice over how much to work[78]. For this workforce for whom working is not a choice, individual choice normally regulated to their domestic domain is eroded by the regular imposition of work on their free time.

Strain-based conflict primarily arose from overload/fatigue, mood disorders, or loss of control. Conflict between work and home life has been associated with higher levels of psychological malaise in both men and women. Second to family conflict, we found a significant portion of respondents experienced social isolation or withdrawal. Several respondents described the need to recover for a day or two from the long days, early start times, or night shifts. Other research has associated work stress, work pace, and work-related fatigue with marital strain and social withdrawal [80,81]. Taxing experiences have been found to reduce the capacity for positive interactions with family[82]; and exhaustion, negative emotions and stress were found to be responsible for spillover into marital interactions[83]. Research on overload indicates that low energy levels and exhaustion may be a greater predictor of spillover into home life than negative affect [84]. Withdrawal may also be a necessary buffer from overload or job strain. The desire to withdraw following busy days has been identified as an attempt to return to baseline levels of emotional and physical arousal[85]. In our study population, withdrawal was

often accompanied by expressions of isolation and regret over the loss of friendships, family ties and social activities.

Limitations

This was a cross sectional study, in which it is not possible to establish causal relationships. Limitations of the study include self-reported data, low response rate, and potential for selection bias among survey respondents. Because recruitment materials advertised a health study on rotating shift work, it is likely that interested participants could have been motivated by a personal concern about shift work related health complaints. However, the content discussed in this paper (work life balance) may be less dependent on health status. As a result we anticipate that the potential selection bias for health complaints, if present, may not have as strong an effect on the results discussed in this paper. Further, although the response rate is low, it is within the range of published response rates to direct mail surveys (DMIS, 2005; Bourque & Fielder, 2011, Dillman et al, 2011).

Table 4.1 – Multi-dimensional model of Work-Family Conflict[1]

	Conflicted		Enhanced/Enriched	
	Work → family	**Family → work**	**Work → family**	**Family → work**
Time-based	Time at work interferes with family	Domestic obligations interfere with work	Work schedule facilitates family time	Family accommodates work schedule
Strain-based	Stress from work interferes with family	Stress from home interferes with work	Work relieves stress from home	Family relieves stress from work
Behavior-based	Behavior at work conflicts with family	Behavior at home conflicts with family	Behavior at work enhances family role	Behavior at home enriches work role

[1] Adapted from Greenhaus & Beutell, 1985; Carlson, 2000.

Table 4.2 - Demographics of respondents to open-ended questions (N=354)

Characteristic		N	%
Gender	Male	309	87.3
	Female	45	12.7
Race	White	250	70.6
	Hispanic/Latino	42	11.8
	Black	40	11.3
	Asian/Pacific Islander	12	3.4
	Native American	2	0.6
	Other	5	1.4
	No answer	3	0.9
Education	HS/GED	71	20.1
	Some college	156	41.0
	AA/Bachelors	136	33.0
	Graduate degree	11	2.8
Marital status	Married	268	75.7
	Divorced/Separated	40	11.3
	Single	22	5.9
	In a committed relationship	19	5.4
	Widowed	4	1.1
Children	Have no children	57	16.1
	Have children	296	83.6

Table 4.3 - Characteristics and prevalence of work life conflict among survey respondents (N of study population=354)

Work Life Conflict Dimension		No. of mentions	Frequency in pop.
Family			**0.610**
	Miss family events	109	0.308
	Miss holidays	62	0.175
	Miss home life	61	0.172
	Miss special occasions (birthdays, weddings)	122	0.169
	Can't attend children's activities	38	0.107
	Limited time for domestic duties	17	0.048
	Schedule is a burden on family	16	0.045
	Childcare conflicts	7	0.020
	Conflicts with parent/elder care	4	0.011
Social life			**0.367**
	Miss friends/socializing	42	0.119
	Don’t have a social life	22	0.062
	Lost contact with family & friends	19	0.054
	Social isolation described	19	0.054
	Stopped getting invites (can't come)	11	0.031
	Friends don't call (don't want to wake)	4	0.011
Personal life			**0.212**
	Work days too long to do anything else	23	0.065
	No personal life	20	0.056
	Miss pursuing personal interests	18	0.051
	Miss church participation	5	0.014
	No time for self care	5	0.014
	No time to exercise	4	0.011
	Miss volunteer work	3	0.008
Relationship			**0.184**
	Schedule causes strain	23	0.065
	Schedule places burden on spouse	14	0.040
	Schedule a factor in divorce	13	0.037
	Time together is limited	10	0.028
	Dating is difficult	5	0.014

