FATIGUE, SHIFT WORK CHARACTERISTICS, AND OCCUPATIONAL INJURY AND ILLNESS IN EMERGENCY MEDICAL SERVICES

by

Matthew D. Weaver

B.S. in Emergency Medicine, University of Pittsburgh, 2009

M.P.H. in Epidemiology, University of Pittsburgh, 2011

Submitted to the Graduate Faculty of

the Department of Epidemiology

Graduate School of Public Health in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2014

UNIVERSITY OF PITTSBURGH

Graduate School of Public Health

This dissertation was presented

by

Matthew D. Weaver

It was defended on

December 12th, 2014

and approved by

P. Daniel Patterson, PhD, NRP, Assistant Professor, Department of Emergency Medicine, School of Medicine, University of Pittsburgh

Anthony Fabio, PhD, MPH, Assistant Professor, Department of Epidemiology, Graduate School of Public Health, University of Pittsburgh

Charity G. Moore, PhD, Associate Professor, Department of Medicine, Division of General Internal Medicine, University of Pittsburgh

Matthew S. Freiberg, MD, MSc, Associate Professor, Department of Medicine, School of Medicine, Vanderbilt University

Dissertation Director: Thomas J. Songer, PhD, Assistant Professor, Department of Epidemiology, Graduate School of Public Health, University of Pittsburgh

Thomas J. Songer, PhD

FATIGUE, SHIFT WORK CHARACTERISTICS, AND OCCUPATIONAL INJURY AND ILLNESS IN EMERGENCY MEDICAL SERVICES

Matthew D. Weaver, PhD

University of Pittsburgh, 2014

ABSTRACT

The relationship between work scheduling, fatigue, and risk of injury and illness among Emergency Medical Services (EMS) workers is not well understood. Evidence in other settings suggests that work duration contributes to fatigue and increases the risk of accidents and occupational injuries. Rates of occupational injury are high. Extended shifts and overtime hours are common. Workers often report fatigue and poor sleep quality. Evidence is needed to inform policy-making and promote safety.

Shift schedules and occupational injury and illness reports were obtained for 14 EMS agencies over a three-year period. The cohort contained 966,082 shifts, 4,382 employees, and 950 total injuries. Analyses examined the association between shift length, weekly work hours, crewmember familiarity, and occupational injury and illness. An increased risk of occupational injury and illness was hypothesized for individual shifts >8 hours and ≥48 weekly work hours. The proposed mechanism for increased risk was on-shift fatigue. A systematic literature review was performed to better understand differences in prior estimates of fatigue in EMS by methodologic approach.

Risk of occupational injury and illness was increased for shifts >8 & ≤12 hours (RR 1.43; 95% CI 1.04-1.97), shifts >12 & ≤16 hours (RR 1.82; 95% CI 1.17-2.82), and shifts >16 and ≤24 hours (RR 2.29; 95% CI 1.52-3.46), compared to shifts ≤8 hours in duration. There was no increase in risk of occupational illness or injury with increasing weekly work hours. Crewmember familiarity was not associated with the outcome. Nightshift work was protective.

Shift length is associated with occupational injury and illness in this cohort. As shift length increases, the risk of workplace injury and illness increases. These findings are based on observational data and are not generalizable to all EMS agencies. Evidence should be used to justify comprehensive prospective study.

These projects are significant to public health. Calls for research were addressed from the National Occupational Research Agenda and the National EMS Advisory Council, government bodies who identified gaps in the knowledge of these issues. These data may serve as a foundation for future studies to inform decision-making at EMS agencies nationally and protect the health of the EMS workforce.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

Work on this research was supported in part by a grant from the National Institutes for Occupational Safety and Health (NIOSH) at the Centers for Disease Control and Prevention (CDC), grant # 1R21OH010025-01A1: Principal Investigators (Patterson & Yealy).

This work would not have been possible without the support of the University of Pittsburgh, Department of Emergency Medicine, or the valuable insights and encouragement from members of my committee.

For Trang, my strength and love.

1.0 INTRODUCTION

Recent reports have called attention to the safety of Emergency Medical Services (EMS) workers and the high rate of injury in this setting. There is reason to believe that scheduling and shiftwork may contribute to fatigue and safety. This research study will advance our current understanding of the relationship between work scheduling, fatigue, and risk of injury and illness among EMS workers.

There is a considerable body of evidence in other settings to suggest that work duration contributes to work-related fatigue and increases the risk of medical error, adverse events, and occupational injury.[1-5] Preliminary evidence suggests this problem is also prevalent in EMS.[6] The EMS community has recognized this evidence and identified the need to determine the ideal shift length and rest intervals for the EMS workforce. Four essential questions have been outlined that require answers to support future policy-making decisions.[7] This dissertation addresses two of the four essential questions. First, "Do extended shift structures in EMS result in fatigue and/or negative safety outcomes"? This question will be addressed directly from multiple angles in Aims 2 and 3 of this dissertation, using several years of data from a diverse set of agencies across the United States. Second, "How common is it for EMS providers to be fatigued while at work? What is the magnitude of the problem?" This question will be addressed in the work related to Aim 1 of the dissertation.

EMS workers are at high risk for occupational injury. The rate of occupational fatalities (6.3 per 100,000) is over 60% higher than the general public (4.0 per 100,000) by the most conservative estimate, and has been reported as high as 2.5 times the rate of the general working public.[8,9] In one specific sector of EMS, helicopter EMS or HEMS, the rate of fatal occupational injury has been estimated at 113 per 100,000 employees.[10] Non-fatal injuries are common. There are approximately 20,000 non-fatal injuries reported each year.[8,11] The rate of non-fatal injuries requiring time away from work is 350 per 10,000 FTE, three times the rate of all private industry occupations.[12] The cost of injuries is estimated to be $250 billion annually in the general US workforce.[13] The rate of non-fatal injuries is disproportionately high in EMS even when compared to other public safety sectors, such as police or fire.[14] This burden of injury is significant and impacts a considerable proportion of the estimated 1 million EMS workers nationally.[15]

Shift work refers to "any arrangement of work hours other than standard daylight hours", commonly limited to hours between 7 a.m. and 6 p.m.[16,17] Approximately 20% of all workers are described as shift-workers.[18] EMS workers are shift-workers by necessity to meet need and demand 24 hours each day. Shift work has been associated with a multitude of detrimental health effects, including coronary heart disease, decreased kidney function, and obesity.[19-21] Shift workers commonly report worse sleep than standard day workers, even after exiting the workforce.[22] Shift work has also been shown to directly alter sleep, fatigue, and alertness and it is believed that many of the health and safety risks linked to shift work are the result of fatigue-related performance decrements.[18,21,23,24] Aims 2 and 3 of this project will investigate the association between shift structure and occupational injury in EMS. This investigation is focused on an evaluation of a large dataset containing nearly 1,000,000 shift records and 1,000 injuries. This dataset represents the largest source of information on this topic to this point available in the EMS population.

This project is seen as needed by government stakeholders as it seeks to address the stated priorities of two independent government agencies. The National Occupational Research Agenda (NORA), National Public Safety Agenda highlighted the public health significance of these issues in 2009 by reporting the following as Strategic Goal 15: “Identify and implement effective policies among EMS agencies regarding work organization factors to reduce related illnesses and injuries”. Intermediate Goal 15.1 goes on to specify, “Develop effective guidelines to reduce worker fatigue and occupational stress among EMS personnel”. Furthermore, Activity/Output Goal 15.1.1: “Fatigue from work schedules in EMS – Identify the extent and severity of adverse health outcomes such as job fatigue and sleep disorders that may be associated with shift work, overtime, and other factors among EMS personnel”. These goals were targeted for completion by 2012.[25] Concern for injuries due to fatigued EMS workers has also been voiced by the National EMS Advisory Council, who issued a call for the Department of Transportation’s Office of EMS to address fatigue as a threat to worker and patient safety.[26]

This analysis is limited to the EMS population. While EMS does have unique risk factors for injury, the findings from this work may be generalizable to other populations. This work will also expand the understanding of the impact of shift structure on hard outcomes such as injury – findings that will translate to other occupational injury settings as well.

The project to be described in detail utilizes a cohort of shift records and occupational injury and illness reports from 14 EMS agencies across the nation. In Aim 1, the literature is reviewed to better understand the measurement of fatigue and sleepiness in EMS settings. In Aim 2, the cohort of shifts is examined to determine the association between weekly hours of work and reported occupational injury or illness. The final aim tests the relationship between shift length and occupational injury or illness.

2.0 OVERARCHING BACKGROUND

2.1 WHAT IS EMS?

Emergency Medical Services (EMS) is a branch of public safety that responds to medical emergencies reported to 911 dispatchers. It is a system of care and transport characterized by rapid response, stabilizing treatment of life-threatening injury or illness, determination of an appropriate facility where definitive treatment can be obtained, continued care throughout the transport, and then a comprehensive handoff to nurse and physician caregivers at the hospital. The workload is difficult to predict. EMS workers will be sent to help if a motor vehicle accident occurs on the roadway, if a sudden onset of chest pain occurs in the home, or if a patient requires assistance in traveling to regular dialysis appointments.

EMS workers respond to emergencies 24 hours per day, 7 days a week. A multitude of factors including setting, structure, ownership strategy, and available resources of the agency, all combine to create a unique and unpredictable work experience across agencies. A theoretical example of work demands is shown below. (Figure 1)

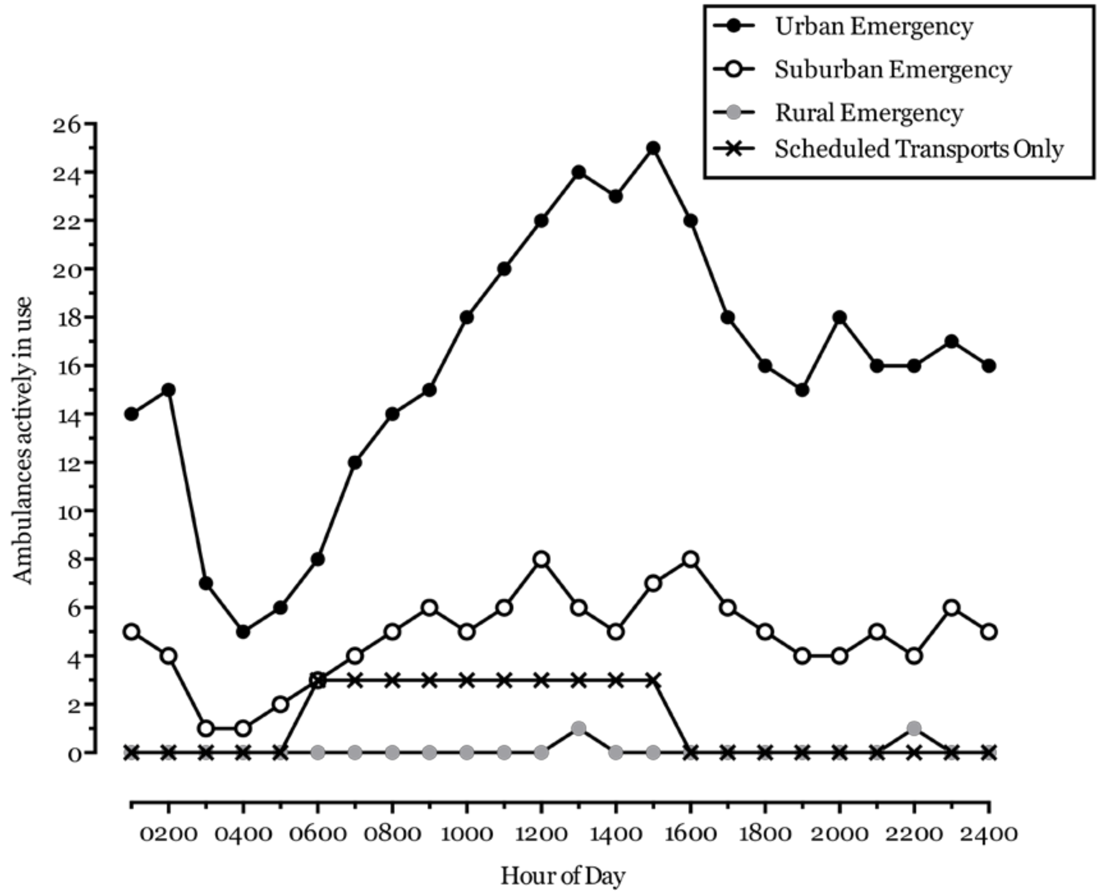


Figure 1. Example of variation in work demands across agency characteristics

EMS workers operate under the license of a physican who provides medical direction for the agency. These workers have varied levels of training, responsibilities and scopes of practice across agencies and regions, as well as at the discretion of their medical direction. Basic-level training presently involves approximately 120 hours of classroom education. These workers may operate an ambulance, deliver oxygen, assist with delivery of medication, and provide first-aid. Paramedic-level training is currently over