Table 4.4 - Prevalence of health and mental health outcomes (N of study population=354)

Outcome		No. of mentions	Frequency in pop.
Fatigue			**0.172**
	Overload	24	0.068
	Too tired to enjoy/participate	23	0.065
	Too tired to socialize	16	0.045
	Sleep debt	18	0.051
	Need recovery time	18	0.051
	General fatigue	13	0.037
	Too tired to think clearly	11	0.031
	Sleep problems	11	0.031
	Would like to nap at work	14	0.040
Mood			**0.083**
	Down/depressed	15	0.042
	Irritable	11	0.031
	Antisocial	3	0.008
	No sex drive	3	0.008
Health			**0.045**
	General health complaint	5	0.014
	Chronic disease	5	0.014
	Weight gain/diet	4	0.011
	Aging prematurely	2	0.006

Table 4.5 - Stressors contributing to work life imbalance (N of study population=354)

Stressor		No. of mentions	Frequency in pop.
Work Organization Factors			**0.223**
	Understaffed	35	0.099
	Mandatory overtime creates conflict	26	0.073
	Overtime is difficult	20	0.056
	On-call/stand-by on days off	15	0.042
	Can't use sick or vacation time	5	0.014
Job Stressors			**0.294**
	Unable to plan	38	0.107
	Wants to maintain original schedule	36	0.102
	Lack of consideration for shiftworkers	18	0.051
	Would like some control over schedule	16	0.045

Table 4.6 - Dimensions of Work-Family Conflict found in Study Population

	Conflicted		Enhanced	
	Work interferes with family	**Family interferes with work**	**Work enriches family**	**Family facilitates work**
Time-based	Working when others are off/Off when others are working			
	Misses occasions Weekend work Works holidays	May request schedule changes	Weekday errands Kids activities	Planning Accommodation
	Extended shifts			
	Long days Away in the morning Miss routine activities	Special childcare arrangements	Compressed schedule = free time	Stay at home spouse
	Night work			
	Away at night Sleeping during day	Kids interfere with day sleeping	Home in the day	
	Overtime			
	Unscheduled overtime On-call/standby Cancels plans Unable to plan	Domestic duties take up recovery time	Increased household income	
Strain-based	Overwork/overload Fatigue	Family demands		Expects standard of living
	Anxiety/depression Irritability Apathy/burnout			
	Loss of control			
Behavior-based	Vigilant work			Breadwinner role
	Work engagement			

	Day of the week																									
Schedule	S	M	T	W	R	F	S	S	M	T	W	R	F	S	S	M	T	W	R	F	S	S	M	T	W	R	F	S
2-3-2 schedule	O	D	D	O	O	N	N	N	O	O	D	D	O	O	O	N	N	O	O	D	D	D	O	O	N	N	O	O
With 27% OT	O	D	D	**D**	O	N	N	N	O	O	D	D	**D**	O	O	N	N	**N**	O	D	D	D	O	O	N	N	**N**	O
4x4 schedule	O	D	D	D	D	O	O	O	O	N	N	N	N	O	O	O	O	D	D	D	D	O	O	O	O	N	N	N
With 27% OT	O	D	D	D	D	**D**	O	O	O	N	N	N	N	**N**	**N**	O	O	D	D	D	D	O	O	O	**N**	N	N	N
Dupont schedule	N	N	N	N	O	O	O	D	D	D	O	N	N	N	N	O	O	O	D	D	D	O	O	O	O	O	O	O
With 27% OT	N	N	N	N	O	O	**D**	D	D	D	O	N	N	N	N	**N**	O	O	D	D	D	**D**	**D**	O	O	O	O	O

Figure 4.1 - Three common 24/7 rotating shift schedules in the oil industry, displayed again with the addition of 27% overtime (additional shifts noted in bold). D=day shift, N=night, O=off.