1,000 hours of classroom education. The scope of practice for paramedics includes electrocardiogram interpretation, obtaining intravenous or intraosseous access, medication administration (including narcotic and vasoactive medications), endotracheal intubation, and other invasive procedures.[27]

2.2 WHAT IS SHIFTWORK?

Shift work refers to “any arrangement of work hours other than standard daylight hours”- standard daylight hours being commonly understood as hours between 7 a.m. and 6 p.m.[16,17] Shift work is prevalent in industries and occupations where “around the clock” coverage is required. Alterman et al. used data from the 2010 National Health Interview Survey (NHIS) to calculate the prevalence of shift work in the United States.[28] They characterized an alternative shift structure as anything other than regular day shift. By this definition, 28-30% of the general working public was engaged in shift work in 2010. The prevalence was higher in healthcare - between 30% and 41% of healthcare practitioners and healthcare support staff reported shift work at their primary workplace during the same time period.

In professions requiring 24-hour availability, at least some people must engage in shift work to fulfill workforce needs. The optimal number and length of shifts is an interesting and multifaceted problem. Shorter shifts may permit employees to perform at a high level throughout the entire duration of the shift and thus may be safer. In industry, short shifts have been associated with individual productivity and job satisfaction.[29] Short shifts, however, require more workers to be hired and trained to fulfill workforce needs. Longer shifts in general allow for a smaller overall workforce, thus lowering overhead benefit costs.[30] Longer shifts may introduce a greater risk of fatigue-related performance deficiency.[31] These extended shifts likely require more preparation on the part of the worker to arrive capable of working for an extended period. Extended shifts also require a comparatively longer duration of downtime after the shift for recovery purposes, particularly if the shift involves nighttime work.[32]

2.3 SHIFTWORK AND SAFETY OUTCOMES

There is substantial evidence that suggests shift workers more often experience undesirable health outcomes when compared to day workers. Shift work has been linked to cardiovascular disease, diabetes, stroke, cancer, and various other chronic conditions; likely moderated to some extent by the adoption of harmful health behaviors such as smoking and poor nutrition.[33-38]

Shift workers report worse sleep than day workers, even after the shift workers have entered retirement.[22] It has been posited that shift work may have a multiplicative effect on fatigue.[39,40] Shift workers report more sleepiness while driving to and from work, and also have been linked to an increased likelihood of a motor vehicle accident on their work commute.[41] Fatigue and sleepiness have been associated with accidents, workplace injury, and medical error.[42,43]

Shift work has been linked to injury across a variety of workplace settings. A ten-year national study of workers in Canada detected an excess risk of workplace injury of 14% for women and 8% for men attributable to shift work.[44] Violanti et al. noted a 72% increased risk of injury among urban police officers on night shift relative to day shifts.[45] Folkard and Lombardi reviewed the shift work safety literature in 2006. They noted that the risk of injury varied across shift in nearly all published studies, with risk of injury elevated for non-day shifts.[46]

Workplace safety may be compromised as shift length increases. Folkard and Tucker observed twice the risk of workplace accident after 10 hrs on-shift.[47] Rosa showed a three-fold increase in risk of accident after 16 hrs on-shift.[48] Other efforts focus on the long-term perspective. Vegso et al. designed a case-crossover study to test this viewpoint. They demonstrated an 88% increased risk of injury among workers who exceeded 64 hours of work in the week preceding the shift under study, compared to a standard 40 hour work week, and noted that hours worked prior to the injury were significantly greater than hours worked in the control week.[49]

In-hospital provision of medical care is delivered by healthcare shift workers. Some stakeholders have campaigned to limit work hours by healthcare workers to promote patient safety. The European Union limits the maximum hours of work in a week to only 48 hours, with a maximum of 10 consecutive hours of work at a time, and at least 11 hours of required rest between shifts. Hours of work for healthcare providers were largely unregulated in the United States for many years – particularly in the case of physicians in training. In some instances, resident physicians worked 100 hours per week, or 36 consecutive hours at a time. In 2003, the Accreditation Council for Graduate Medical Education (ACGME) governed the hours of work for medical residents, restricting the average hours of work per week to 80 hours and the number of allowable consecutive hours to 24. One day off entirely is required each week.[50]

A seminal study by Landrigan et al evaluating a randomized assignment of these restrictions reported nearly 6 times as many diagnostic errors and a 36% increase in serious medical errors with unrestricted scheduling compared to ACGME compliant schedules.[51] Prospective study of the changes in the decade since have been mixed, with two recent reviews suggesting low quality evidence with equivocal results.[52,53] Some research does suggest shift length can have a downstream impact on patient-centered outcomes. In a sample of 22,275 nurses, 577 hospitals, and four states, patients were less satisfied with care when the hospital employed higher proportions of nurses working shifts of 13 or more hours.[54]

Few efforts have sought to evaluate the impact of work hours and shift length on accidents and injuries in a healthcare setting. Barger et al published an investigation on this topic in the New England Journal of Medicine. They surveyed over 2,000 resident physicians nationwide about hours of work, shift length, and falling asleep when they did not intend to.[55] A “near-miss” or an actual motor vehicle crash while traveling home was more than twice as likely after a 24 hour shift, compared to a shift of shorter duration. In fact, for every 24-hour or longer shift, the monthly risk of motor vehicle crash increased by 9%.

Other characterisics of shift work – including night work and recovery hours – distinguish shift work from regular day work. Researchers were able to analyze over 7,000 injuries occurring to hospital employees in Oregon over a 7-year period. Relative to day shifts, evening shifts increased risk of injury 81%, and night shifts increased risk 59%.[56] After controlling for weekly work hours and shift length, non-day work was associated with greater than 50% increased odds of injury in a different population of nurses as well (OR 1.54; 95%CI 1.07-2.24).[57] Eldevik surveyed over 1000 nurses in Norway about time off between work shifts. Less than 11 hours of rest between shifts was associated with sleepiness, fatigue, and shift work disorder.[58]

2.4 WHAT DO WE KNOW ABOUT SHIFT WORK IN EMS?

The shift work literature in the EMS setting is limited. There are few research efforts that have sought to examine this topic. The Longitudinal EMT Attribute Demographic Study (LEADS) is a 10-year, longitudinal survey of nationally registered EMS providers. The LEADS survey found that EMT-Basics were available for EMS response a median of 48 hours per week, while EMT-Paramedics were available for 52 hours per week.[59] This estimate is the most robust available (a national sample of >100,000 providers), but is difficult to interpret. The work hours are not stratified by volunteer status. Many EMS workers nationally are volunteers, meaning they are generally unpaid employees who could be at their homes and respond to the station only if a call occurred in the service area. There is likely variation in the interpretation of this question depending on the volunteer status of the respondent.

It is common for EMS providers to work multiple jobs. A cross-sectional survey of EMS providers in Washington state estimated that between 42% of all paramedic fire personnel maintained outside employment, logging an average of 25 hrs per month at their second job.[60] The same effort derived sleep disturbances as the factor which contributed the most to occupational stress in their sample. In another survey of 511 EMS workers nationally, 34% reported actively working at more than 1 EMS agency.[6]

Scheduling practices vary widely, but the most common shift lengths in EMS are 12 or 24 hours in duration. In our study of 511 EMS workers, approximately 50% (48.5%) of respondents reported working 24-hour shifts, while 38.4% reported working 12-hour shifts.[6]

It is commonly believed that rural agencies are more likely to schedule shifts of 24 hours or longer duration. An increased prevalence of extended shifts in rural areas may be necessary to provide 24-hour coverage with smaller workforces. The actual distribution is not clear. Chng et al. found, among 425 conference attendees in Texas, 40% of urban attendees worked 24-hour shifts, compared to 31% of rural attendees.[61]

Studies of shift length specifically in EMS are sparse. Allen et al. compared the endotracheal intubation success rates of Air Medical providers for 12-hour and 24-hour shifts after an organization wide change in shift length.[62] They concluded that since success rates were not different before and after the change, they psychomotor agility of providers was not affected by increasing shift length from 12 to 24 hours. Thomas et al. similarly found no difference in cognitive performance for 12 vs. 18 hour shifts in a population of 10 flight nurses.[63] In another study, 511 EMS providers nationally were administered a cross-sectional survey on sleep, fatigue, and safety.[6] The results indicated the proportion of providers considered to be fatigued was highest among those working 24 hour shifts. Boudreaux et al. performed a before and after study at a small EMS agency, administering a series of stress and job satisfaction surveys before and after eliminating 24 hour shifts and replacing them with 12 hour shifts.[64] They found that personnel viewed the 12-hour schedules more positively and described less disruption in their social lives, but this positive viewpoint did not remain 12 months later.

Five years of EMS patient care report (PCR) summary data from the state of Mississippi were collected to perform an analysis of the impact of fatigue on performance measures.[65] The researchers attempted to reconstruct shifts for providers based on periods of inactivity. When an EMT was active (listed on a filed PCR) marked the start of a shift. They then looked at the next instance of activity. When 10 consecutive hours of inactivity had passed, they marked the end of the shift. They used this characterization to make two categories of shift length, 12 and 24 hours (described as short and long). Shift length was treated as the exposure, and the primary outcomes of the analysis were response time and the number of interventions performed during the transport. They determined that response times were prolonged when the providers were on the nighttime portion of 24-hour shifts, and fewer interventions were performed as well.

Pirrallo et al. used LEADS data to evaluate the prevalence of sleep problems in EMS workers nationally.[66] They noted that sleep maintenance disorder was more common in providers working 24-hour shifts, those working more than 40-hours in a week, and also providers working in rural areas. We had observed an association between shift length and fatigue, with providers working longer shifts reporting a higher prevalence of severe fatigue, but this association resolved after adjustment for confounding variables.[6]

Sofianopoulos reviewed what is known regarding the effects of shift work on sleep among prehospital providers.[67] Twelve articles were identified using the following search terms (mesh if available, otherwise keyword): shift work, sleep disorder, sleep deprivation, circadian rhythm, fatigue, and occupational stress. This review is a suitable introduction to what is known regarding the sleep quality of EMS providers, however, the authors comment little on shiftwork. Shift work is not mentioned in the title or abstract of any of the studies included in the review. It is implied that the findings are a direct result of shift work, and recommendations are made as a part of the review. The authors conclude that 1) Scheduling and sleep are important, 2) Clockwise rotation of shifts may be undesirable, 3) Napping before, during, and after night shifts increases performance and reduces fatigue.

2.5 PROVIDER SAFETY IN EMS

The delivery of prehospital emergency care by EMS workers is physically and mentally demanding. In contrast to many other occupations, the need or demand for prehospital care is not scheduled, and the amount of physical or mental work required for each patient is unpredictable. EMS workers must possess both physical strength and aerobic capacity to safely access and extricate patients. An EMS worker relies on core strength and flexibility to move patients.[68] Many EMS workers, however, are at risk of a non-fatal injury due to poor physical health and conditioning.

The rate of occupational fatalities in EMS (6.3 per 100,000) is over 60% higher than the general public (4.0 per 100,000) by the most conservative estimate, and has been reported as high as 2.5 times the rate of the general working public.[8,9] Driving with lights and sirens is the most common cause of fatal injury.[9] In one specific sector of EMS, helicopter EMS or HEMS, the rate of fatal occupational injury has been estimated at 113 per 100,000 employees.[10]

Non-fatal injuries are common. There are approximately 20,000 non-fatal injuries reported each year.[8,11] The rate of non-fatal injuries requiring time away from work is 350 per 10,000, three times the rate of all private industry occupations.[12] The cost of injuries is estimated to be $250 billion annually in the general US workforce.[13] The rate of non-fatal injuries is disproportionately high in EMS even when compared to other public safety sectors, such as police or fire.[14]

EMS is a high-risk subset of shift workers with regard to occupational injury. There are few similar jobs where the environment is uncontrolled and the work is physical in nature, often with just a single partner for assistance in lifting and moving patients. Despite this, there are few studies of occupational injury in the EMS setting. (Table 1) Reichard et al studied EMS workers and found 99,400 injuries between 2003 and 2007 that resulted in treatment at an emergency department.[8] The injuries were most commonly sprains or strains (38%) and often to the neck or back (31%). Another survey of 2,367 EMS workers in the US and Canada in 2010 and 2011 found that nearly half (45.8%) reported sustaining an injury during their shift during the previous 3 months. [69] The injuries occurred most commonly while lifting or moving a patient, seemingly consistent with the findings from Reichard et al.

Patients can pose additional hazards for EMS worker safety. The National Study to Prevent Blood Exposure in Paramedics surveyed 2,664 paramedics and noted that exposure to blood occurred 6 times in every 10,000 calls.[70] More than 60% of EMS workers in one system in California were assaulted while at work.[71] The finding is not unique to that system, as approximately 9% of all patient encounters were characterized as violent by Grange et al, and Mock noted that the rate of violent patients to be 1 out of every 19 calls.[72,73]

Table 1. Summary of literature studying occupational injury in EMS

Title	Author	Year	Design	n	Relevant Findings
Evaluation of the injury profile of personnel in a busy urban EMS system	Hogya & Ellis	1990	Retrospective cohort	254 injuries (1 Agency)	EMT-B, young age at increased risk
Review of accidents/injuries among emergency medical services workers in Baltimore, Maryland	Gershon et al	1995	Retrospective cohort	226 reports (1 Agency)	Fatigue was considered a factor in two incidents (1%)
Occupational fatalities in emergency medical services: A hidden crisis	Maguire et al	2002	Retrospective cohort	114 fatalities (FARS)	12.7 fatalities per 100,000 EMS workers 5.0 fatalities per 100,000 general workers
Occupational injuries among emergency medical services personnel	Maguire et al	2005	Retrospective cohort	489 reports (Two urban agencies)	34.6 injuries per 100 FTE
Health status in the ambulance services: a systematic review	Sterud et al	2006	Systematic Review	49 studies	"Surprisingly few studies have investigated physical health, especially musculoskeletal complaints, of ambulance workers"

Table 1. Continued

On the job illness and injury resulting in lost work time among a national cohort of emergency medical services professionals	Studnek et al	2007	Panel Study with cross-sectional analysis	1,862 workers (LEADS)	8.1 per 100 FTE rate. Injury associated with increasing call volume, urban environment, and history of back problems. Reported sleep problems not associated with injury.
Characteristics of emergency medical technicians involved in ambulance crashes	Studnek & Fernandez	2008	Case cohort	1,775 respondents (LEADS)	Odds of involvement in an ambulance crash significantly higher for those reporting sleep problems
Occupational injuries among emergency responders	Reichard & Jackson	2010	Retrospective cohort	21,900 reports (NEISS)	3.0 per 100 FTE rate of injury requiring treatment
Association between poor sleep, fatigue, and safety outcomes in emergency medical services providers.	Patterson et al	2012	Cross-sectional	511 workers	Fatigue associated with self-reported occupational injury
The association between EMS workplace safety culture and safety outcomes	Weaver et al	2012	Cross-sectional	416 workers	Lower safety culture scores associated with higher likelihood of self-reported injury. 16% report injury in previous 3 months.
Injuries and fatalities among emergency medical technicians and paramedics in the United States	Maguire et al	2013	Retrospective cohort	21,749 reports (DOL, BLS)	3.5 per 100 FTE rate resulting in lost work time.

2.6 IS THERE RESEARCH INVESTIGATING BOTH SHIFTWORK AND PROVIDER SAFETY IN EMS?

Varying rates of occupational injury are observed across different patterns of shift work in a variety of settings, including in-hospital nurses.[74] In EMS we know very little about the relationship between shift work characteristics, fatigue, and safety outcomes such as injury.[7] There are four studies which specifically report on both elements of shift work and occupational injury.

First, in 1995, Gershon et al. reviewed all accident and injury reports in the City of Baltimore over the course of 1 year. The affected individual(s) listed a cause for each reported event. In two cases (1%), fatigue was listed as the cause – one being a car accident and the other a needlestick injury.

For the second and third studies, the LEADS survey described previously was utilized. Initially, Studnek et al. examined sleep problems as a predictor variable and did not find a significant association between reported sleep problems and overall reported occupational injury.[75] Then, Studnek and Fernandez designed a case-cohort study on the same dataset; isolating as cases personnel who reported being involved in an ambulance crash. They noted that the odds of being involved in an ambulance crash were significantly higher for those respondents who also reported sleep problems.[76]

The fourth study is the Patterson et al cross-sectional survey.[6] Providers who most commonly worked 24-hour shifts were more likely to report fatigue. Providers with fatigue (≥4 on CFQ) were more likely to report recent injury (OR 2.9; 95% CI 1.8-4.6), medical error or adverse event (OR 2.3; 95%CI 1.5-3.3), and safety compromising behaviors (OR 4.9; 95%CI 2.4-9.8).[6]

The association between many characteristics of shift work and safety outcomes is not known. No EMS research has tested whether weekly work hours are associated with safety outcomes such as injury. Similarly, there have been no studies designed to examine the safety of extended shifts. This dissertation aims to address these current research needs.

3.0 MEASUREMENT OF FATIGUE AND SLEEPINESS IN EMS: A LITERATURE REVIEW

Objective This work provides a systematic review and critical evaluation of the literature on fatigue and sleepiness measurement in EMS. Differences in fatigue and sleepiness prevalence estimates are explored by measurement method and study characteristic.

Methods The following databases were searched to identify literature indexed as studying fatigue, sleepiness, or work schedule tolerance in a population of emergency medical services providers: Scopus, PubMed, CINAHL, and EMBASE. We performed secondary searches of manuscript bibliographies for relevant literature. Literature was included if the research effort attempted to quantify or measure fatigue or sleepiness in EMS providers. Literature was excluded if the study aim was to assess transient physical fatigue or fatigability, emotional exhaustion, burnout, compassion fatigue, or stress perception.

Results Nineteen manuscripts met inclusion criteria and 16 manuscripts were written in the English language and eligible for full analysis. There were nine different methods for measurement of fatigue or sleepiness in EMS providers. Only half of all manuscripts/studies reported the proportion of EMS workers classified as severely

fatigued or excessively sleepy. Prevalence estimates of severe fatigue and excessive daytime sleepiness ranged from 3% to 92%.

Conclusions Findings from this systematic review show wide variation in approaches to measurement and prevalence estimates of fatigue and sleepiness among EMS providers. Findings suggest caution be used when selecting a measurement method. The optimal measurement method is not known.

3.1 INTRODUCTION

Emergency medical services (EMS) workers are available 24 hours a day, each day of the year to aid and protect their local communities. They are a common gateway to other health care services, with patient access to the health care system often initiated by activation of emergency services. EMS workers transported an average of 19 million patients annually from 2003-2010, corresponding to 16% of all visits to the Emergency Department nationally.[77] Financial compensation is modest,[78] and many EMS personnel work multiple jobs, extended shifts (e.g., >12 hours), and overtime.[6,79] These occupational obligations and staff characteristics combine to influence the hours of work (and hours of rest) to ensure adequate staffing at EMS agencies.

Delivery of EMS requires time-sensitive decisions and rapid performance of interventions with limited information and resources. EMS personnel transport patients in extremis, after removing them from uncontrolled and stressful environments.[80] They must operate an emergency vehicle on public roadways, often driving in an unconventional manner with other motor vehicle operators in close proximity. There is most often a single caregiver or dyad of caregivers providing treatment for patients who are ill or injured, in contrast to a hospital setting, where teams of providers provide layers of support against error.[81] Delivery of care in this manner makes it important to identify areas of vulnerability to patient or provider harm and reduce risk of unnecessary harm where possible.[82]

One area of vulnerability that is not well understood is the impact of fatigue and sleep deprivation in EMS performance[7] Available evidence indicates that there is increased work-related fatigue among EMS workers.[6,7,67,83] Greater than 50% of EMS workers self-reported high levels of mental and physical fatigue.[6,83] More than one-third of workers suffer from excessive daytime sleepiness.[66] Estimates of fatigue and pathologic sleepiness, though, range widely. Further, the role of fatigue and sleepiness as a risk factor for EMS worker and patient safety is not clearly understood at this time.

Lack of data and information on fatigue in EMS may be linked to a lack of reliable and valid tools for measuring fatigue. There can be confusion between the distinct concepts of fatigue and sleepiness, and the view that these concepts are one and the same.[84] Sleepiness is generally defined as an urge to sleep, while fatigue is a subjective feeling of tiredness that can vary in intensity and duration.[18] Fatigue and sleepiness may be the result of sleep loss or sleep debt. Fatigue or sleepiness from shift work, inadequate sleep, or alteration of circadian rhythm impairs fine motor skills and performance on cognitive tasks in controlled experiment settings.[85-87] Fatigue prolongs reaction time and has been implicated as a common factor in automobile accidents.[86,88]

The larger medical community has recognized sleep and fatigue as important safety issues. The Accreditation Council for Graduate Medical Education has twice altered duty hour limits for physicians in training in hopes of improving the safety of medical care.[89] In one study, nearly half of 1,366 physicians reported a fatigue-related clinical error in the previous 6 months.[90] The physical and cognitive decrements produced by inadequate or disturbed sleep may also present a threat to the safety of EMS providers as well as the safety of the patients they treat. However limited research exists on sleep, fatigue, and factors that impact sleep and fatigue in the EMS setting.