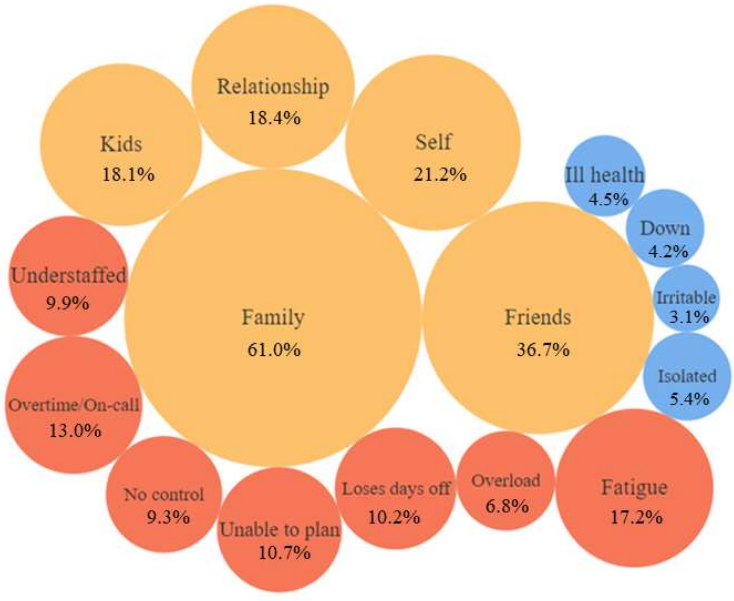

Figure 4.2 - General domains of work life conflict (yellow), stressors (orange), and health/mental health outcomes (blue). Relative size is based on frequency.

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CONCLUSIONS AND RECOMMENDATIONS

The study population as a whole exhibited a high prevalence of sleep disorders and work life conflict, and reported average overtime rates of 27% (with some overtime rates exceeding 100%). Sleep durations were lower than national averages and below other published research on shiftworkers. Sleep quality scores were within the range of severe clinical sleep disorders. Poor sleep quality and quantity correlated with health outcomes associated with shiftwork, including hypertension, GI illnesses, anxiety and depression. Mandatory overtime rates were associated with job stress, low morale, and low personnel coverage (particularly for safety functions). Mandatory overtime and on-call status were frequently mentioned as drivers for work life conflict--primarily family conflict and social isolation.

Fatigue Risk Management Guidelines

Limitations of the API's Fatigue Risk Management guidelines (RP755) were revealed in the severe sleep deficiencies reported in the study population, even among those who complied with its hours of service guidelines. Under RP755, one can work 84 hours in a single week during normal operating conditions and still meet its Hours of Service guidelines—more than double what is considered a full time work week elsewhere. In our study population, among those in compliance with RP755, some had added a 58% overtime rate to their schedule and were still within the acceptable limits. Despite the leniency of RP755, 28% of the study participants still did not meet the guidelines in the last 4 weeks, either by missing recommended rest breaks or exceeding maximum work sets. Some exceeded them excessively. Individuals with three or more violations worked an average of 61-80 hours/week during the 4 weeks monitored. Those who reported more deviations from the guidelines also reported greater job demands associated with fatigue (increased pace of work and physical exertion). These data

suggest that voluntary industry guidelines may not be effective at maintaining hours of service, and that more protective and enforceable guidelines are warranted.

Further research is needed to establish a health-based criteria for minimum rest breaks, adequate recovery periods and maximum work sets. In our study, we found that drowsiness and sleep quality were not significantly different for those in compliance with the fatigue guidelines compared to those who had one deviation, or two or more. This raises the question: what is the prevalence of fatigue for those working within the guidelines? A more detailed exploration of these data could reveal lower thresholds for fatigue within our compliant schedule group. But clinical studies assessing the impacts of these schedule conditions are also needed. We did not measure alertness, cognitive function, or physical exhaustion in relation to work demands. These outcomes are important leading indicators of fatigue related accidents. A better understanding of these interactions, testing realistic working conditions, would inform more protective hours of service guidelines.

Overtime

The majority (83%) of the study participants worked overtime during the period monitored, averaging one extra shift per week, up to a maximum of 84.25 hours per week. High mandatory overtime rates were associated with low employee morale (diminished perceptions of fair treatment, support, and safety culture, and decreased job enjoyment). Increasing rates of mandatory overtime also correlated with poor mental health. Mandatory overtime was frequently cited as a stressor in the work life balance open-ended responses, as was on-call/standby duty, which we did not measure. Participants described an inability to meet personal commitments, and having to cancel on family and friends as a result of last minute schedule changes. High mandatory overtime was associated with lower personnel coverage,

particularly for safety program functions (quality control/contractor oversight, drills, emergency response activities, and responding to process upsets). Low personnel coverage was also strongly associated with high job stress. These data suggest the need for enforceable overtime limits, and for an analysis of available staffing as part of fatigue hazard assessments.