The balance between performance and fatigue has been identified as an ethical challenge to the EMS profession.[91] At present, the evidence base for linking sleep and fatigue to poor workforce outcomes is insufficient to guide decisions on shift-length and workload risk management policies. The purpose of this study is to contribute to this discussion by systematically reviewing the literature on fatigue and sleep-related deficit in EMS. The specific focus of the paper is to describe the methods used to measure fatigue and sleepiness and to explore differences in prevalence of these issues by measurement method and study characteristics.

3.2 METHODS

In this systematic review, the databases Scopus, PubMed, CINAHL, and EMBASE were searched using the following population MeSH terms: emergency medical services, emergency medical technicians, allied health personnel, or firefighters; with either of the following fatigue MeSH terms, sleepiness, work schedule tolerance or fatigue. An article was also retrieved if the MeSH terms were applicable and fatigue or sleepiness appeared in the article's title or abstract (a complete listing of the search criteria is included in Appendix A). The search was not limited to time period or language.

The articles returned by the search were pooled and duplicate manuscripts were removed. The abstracts and titles were reviewed for relevancy. Inclusion criteria required that the manuscript be primary research (not a review) and that the manuscript attempted to quantify or measure fatigue or sleepiness in EMS providers as a primary or secondary aim. Studies of fire personnel met criteria for inclusion only if it was made clear in the description of the study population that the firefighters were dispatched to medical emergencies and had duties including medical care. Full manuscripts were acquired for final determination of inclusion/exclusion status by the first author. The references of each manuscript that met criteria for inclusion were reviewed to search for additional eligible manuscripts. Articles concerning transient physical fatigue or fatigability (i.e. CPR quality), emotional exhaustion, burnout, compassion fatigue, and stress perception were excluded. These exclusion criteria were defined a priori in effort to isolate research on fatigue and sleepiness stemming from shiftwork or sleep deprivation. Non-peer reviewed literature from trade journals and magazines was also excluded.

Elements extracted from the studies included the study design, stated purpose of the study, the setting, and the sample size. The measurement method was collected. The proportion of the study sample classified as fatigued or sleepy was also extracted.

A manuscript was considered to address fatigue or sleepiness as a secondary aim if the article met inclusion criteria but did not explicitly state its purpose to be the assessment of fatigue or sleepiness. Articles using a variety of methods to capture performance deficit (suspected to be due to fatigue or sleepiness) were collapsed into a category called neurocognitive test battery. The design of the study in each manuscript was determined by the authors when it was not explicitly stated in the methods section. In classifying study designs, cross-sectional and within subject designs (where subjects were exposed to different shift structures) were not considered prospective in nature.

Counts and proportions are reported to summarize characteristics of the sample. Data description was performed using Stata version 12 MP (College Station, TX). Figures were produced using GraphPad Prism software version 4.

3.3 RESULTS

The search process yielded 794 unique manuscripts. After review and limiting per the case definition, the final sample included 19 manuscripts. (Figure 1) The first paper on this topic was published in 1978, with interest renewed in the early 1990's and peaking in recent years. (Figure 2) Three manuscripts (16%) were published in a language other than English, prohibiting detailed review of the full manuscript. The remaining results are presented for n=16 publications. (Table 1) One-half of these 16 research efforts used a study sample from the United States. There were three manuscripts each set in Australia and Japan respectively, and the remaining 2 manuscripts used European EMS providers. One effort specifically targeted EMS workers serving rural areas.

3.3.1 Study Design & Sample Size

The 16-study sample was comprised of 4,442 subjects. The most common study designs were cross-sectional (n=6/16, 38%) and cohort designs (n=6/16, 38%). Cross-sectional studies accounted for over 2/3 of the subjects in the total sample (n=3,072/4,442, 69%). The cohort designs accounted for the second largest proportion of research subjects (n=823/4,442, 19%). There were also two panel studies – repeat respondents from national cross-sectional surveys conducted for several consecutive years. These panel studies contributed 11% of the total number of subjects (n=503/4,442). The remaining studies were within-subject comparisons of different shift lengths. There were 44 total subjects enrolled in these efforts, or 1% of all subjects in the study sample.

3.3.2 Purpose

The assessment of fatigue or sleepiness was the primary aim of the research in 5 of the manuscripts. Eleven of the manuscripts addressed fatigue or sleepiness as a secondary aim. (Table 1)

3.3.3 Instruments & Methods

There were a total of 9 different measurement techniques/tools used for assessment of fatigue or sleepiness across the 16 articles. All of the manuscripts used at least one validated measurement method in the assessment of fatigue or sleepiness. Some reports also included additional individual items related to fatigue or sleepiness that have not yet been validated. The Epworth Sleepiness Scale was the most commonly used tool

(25%). The next most frequently used tool was the Chalder Fatigue Questionnaire (19%). The Checklist Individual Strength and Standard Shiftwork Index, respectively, were each used in two efforts (13%). Studies using the CFQ, ESS, and CIS all used the same, established cutpoints for classification of excessive sleepiness or severe fatigue. In six studies (38%), an attempt was made to capture some physiologic information from the participant, such as oral temperature, grip strength, reaction time, or dexterity.

3.3.4 Burden of Fatigue and Sleepiness

Eight manuscripts reported an estimate of the percentage of their population considered fatigued or excessively sleepy. (Figure 3) Among these manuscripts, the lowest estimate of fatigue was 3%, obtained by the Checklist Individual Strength (score >76) among 194 rescue workers who had not been exposed to an air disaster. Among 334 exposed rescue workers in the same study, 12% were considered fatigued by the same measure. The highest estimate of fatigue was 92%, obtained through a single-item self-rating of fatigue in a cross-sectional sample of 60 Australian EMS providers. Other estimates of fatigue ranged between these two extremes and were based upon different instruments, the CFQ and VAS. (Figure 3) Two reports examined the frequency of excessive sleepiness using the Epworth Sleepiness Questionnaire (ESS>10). Both studies identified a similar prevalence of excessive daytime sleepiness of 30-36% in the samples, respectively.

3.4 DISCUSSION

There were 16 sources of primary research information identified in the review to inform our knowledge on fatigue and sleepiness in EMS. The majority of studies assessed fatigue or sleepiness indirectly through the use of a survey instrument. Only eight manuscripts provided an estimate of the proportion of providers with fatigue or excessive sleepiness, the other 50% of manuscripts used fatigue or sleepiness measurement for other purposes – four compared task performance across different shift length or scheduling characteristics, two manuscripts reported mean scores compared to other working populations, and the final two manuscripts reported factors associated with sleepiness scores.

The majority of studies found evidence of fatigued or sleepy EMS workers, but there is a 30-fold difference in these estimates across the studies (3% to 92%), suggesting a great deal of uncertainty regarding the burden of fatigue or sleepiness. Some of the variation in estimation of fatigue appears attributable to the method used for assessment. While estimates across survey tools varied substantially, studies on separate populations using the same tool were fairly consistent. Where a method was implemented in more than one study population, the estimate of the burden of fatigue or sleepiness never varied by more than 10%.

The most commonly used tool for the assessment of sleepiness was the ESS. Estimates of the prevalence of sleepiness from the ESS were close, ranging only from 30% to 36%. Longitudinal studies using the ESS did not report an estimate of sleepiness over time in the population, but did detect an association between lower ESS scores and better perceived health.[92] The ESS was developed in a population of subjects with sleep-disordered breathing complaints.[93] The original intent of the ESS was not to measure drowsiness, but rather, the propensity of a subject to fall asleep in eight different hypothetical situations.[94] This is unique among tools seeking to assess sleepiness, as it seeks to capture a likely behavior, not an internal state, feeling, or symptom.[95] The ESS largely addresses trait sleepiness, or sleepiness that is persistent and stable, rather than state sleepiness, which is the level of sleepiness at the specific time when the questionnaire is completed. Other measures of state sleepiness include the Karolinska Sleepiness Scale and the Stanford Sleepiness Scale.[84] The ESS tool has been widely implemented, likely due to its ease of use and minimal time necessary for completion.[18]

The lowest estimates of fatigue were consistently obtained when the Checklist Individual Strength (CIS) was used to characterize fatigue (12% & 3% in one study, and 10% in another). The CIS was developed for the purpose of chronic fatigue measurement.[96] It has demonstrated discriminant validity in an occupational setting.[97] The tool may give more weight to mental causes of fatigue than some other potential causes.[97] The chronic fatigue identified by the CIS is unlikely to be attributed to a single cause, and is likely to impact quality of life and daily activities.[84]

The Chalder Fatigue Questionnaire (CFQ) seeks to measure enduring or chronic symptoms of fatigue. It was developed in a population of general practice patients.[98] In the general population, approximately 18% of adults are considered to have severe mental or physical fatigue using this tool.[99] Two reports in this review used the CFQ to assess fatigue, and observed a 44% prevalence of fatigue in a local, convenience sample of EMS workers, and a 55% prevalence of fatigue in a national sample of EMS workers.[6,83]

The highest estimate of fatigue was obtained using a single-item measure where participants were asked if they experienced fatigue over the last 6 months (92%). Most subjects also reported that fatigue affected their work performance (88% overall). The frame of reference (recall over the previous 6 months) does not differentiate between acute episodes of fatigue or chronic fatigue. The investigators in this report also found that the single-item measure of fatigue was negatively correlated with the Pittsburgh Sleep Quality Index score, a continuous score from 0-21, with higher values indicating worse sleep quality.[100,101] A negative relationship between fatigue and sleep quality is unexpected and perhaps a consequence of an overly sensitive measure of fatigue. Single-item fatigue measures have been used in other settings, but are commonly implemented as visual analog scales or other ordinal representations, allowing for an outcome that is not dichotomous.[84] Motohashi implemented these methods in papers captured in this review, and they are commonly used as state sleepiness measurements.[84,102,103]

A meaningful, overarching goal of these works could be distilled to a determination of whether EMS providers are impaired by fatigue or sleepiness while at work. The majority of papers in this review did not attempt to measure fatigue or sleepiness during the time the respondent was at work. Variation in estimates of fatigue is likely affected by timing of measurement and historical time period they are instructed to reference. This review suggests the proportion of providers who are impaired while at work is unknown. Existing tools are also limited in this regard in that they were not designed to address this question. The CIS was designed to measure chronic fatigue.[96] The CFQ does not reference a time period for the fatigue reporting.[98] The ESS seems to address a different question, in assessing the likelihood of falling asleep in a hypothetical situation.[95]

Neurocognitive batteries do measure cognitive impairment, and they are often administered either before or after the time at risk in the studies captured in this review. However, neurocognitive batteries take time and inherently deprive the subject of cognitive reserve, limiting their utility as a form of regular momentary assessment. Braude et al. made an effort to characterize the readiness to work of providers using a computerized test battery.[104] Providers demonstrated a diminished readiness score at the end of the shift, and the readiness to work was also affected by sleep and rest. This work is an important step forward in determining, at the time providers are expected to perform their tasks and care for patients, whether a meaningful impairment is present. An unobtrusive, objective, valid measurement of fatigue that is repeated while the subject is at work would seem to be optimal.

There were 6 cross-sectional studies designed to estimate the prevalence of fatigue or sleepiness in an EMS population .Two of the studies are limited by sample size and sampling frame, and estimates of prevalence from these efforts should be viewed conservatively.[83,100] Another effort specifically examined fatigue among paramedics in rural Australia – severely limiting its generalizability.[105] The remaining three studies comprise a total of 2,743 workers, and each of these research efforts utilized a different method to measure fatigue and sleepiness.[6,66,106] Our ability to generalize these results to a large and diverse body of workers is limited. Several efforts did provide data to compare the fatigue, sleepiness, or sleep quality of EMS providers to those of normal populations or other working populations – in every case the EMS worker scores were more severe.[83,106,107]

3.5 LIMITATIONS

This review may be affected by structural limitations. Bias was reduced by ensuring the criteria for inclusion in this review were specific so that the full breadth of literature would be identified. However, in this process, some research may have been missed. It was not uncommon for fatigue to be mentioned in various studies, but the population was not specific to EMS, or it was not possible to distinguish EMS workers in the study results. One such example is an effort by Hardy et al. from the National Health Service (NHS).[108] The authors sampled from among NHS employment groups to obtain a representative estimate of the burden of fatigue across all NHS providers. EMS personnel were included in the sample, but the estimates for these providers are collapsed into a larger group inclusive of allied health professionals. Several studies were included where fatigue was measured as part of an overarching goal – commonly to compare the effects of varying shift schedules. Fatigue was measured and was a goal of the study, but the outcome was reported in terms of differences across shift schedule, not an estimate of prevalence of fatigue.

The search strategy included search terms relevant to firefighters as well as EMS providers in order to be as sensitive as possible in our search strategy. There were several research efforts that captured fatigue in populations of firefighters. Those articles were excluded unless the duties of study population specifically described patient care. Exposure to fire suppression and the call volume of a fire-only service may be sufficiently different from fire-EMS and EMS-only to require separate investigation. Those interested in fire-specific efforts could review these relevant cited works.[109-115]

3.6 CONCLUSION

There is a small and limited body of evidence to inform our knowledge of the magnitude of the problem of fatigue and sleepiness in EMS providers. The proportion of providers determined to be excessively sleepy or severely fatigued seems to largely be determined by the chosen measurement method. The optimal measurement method is not known. Future efforts should seek to characterize fatigue and sleepiness while providers are at work, and also provide comparisons to normative population data where it is possible.

3.7 FIGURES

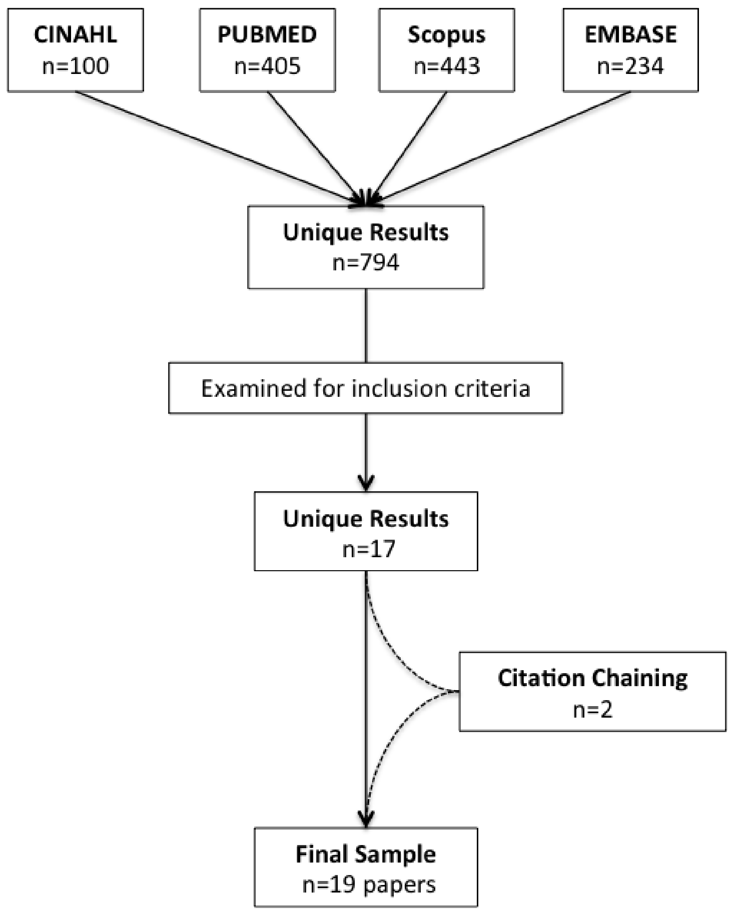


Figure 2. Flowchart of review process

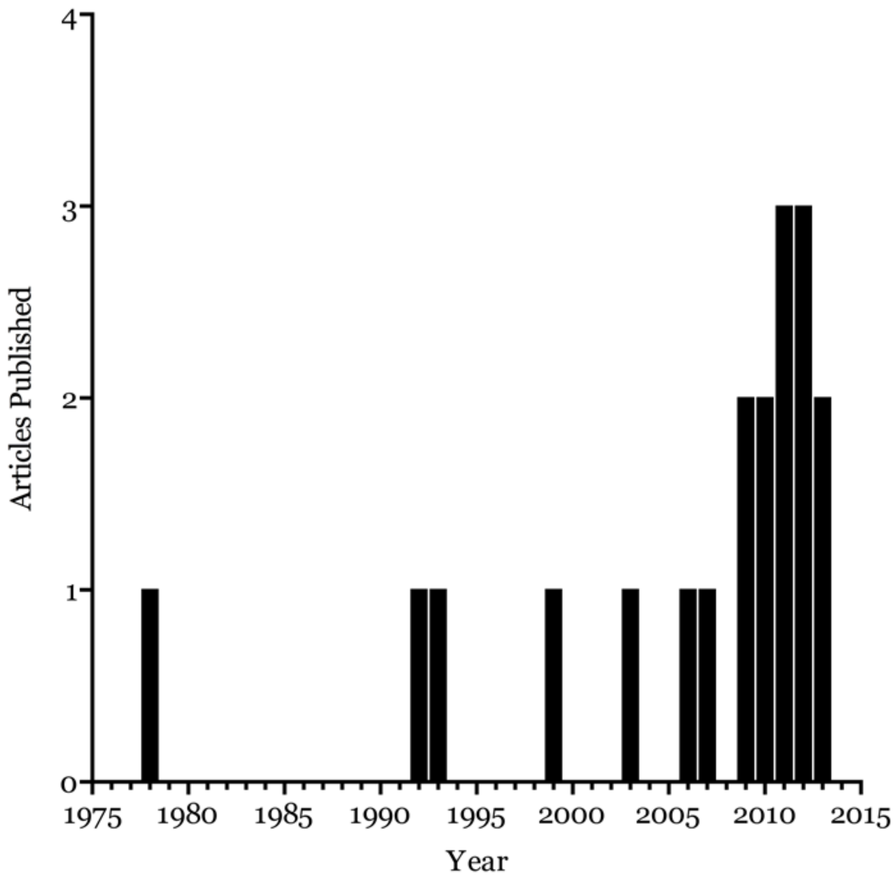
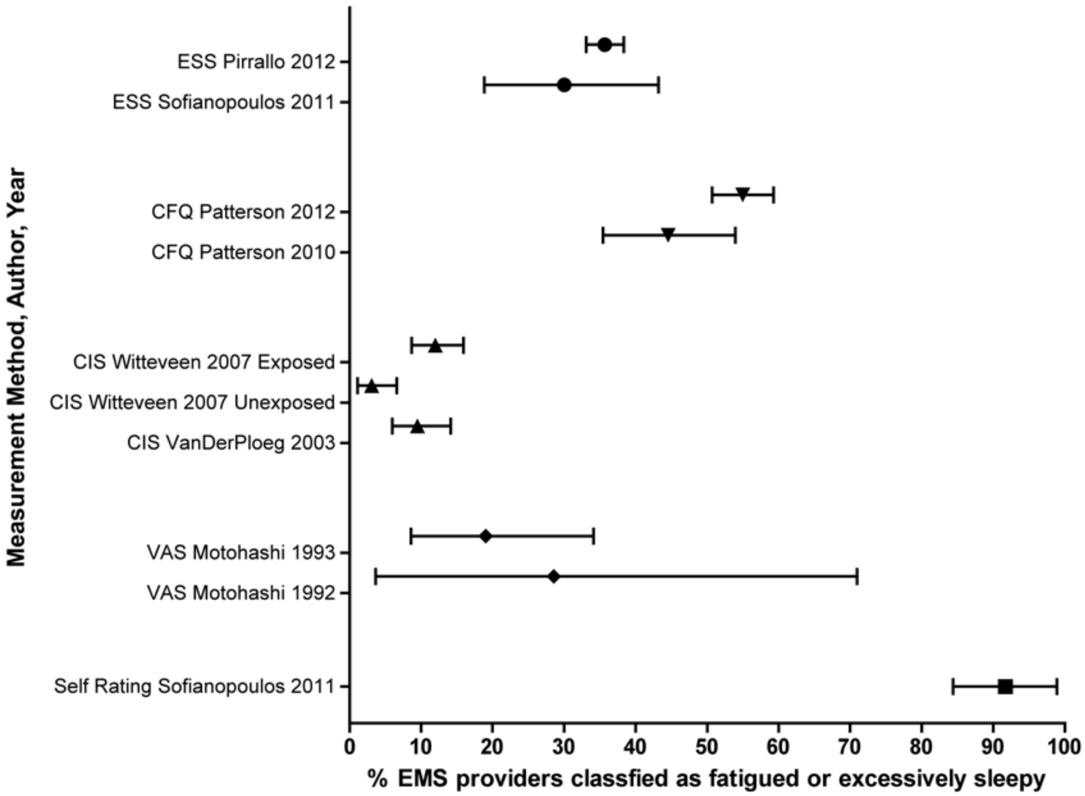


Figure 3. Trend in publications on fatigue and sleepiness in EMS workers over time



* In cases where the 95% confidence interval was not provided, the exact confidence interval was calculated from a binomial distribution using the summary statistics provided.