12-hour Shift

Increased demands of the 12-hour shift were demonstrated by shorter sleep durations, higher overtime rates reported, and mentions of work life conflict. Our respondents reported less sleep on the 12-hour shift than on 8- and 10-hour shifts. Further, sleep durations we measured on the R12 schedule were approximately an hour shorter that those reported in a meta-analysis of 36 shiftwork studies that only looked at three 8-hr rotating shifts (Pilcher et al, 2000). Of particular note in the comparison to Pilcher's study, evidence of recovery (more than 8 hour sleep durations) previously provided by the swing shift has been eliminated by the two 12-hour shifts. In our work life conflict data, the long days were described by participants as limiting exercise, socializing, family time, and domestic duties. The 12-hour shift also creates a more extreme desynchrony during shift rotation. The previous three shift rotation provided a more gradual adjustment in sleeping and waking times (shifting 8 hours instead of 12). The severity of the change from a 5 am to a 5 pm start time is evidenced in the social jet lag figures we calculated. Fatigue risk from the 12-hour shift should be more carefully assessed using current overtime rates, rotation frequencies, and available recovery periods. Additional research is needed on health outcomes associated with extended shifts as well, as they increase exposure duration to other workplace hazards.

Shift Start Times

The most common shift start time for the 12-hour shift was 5 am (57% frequency), followed by 6 am (29%), 4 am (11%), 7 am (2%), and 3 am (1%). We found that as start times drifted earlier, sleep duration decreased and sleep quality deteriorated. This association has been well established in the literature. We found that sleep durations increased 19 minutes with each additional hour later in start times for the day shift. The high prevalence of very early chronotypes (estimated by their midpoint of sleep on free days, MSF) we saw in our study population could reflect an adaptation to these early start times, combined with the shorter than average sleep durations. Other research has demonstrated associations between shiftwork adaptation and morningness, revealing a possible survivor effect in our data set. When we explored associations between chronotype and sleep quality, we found that maximum sleep durations coincided with best sleep quality scores and lowest drowsiness for chronotypes (MSF) that fell between 2:30-4:30 am. Using a sleep duration of 7 hours, this chronotype would naturally wake around 7 am. Later shift start times would minimize the adjustment required for day shifts, and could facilitate improved sleep outcomes and positively impact sleep during work sets. These changes have the potential to increase alertness and productivity as well. However, the lag that occurs when transitioning to night shifts would remain.

Rapid Shift Rotation

Shift rotation was identified as a stressor among respondents and was associated with the shortest sleep durations measured: less than 5 hours of sleep was logged following shift rotations. Participants who reported sleep durations in this range also reported the most frequent drowsiness (difficulty staying awake during engaged activities 3 or more times a week). We calculated social jet lag values of nearly 7 hours when transitioning to the night shift, demonstrating the extent of desynchrony involved in shift changes. Considering this, adding

frequent shift rotation to the existing demands of a 2 shift system appears to be a dangerous combination. In the open-ended questions, we solicited suggestions from participants for schedule improvements; these data are not reported here. But relevant to these recommendations is the frequent suggestion made by participants to lengthen the duration between shift rotations. Although conclusions on this have varied in the literature, Pilcher's analysis demonstrated increased sleep durations among rotations 5 days and longer. Among our respondents, 5.5% mentioned the rapid rotations as a hardship and 15% expressed a preference not to rotate at all. Specific suggestions regarding rotation frequency included month long rotations (8.7% total prevalence), followed by 1 week (5.2%), then two weeks (2.6%), then quarterly or more (2.3%). Together this comprises nearly 25% of respondents requesting longer rotating frequencies. Overall it does not appear the diminished sleep quality and quantity we observed on the 12-hour shift is appropriate for rapid rotation, which further impacts sleep duration and function.

Work Life Conflict

In their responses to the open-ended work life balance question, 88% of participants described more work life conflict than balance. Participants described in detail numerous aspects of their personal lives that were impacted by their rotating shift schedules, including immediate and extended family, social lives, romantic relationships, and children. Of note was a theme that the hardship of the schedule was not well understood by others (including friends, their children, and management). Indeed, the fact that significant work life conflict is inherent in the nominal schedules alone seemed to be overlooked by their employers in light of the additional overtime obligations imposed. The majority of work life conflict was time-based strain arising from the nominal schedule characteristics (night, weekend and holiday work). But the addition of excessive overtime added significant strain-based conflict as well, including fatigue, overload,

and withdrawl. Many described that their available free time was consumed by trying to recover from the exhaustion of the work set, and not feeling able to. The 12-hour shift, originally intended as a compressed work week, in practice has become a means to extending it in both intensity and duration. Maintaining an adequate number of days off to provide recovery and being able to rely on scheduled days off appears crucial to the health and well-being of this workforce. Reducing mandatory overtime has the potential to improve morale and job satisfaction as well.