ESS: Epworth Sleepiness Questionnaire

CFQ: Chalder Fatigue Questionnaire

CIS: Checklist Individual Strength Survey

VAS: Visual analog scale

Figure 4. The proportion of EMS providers classified as fatigued or excessively sleepy by survey method

3.8 TABLES

Table 2. Summary of English language manuscripts which evaluated fatigue or sleepiness in EMS workers

Number	Title	Author	Year	Design	Aim	n	Primary Measurement Method
1	Alteration of circadian rhythm in shift-working ambulance personnel. Monitoring of salivary cortisol rhythm.	Y Motohashi[116]	1992	Prospective Cohort	Secondary	7	Visual Analog Scale
2	Effects of 24-hour shift work with nighttime napping on circadian rhythm characteristics in ambulance personnel.	Y Motohashi & T Takano[117]	1993	Prospective Cohort	Secondary	42	Visual Analog Scale
3	Efficacy of 24-hour shifts: prepared or impaired? A prospective study.	C Manacci et al.[118]	1999	Prospective Cohort	Secondary	15	Neurocognitive Battery
4	Acute and chronic job stressors among ambulance personnel: predictors of health symptoms.	E Van Der Ploeg & RJ Kleber[119]	2003	Prospective Cohort	Primary	123	Checklist Individual Strength
5	Sleep and cognitive performance of flight nurses after 12-hour evening versus 18-hour shifts.	F Thomas et al.[120]	2006	Within Subject	Secondary	10	Neurocognitive Battery
6	Psychological distress of rescue	AB Witteveen	2007	Retrospective	Secondary	528	Checklist Individual

Table 2. Continued

	workers eight and one-half years after professional involvement in the Amsterdam air disaster	et al.[121]		Cohort			Strength
7	Effects of a modified ambulance night shift system on fatigue and physiological function among ambulance paramedics	H Takeyama et al.[122]	2009	Prospective Cohort	Primary	10	Original Questionnaire (by the Industrial Fatigue Research Committee of the Japan Society for Occupational Health)
8	Caring for the Carers: Fatigue, Sleep, and Mental Health in Australian Paramedic Shiftworkers.	Courtney et al.[106]	2010	Cross-sectional	Primary	338	Modified Standard Shiftwork Index
9	Sleep quality and fatigue among prehospital providers.	PD Patterson et al.[123]	2010	Cross-sectional	Primary	119	Chalder Fatigue Questionnaire
10	Exploring the impact of sleep-related impairments on the perceived general health and retention intent of an Emergency Medical Services (EMS) sample	G Blau[124]	2011	Panel	Secondary	288	Epworth Sleepiness Scale
11	Perceived health as a robust correlate of perceived sleepiness in an emergency medical services (EMS) sample	G Blau[92]	2011	Panel	Secondary	215	Epworth Sleepiness Scale
12	The exploration of physical fatigue, sleep and depression in paramedics: a pilot study.	S Sofianopoulos et al.[125]	2011	Cross-sectional	Primary	60	Epworth Sleepiness Scale
13	Association between poor sleep, fatigue, and safety outcomes in emergency medical services providers.	PD Patterson et al.[126]	2012	Cross-sectional	Secondary	547	Chalder Fatigue Questionnaire

Table 2. Continued

14	The prevalence of sleep problems in emergency medical technicians.	RG Pirrallo et al.[127]	2012	Cross-sectional	Secondary	1,854	Epworth Sleepiness Scale
15	The effect of shift length on fatigue and cognitive performance in air medical providers.	FX Guyette et al.[128]	2013	Within Subject	Secondary	34	Chalder Fatigue Questionnaire
16	Caring for the Country: Fatigue, Sleep and Mental Health in Australian Rural Paramedic Shiftworkers.	Courtney et al.[129]	2013	Cross-sectional	Secondary	150	Modified Standard Shiftwork Index

4.0 THE ASSOCIATION BETWEEN WEEKLY WORK HOURS, CREW FAMILIARITY, AND OCCUPATIONAL INJURY AND ILLNESS IN EMS

Objective: Emergency Medical Services (EMS) workers are shift workers in a high-risk, uncontrolled occupational environment. Fatigue has been associated with self-reported injury in this population, but the influence of extended weekly work hours on injury risk is unknown.

Methods: A retrospective cohort study was designed using historical shift schedules and Occupational Safety and Health Administration (OSHA) 300 logs. We examined the association between weekly work hours, crew familiarity, and a recorded injury or illness.

Results: A total of 966,082 shifts and 950 OSHA records across 14 EMS agencies were obtained over a 1-3 year period. Weekly work hours were not associated with occupational injury or illness. Schedule characteristics that yield decreased exposure to occupational hazards, such as part-time work and night work, conferred reduced risk of injury or illness compared to full-time work and daytime work.

Conclusions: Neither extended weekly work hours nor crew familiarity were associated with occupational injury or illness. Future work should focus on transient exposures and agency-level characteristics that may contribute to adverse work events.

4.1 INTRODUCTION

The average weekly hours of work for all occupations in the US is approximately 39 hours.[130] As a process of scheduling or voluntary overtime, healthcare workers commonly work beyond the weekly average, contributing to shorter sleep duration, increased sleepiness, and fatigue.[131,132] Evidence links extended weekly work hours and extended shifts (e.g., ≥12-hours) to increased risks of poor worker performance, health, and safety.[133,134] Emergency Medical Services (EMS) clinicians typically work 12h or 24h shifts. Approximately half of EMS workers exceed 45 hours of work per week, with many working at more than one EMS job. More than half report work-related fatigue.[6,79,83,135] Concern for EMS shift work, shift length, and work hours has risen, due in part to recent data linking EMS worker fatigue to negative safety outcomes.[6,7] Despite these data, research on the link between EMS worker weekly hours, shift work, and occupational injury is limited.

Emergency Medical Services (EMS) workers are vulnerable to negative safety outcomes. An EMS clinician works in hazardous conditions where the workload and demands are often unpredictable. Over half of EMS workers report being assaulted at work, and 5-10% of all calls involve a violent patient.[71-73] Exposure to blood and infectious illness was reported by 20% of providers nationally in a single year.[70] Greater than 1% of EMS providers reported being involved in an ambulance collision in just a 3-month time period.[69]

Approximately 20,000 non-fatal injuries are reported each year in the EMS setting; a rate three times that of all private industry occupations.[136-138] The rate of non-fatal injuries is disproportionately high in EMS compared to other public safety sectors with similar risk profiles, such as police or fire.[139] While shift work is a known factor in safety outcomes for other occupations, its role in safety for EMS workers remains unclear.[7]

There is have reason to believe that lack of familiarity between EMS workers combined with excessive fatigue due to extended shift work may result in greater incidence of work related injury.[81,140] Communication and trust are key factors in teamwork and team performance.[141,142] When fatigued, communication and trust may be negatively affected, raising the risk of a negative outcome.[143] EMS workers have limited opportunities to develop positive teamwork behaviors due to working on average with four different partners every 10 shifts.[81,144] Lack of familiarity between teammates/partners is associated with poor performance and negative outcomes.[145-147]

The objective of this work is to determine if occupational injury is associated with weekly hours of work for EMS providers, while controlling for familiarity between EMS crewmembers (teammates). We hypothesized that increased weekly work hours would significantly increase the likelihood of occupational injury and illness.

4.2 METHODS

This study followed a retrospective cohort study design, utilizing information available from 14 geographically distinct EMS agencies with 37 individual base sites distributed across the United States. Participating organizations represent a convenience sample of organizations providing historical scheduling records and occupational injury and illness records for a period of 1-3 years. The unit of analysis was a workshift. Shifts were characterized as exposed or unexposed based on the hours of work in the 7 days preceding each shift (weekly work hours).

4.2.1 Study Protocol

Agencies participated voluntarily and provided historical administrative records of employee shift schedules and Occupational Safety Health Association (OSHA) occupational injury or illness reports. All reports were matched to specific shifts using multiple variables including date, location (agency/base site), and employee identification number. If the employee and location matched the injury record, but the shift time did not, the injury record was matched to the most proximal previous work shift as long as the shift occurred within 4 days of the recorded injury or illness. The limit of 4 days was used to maximize the likelihood that the OSHA report be matched to the shift on which the incident occurred. OSHA stipulates an injury must be recorded within 7 days. Shift records were excluded from analysis if the shift was designated for a non-clinical task, for example, work as maintenance, billing staff, or vehicle service technician.

4.2.2 Outcome Variable of Interest

The outcome of interest was OSHA-reportable work-related injury or illness.[27] We measured injury and illness using a standardized US-based reporting record of injuries, the OSHA 300 log. The OSHA form 300 log was obtained from each of the participating EMS agencies for all 37 base sites. The OSHA form contains a short, free-text description of the event along with the assignment of the event into categories of injury or illness, with several subcategories beneath the illness designation. Two investigators reviewed each reported injury or illness and determined whether or not the report met the OSHA definitions and criteria for occupational injury or illness. Reports were excluded if they did not meet the benchmark for OSHA recording. The purpose of reviewing each record was to minimize potential biases that could be present in cases of differential thresholds for reporting injuries or illnesses across agencies and individuals.

4.2.3 Independent Variables of Interest

We extracted all independent variables of interest from historical shift schedules. Cumulative hours of work in the 7 days preceding each shift was considered the primary independent variable of interest. Weekly work hours was defined as the total number of work hours over a seven-day period and measured by summing the hours of work in the 7 days prior to each shift. We treated the variable as categorical in nature for practical interpretation of the findings, as well as for comparison with prior benchmarking publications.[28] The categories of weekly work hours were <48 hrs, 48-59 hrs, and ≥60 hrs. Shifts with <48 hrs of work in the previous 7 days were considered the unexposed referent group in the cohort analysis.

Teammate familiarity was defined as the number of shifts the employee worked with the partner(s) assigned for the shift of the interest within the 8 weeks preceding the shift. The familiarity variable was categorized using quartiles. The 8 week interval was chosen based on prior literature suggesting that 8 weeks is the maximum period of recall of team interactions.[148,149]

The recovery time, or the number of hours since the end of the most recent shift, was calculated from the shift schedules. Recovery was treated as a binary variable - situations where the end of the most recent shift occurred less than 11 hours prior to the shift of interest were considered to have a short recovery periods.[58] Night hours were defined as hours of work from 10pm until 6am. The proportion of night hours was calculated as the shift duration in hours divided by the number of night hours. Part-time employees were defined in accordance with the Bureau of Labor Statistics (BLS) standard.[150] The BLS considers an employee to be part-time if their hours do not exceed 34 hours per week. We calculated the average hours worked per week for each month of the study – employees averaging at or below 34 hours per week for that month were considered to be part-time employees for all shifts within that month. The number of shifts in a month was calculated as the number of shifts worked in the 4 weeks immediately preceding the shift start date, not including the shift of interest.

Workforce size has been associated with injury reporting in other settings.[151,152] The number of unique employees working a shift during a 4-week period was used to estimate the number of workers employed by each agency. The month corresponding to the midpoint of the data collection period was used to generate this estimate.

4.2.4 Statistical Analysis

Variables of interest are described using mean and standard deviation when normality is present, and with median and interquartile range otherwise. The rate of OSHA reports was calculated as the number of reports per 100 Full-time Equivalent (FTE) per year. An FTE was defined as 2000 hours of work per year.

Multivariable mixed effects logistic models were constructed for hypothesis testing. The fixed effects were specified as hours of work in the previous 7 days, categorical quartile of familiarity of crew on the shift, recovery less than 11 hours, number of shifts in the month, and the percentage of work hours occurring between the hours of 10pm and 6am. A random agency effect was implemented to account for the clustering of EMS workers within agencies and a random worker effect to account for the correlation between repeated measures within worker. The analysis was performed using Stata version 12.1 MP, College Station, TX: StataCorp LP.

The primary outcome was the presence/absence of an OSHA reportable occupational injury or illness. A sensitivity analysis was performed to assess changes in the observed associations after excluding reports classified as illness. Reports of illness may not share the same relationship between exposure and outcome.

4.2.5 Ethical Statement

This study was reviewed and approved by the University of Pittsburgh Institutional Review Board.

4.3 RESULTS

4.3.1 Study Sample

Administrative shift scheduling and injury data was obtained from 14 EMS organizations, ranging in size from 96 to 348 EMS worker employees. Data are representative of 4,382 employees and 966,082 total work shifts (Figure 1). Total workdays varied by organization from 388 to 1,048. EMS workers in this sample averaged 39 hours of work per week (SD 17). (Table 1)

4.3.2 Weekly Work Hours

Among EMS workers in the cohort, the mean weekly work hours was 39 (SD 17) and the mean number of shifts per work week was 3.2 (SD 1.4). Over 1/3 of shifts were worked with the employee having already logged at least 48 cumulative hours of work in the previous 7 days (n=345,595), and over 10% of shifts came after 60 hours of work in the previous 7 days. (Table 2)

4.3.3 Crewmember/Teammate Familiarity

Nearly 75% of shifts (n=715,768) were comprised of a two-person crew, while 17.4% (n=168,090) were single-person assignments. Twenty-three percent of all shifts were staffed by a crew who had not worked together in the previous 8 weeks. The mean number of shifts worked together over an 8-week period was 10 (SD 10), with a median of 7 (IQR 1-19). (Table 2)

4.3.4 Injuries and Illnesses

A total of 1,128 occupational illnesses and injuries were documented by the EMS agencies. We matched 86.2% of reports to a historical work shift (n=972). After removal of non-clinical workers and review of eligibility criteria, 950 reports of occupational illness or injury were included in the analysis. The analysis was performed on 705 occupational injuries and 245 occupational illnesses. (Figure 1) Among employees reporting an injury, 27% reported multiple injuries or illnesses. The overall rate of reported injury or illness was 5.36 per 100 FTE per year, and ranged from 1.56 to 44.55 per 100 FTE per year across agencies. (Table 1)

4.3.5 Hypothesis Testing

Bivariate analyses revealed that none of the covariates of interest were associated with OSHA reports of occupational injury or illness. (Table 3) In a multivariate model controlling for other work schedule characteristics, familiarity of crewmembers, time of day, and agency size, weekly work hours were not associated with OSHA report. (Table 3)

Familiarity of crewmembers was not significantly associated with the outcome (p=0.44). Part-time worker status was protective against occupational injury or illness (OR 0.70; 95% CI 0.58-0.86). For each additional shift worked in the previous 4 weeks, the odds of an OSHA report decreased by 4% (OR 0.96; 95% CI 0.94-0.98). Results of a model excluding illnesses are very similar. (Appendix A)

4.4 DISCUSSION

In this study population of EMS workers and diverse EMS organizations, there was no association between weekly work hours, crewmember familiarity, and occupational injury or illness. Our findings differ from the general population captured via the National Health Interview Survey, which detected an increasing incidence of injury for 40-50, 50-60, and greater than 60 weekly work hours.[153] Research of 11,516 nurses, who often face similar shift work challenges to EMS, concluded that working more than 40 hours per week on average was significantly associated with work-related injuries.[154] Regarding the role of familiarity, our findings show no association between weekly work hours, familiarity, and injury. This differs from what we hypothesized based on findings from previous research.[145] To the best of our knowledge, our study is one of the first to investigate this relationship in an EMS population.

There are several potential explanations for our findings. It is possible that in the EMS setting, work-related exposures other than weekly work hours are more important drivers of adverse workplace events. The occurrence of an occupational injury or illness can be likened to Reason's Swiss cheese model of system accidents.[148] Deficits in performance due to prolonged weekly work hour may be mitigated by downstream layers of the model. Layers of defense against an injury or illness may be positive safety culture, certain agency policies, or the presence of equipment designed to encourage safety when lifting and moving patients.[155]

EMS care can be characterized as intermittent (episodic) in nature, - specifically, EMS work is episodic in that paramedics and other EMS workers perform patient care when dispatched to do so. This care is not scheduled and can be characterized as unpredictable. Care episodes are separated by periods of rest and precipitated by sensory activations such as alarms, lights, and sirens, which may encourage wakefulness.[61,156] There may be a correlation between the preferred work schedule of an individual and their tolerance to chronic partial sleep restriction.[149] Workers who gravitate to this profession may also maintain vigilance effectively in stressful situations – which may also partially explain the lack of association between familiarity and injury.[57]

We observed decreased risk of occupational injury or illness for shifts where the previous week of work included a higher percentage of night hours, and also for shifts worked by part-time employees. Workers on night shifts may be more susceptible to sleepiness, disrupted circadian rhythms, and have less oversight from management.[157] At the same time, EMS workers may receive sufficient rest during overnight shifts to maintain high performance.[158] Call volume is lowest during night hours[60] and exposure to occupational hazards most often occurs when workers are active. This is also relevant when considering the part-time worker finding. Part-time workers are potentially exposed to a lesser extent to the occupational hazards of emergency medical services work.

Shift work, fatigue, and safety are visible and contentious issues in the EMS community. This analysis contributes to the understanding of these issues by examining nearly 1 million shift records and 1,000 reports of occupational illness or injury. Our findings, while in contrast to prior efforts in other settings, raise important questions which merit further research in the EMS domain. Namely – staffing requirements and the safety of those staffing structures vary by population density, service area, and job tasks. What is a safe and sustainable amount of weekly work in each setting, assuming a given workload and cognitive demand? Also, are historical OSHA 300 log records representative of the burden of injury in a workplace? Further research should seek to utilize and grow data sources to inform these questions.

4.5 LIMITATIONS

This is a secondary analysis of administrative data.. The dataset lacks potential explanatory information on work activities, including unit hour utilization, work environment, and agency culture. Important individual confounding variables are also unavailable – such as medical conditions, dietary habits, and sleep behaviors. Previous literature suggests many EMS workers work multiple jobs.[6,79] Any hours worked outside of agencies participating in data collection are not captured in the analysis.

We consider use of a large dataset of shift schedules as one of several strengths of our study over that of previous research. This may be the largest dataset and analysis of work hours in EMS workers. Our findings suggests that EMS workers work a similar amount of hours per week (39 on average) in comparison to the general working population at their primary job (39 hours). Previous research has relied primarily on self-report and cross-sectional surveys. These prior studies suggest that EMS workers accumulate greater than or equal to 48-hours per week. Specifically, in the LEADS survey (Longitudinal Emergency Medical Technician Attributes and Demographics Study – a national survey of EMS providers constructed by sampling from providers with active national certifications), respondents were asked the number of hours they were available for an EMS response during a typical week. The median value for EMT-Basics was 48.1 hours, compared to 51.8 hours for EMT-Paramedics.[59] Several studies suggest EMS workers often maintain employment at multiple organizations.[6,83] Differences between our findings and previous research may be due to lack of capture of all EMS worker shifts. Future studies should determine how to include both secondary and self-report data to obtain the most accurate measurement of weekly work hours.

Research in other settings using OSHA 300 logs suggests that they are commonly an underestimate of the true burden of injury. The degree to which they underestimate injury rates is thought be between 20 and 70%.[159,160] The extent of underreporting varies widely across occupational setting, and has not been quantified in an EMS setting.[161] Previous studies have found that organizational safety culture is associated with injury reporting. Organizations with negative safety climate had significantly higher rates of underreporting of OSHA eligible injury or illness.[162] We have previously found wide variation in safety climate scores and safety culture as a whole across EMS agencies nationally.[123] We observed a 29-fold difference in OSHA reporting rates across the participating EMS organizations. We attempted to remove potential agency-level confounding by including a random-effect for agency in the multivariable model.

4.6 CONCLUSION

Weekly work hours are not associated with OSHA-reportable occupational injury and illness in this national cohort of EMS providers. Future research should explore the impact of momentary exposures such as unit hour utilization, transient sleepiness and fatigue, as well as incorporate information regarding agency policies and safety culture.

4.7 FIGURES

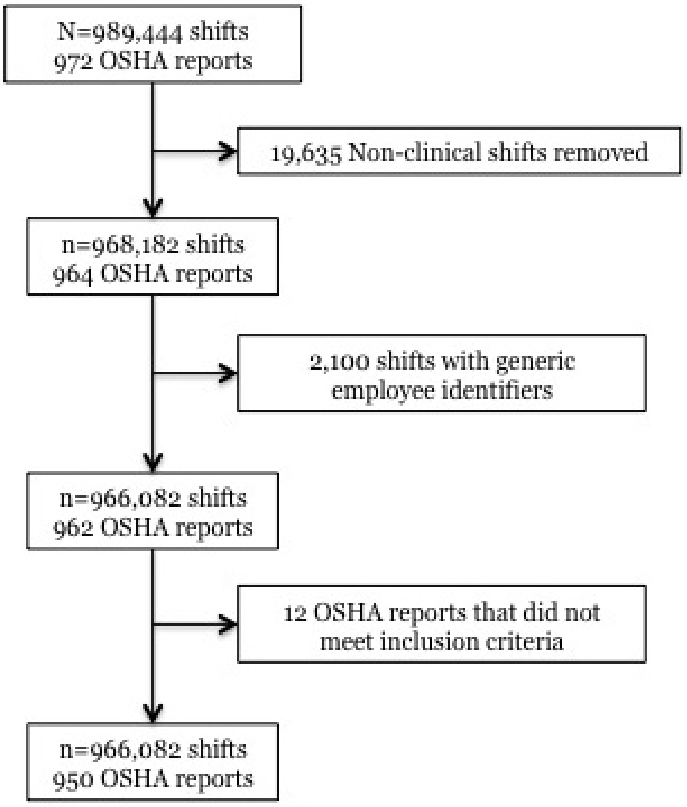


Figure 5: Data obtained and determination of inclusion in the final sample

4.8 TABLES

Table 3. Sampling frame and agency-level characteristics

	Years of data	Cumulative hours of work	OSHA reports	OSHA rate (per 100 FTE per Year)	Midpoint workforce size	Hours of work per employee per week (Mean, SD)
Location						
Agency 1	2.50	1,773,139	90	4.07	348	40.0 (15.3)
Agency 2	1.08	219,762	23	19.42	132	35.2 (14.9)
Agency 3	2.50	778,834	26	2.67	170	33.9 (11.3)
Agency 4	2.76	820,096	68	6.02	145	44.0 (20.8)
Agency 5	2.67	832,416	20	1.80	117	50.2 (20.7)
Agency 6	2.91	1,600,990	136	5.84	255	41.0 (15.5)
Agency 7	2.91	1,097,959	51	3.19	186	40.9 (14.9)
Agency 8	2.52	461,899	40	6.87	96	38.3 (12.8)
Agency 9	2.00	777,045	219	28.22	255	35.6 (19.7)
Agency 10	2.91	718,311	36	3.44	148	38.4 (17.5)
Agency 11	2.85	1,179,573	50	2.97	220	38.4 (20.9)
Agency 12	2.91	1,015,161	23	1.56	222	34.8 (13.9)
Agency 13	1.82	384,328	156	44.55	138	33.7 (14.7)
Agency 14	1.83	524,790	12	2.49	174	33.9 (19.0)
Total	34.17	12,184,303	950	5.36	2,606	38.8 (17.0)

Table 4. Distribution of covariates across exposure categories

	<48 hours (n=620,487)	48-59 hours (n=233,221)	≥60 hours (n=112,374)	Total (n=966,082)
Familiarity (past 8 weeks)				
Median (P25-75)	7 (1-20)	8 (1-19)	5 (1-17)	7 (1-19)
Hours of recovery Median (P25-P75)	19 (12-84)	12 (12-36.5)	12 (11.5-24)	16 (12-60)
Number of shifts in the month Mean (SD)	12.1 (4.6)	13.6 (4.0)	16.0 (4.8)	12.9 (4.7)
Proportion night hours Mean (SD)	0.25 (0.29)	0.29 (0.27)	0.31 (0.26)	0.27 (0.28)
Unique employees	4,382	3,562	2,810	4,382
Part-time employees	4,380	3,332	1,551	4,380
Injuries (n (%))	637 (0.10)	202 (0.09)	111 (0.10)	950 (0.10)
Injuries with work restriction only	137 (0.02)	54 (0.02)	21 (0.02)	212 (0.02)
Injuries requiring time away from work	91 (0.01)	22 (0.01)	8 (0.01)	121 (0.01)

Table 5. Mixed effects logistic regression model results

	Unadjusted OR Injury	p-Value	Adjusted OR Injury	p-value
Hours of work previous 7 days				
<48 hrs	Referent	---	Referent	---
48-59 hrs	0.93 (0.79-1.10)	0.61	0.92 (0.78-1.09)	0.36
≥60 hrs	1.04 (0.84-1.28)		1.12 (0.89-1.41)	0.33
Crewmember Familiarity				
0-1 shifts	Referent	---	Referent	---
2-7 shifts	1.04 (0.88-1.23)	0.63	1.05 (0.89-1.25)	0.54
8-19 shifts	1.11 (0.93-1.33)		1.13 (0.94-1.36)	0.19
≥20 shifts	1.12 (0.91-1.38)		1.18 (0.95-1.47)	0.15
Short Recovery (<11 hrs)	0.93 (0.76-1.13)	0.46	0.95 (0.77-1.17)	0.60
Number of shifts in a month	0.99 (0.97-1.00)	0.08	0.96 (0.94-0.98)	<0.0001
Proportion of night hours	0.80 (0.63-1.00)	0.05	0.78 (0.61-0.98)	0.03
Employment status				
Full-time	Referent	---	Referent	---
Part-time	0.90 (0.77-1.04)	0.15	0.70 (0.58-0.86)	0.001
Midpoint Agency Size (20 person units)	0.99 (0.88-1.11)	0.84	0.99 (0.87-1.12)	0.84

5.0 AN OBSERVATIONAL STUDY OF SHIFT LENGTH, CREW FAMILIARITY, AND OCCUPATIONAL INJURY AND ILLNESS IN EMS

5.1 INTRODUCTION

Emergency medical services (EMS) workers provide the public with medical care and emergent transportation across the United States 24 hours a day. Workplace injury among EMS workers is higher than the general working public and other high-risk occupations.[8,14,163] EMS work is high-risk and involves operating an ambulance at elevated speeds on public roadways, carrying heavy equipment, lifting and moving patients, and stabilizing the ill and acutely injured in settings characterized as uncontrolled.[71-73,164] EMS workers are commonly deployed in teams of two (a dyad) and work shifts of 12 or 24-hours. Recent research raises concern about the safety of EMS workers and patients, revealing a high-level of workplace fatigue and limited familiarity between EMS dyadic crewmembers.[6,81] While fatigue and limited teammate familiarity have been linked to poor safety outcomes and poor performance in a variety of settings,[134] there is limited research involving EMS workers and thus a great deal of uncertainty among investigators and EMS officials regarding the significance of shift length and crew deployment.[7,81]

The Occupational Safety and Health Administration (OSHA) defines a normal work shift as: "a work period of no more than eight consecutive hours during the day, five days a week with at least an eight-hour period of rest."[165] Most EMS workers are scheduled or deployed to work extended shifts of $\geq$12-hours. Research has linked extended shifts to adverse events, medical errors, and attentional deficits in diverse settings, including healthcare.[166] Recent research using cross-sectional survey data links EMS worker self-reported workplace injury to fatigue.[6] Shift length was not a factor in this study, yet there is ongoing uncertainty and debate on the contribution and significance of shift length, timing, and rotation in EMS workplace safety.[7] Specifically, many in EMS administration perceive extended shifts as dangerous and advocate they be eliminated.[167] Others, including EMS workers, may feel differently given a lack of research showing a direct link between shift work factors, including length, and safety outcomes, such as injury or medical error.

Of equal importance is EMS crew deployment and its association with safety. Most EMS systems deploy two crewmembers (a dyad) work staff and ambulance. In most cases, one crewmember will operate the ambulance while the second crewmember provides patient care. There is emerging body of literature that raises concern for the lack of planned deployment of EMS crews. One recent study shows that EMS workers are scheduled with 19 different crewmembers annually, with some workers scheduled with more than 50 different partners in one year.[81] Lack of familiarity between pilots and co-pilot dyadic crews has been linked to a higher rate of errors during take-off and landing versus pilot/co-pilot teams with greater teammate familiarity. Another analysis of aviation data shows that greater than 70% of accidents can be traced back to the pilot/co-pilot dyad's first flight first day together.[145] Other studies also link limited familiarity between teammates with poor performance and poor outcomes.[168,169]

Because EMS work depends on two crewmembers working well together under stressful conditions, there is reason to believe that the dangers of extended shift work combined with limited teammate familiarity pose a risk to safety. In this paper, we explore the interaction between extended shifts and teammate familiarity and the role these threats may play in EMS worker injury. The purpose of this analysis was to evaluate the impact of shift length on internal reports of occupational injury and illness in a national cohort of EMS workers. We hypothesized that the risk of injury or illness would increase with increasing shift length.

5.2 METHODS

This is an analysis of a retrospective cohort of 14 EMS agencies with 37 base sites distributed across the United States. The exposure of interest was shift length, with the outcome of interest OSHA reported injury or illness. Participating organizations represent a convenience sample of organizations providing historical scheduling records and occupational injury records for a period of 1-3 years.

5.2.1 Study Protocol

Agencies provided historical administrative records of employee shift schedules and Occupational Safety Health Association (OSHA) occupational injury or illness reports. OSHA reports were matched to specific shifts using a combination of variables including date, location (agency/base site), and employee identification number. If the employee and location matched the OSHA report, but the shift time did not, the OSHA report was matched to the most proximal previous work shift as long as the shift occurred within 4 days of the recorded injury or illness. The 4 day interval was used to maximize the likelihood that the OSHA report be matched to the shift on which the incident occurred. OSHA stipulates an injury must be recorded within 7 days. Shifts were excluded when the unit variable described a non-clinical task, for example, maintenance worker, billing staff, or vehicle service technician.

5.2.2 Outcome Variable of Interest

The outcome of interest was work-related injury or illness recorded on the agency OSHA 300 log.[27] The OSHA form 300 log from each of the participating EMS agencies was obtained for all 37 base sites. The OSHA form contains a short, free-text description of the event along with the assignment of the event into categories of injury or illness, with several subcategories beneath the illness designation. The assignment of the event into categories is performed by an individual at the EMS agency. The outcome was defined as any report from the OSHA log provided it met the following criteria: Injury: Any wound or damage to the body resulting from an event in the work environment, requiring medical treatment beyond basic first aid, or resulting in loss of consciousness or an inability to perform normal duties without restriction. Illness or Unanticipated Exposure to Illness was defined as: Any illness or exposure to infectious illness that resulted from an event in the work environment and was not prevented by the use of the personal protective equipment. Routine patient care of infectious persons in the course of duty without incident did not meet the threshold for a report and was excluded as an outcome. Each reported injury or illness was reviewed to determine whether or not the report met the criteria for inclusion as an outcome. The purpose of reviewing each record for inclusion was to minimize potential biases that could be present in cases of differential thresholds for reporting injuries or illnesses across agencies and individuals.

5.2.3 Exposure of Interest

The length of the shift was considered the primary independent variable of interest. Shift length was extracted from historical shift schedules. Shift length was treated in several ways for completeness. First, EMS agencies commonly schedule shifts of 8, 12, 16, and 24 hrs. The primary representation of the exposure in this analysis stratifies the continuous shift hours variable into these four sections: Shifts ≤8 hrs were grouped together, shifts >8 hrs and ≤12 hrs, then shifts >12 and ≤16 hours, shifts >16 and ≤24 hours, and shifts >24 hours. Shift length was also stratified into categories of 8-16, 16-24, and greater than 24 hrs, as well as 8-12 and ≥12 hrs. Next, shift length was examined as a dichotomous measure, considering shifts ≥12 hours to be extended in nature. Lastly, shift length was treated as a continuous variable.

5.2.4 Independent Variables of Interest

Teammate familiarity was defined as the number of shifts the employee worked with the partner(s) assigned for the shift of the interest within the 8-weeks preceding the shift. The familiarity variable was categorized using quartiles. The 8-week interval was chosen based on prior literature suggesting that 8-weeks is the maximum period of recall of team interactions.[148,149]

Other relevant covariates were also constructed from the shift schedules. The recovery time was calculated as the number of hours since the end of the most recent shift. Recovery time was treated as a continuous variable. Each shift was classified as overnight or not. The following were defined as overnight shifts: Shifts of at least 16 hrs duration starting at or after 3pm, shifts of at least 12 hrs duration starting at or after 6pm, shifts of at least 8 hrs starting at or after 10pm, and all shifts lasting 24 hrs or more. Any shift with a start-time ≤2 hrs after the end of the most recent shift was considered consecutive in nature.

Part-time employees were defined consistent with the Bureau of Labor Statistics (BLS) standard.[150] The BLS considers an employee to be part-time if their hours do not exceed 34 hours per week. Part-time status was determined for each shift by calculating retrospectively the average work hours for the previous 4-weeks for each shift of each employee. Thus an employee could transition from part-time to full-time status depending on their work schedule throughout the study period.

Workforce size has been associated with injury reporting in other settings.[151,152] The number of unique employees working a shift during a 4-week period was used to estimate the number of workers employed by each agency. The month corresponding to the midpoint of the data collection period was isolated to generate this estimate.

5.2.5 Statistical Analysis

The variables of interest are reported using mean and standard deviation when normality is present, and with median and interquartile range otherwise. The rate of

OSHA reports was calculated as the number of reports per 100 FTE per year. An FTE was defined as 2,000 hours of work per year.

Multivariable mixed effects logistic models were constructed for hypothesis testing. The variables of interest were specified a priori. The fixed effects were the length of the shift in hours, categorical quartile of familiarity of crew on the shift, hours of recovery, whether or not the shift encompassed overnight hours, whether the shift started within 2 hours of the most recent shift end (consecutive shift) full-time vs. part-time employment status, and the size of agency's workforce. A random agency effect was utilized to account for the clustering of EMS workers within agencies and a random worker effect was implemented to account for the correlation between repeated measures within worker. The analysis was performed using Stata version 12.1 MP, College Station, TX: StataCorp LP.

The primary outcome was the presence/absence of an OSHA reportable occupational injury or illness. A sensitivity analysis was perform to examine the association excluding reports classified as illness as they are often exposures to infectious illness, and may have a different relationship with shift length compared to that of injury. Estimates from the multivariable models were used to calculate the number needed to be exposed for one additional person be harmed (NNEH), after adjustment for potential confounders.[170]

5.2.6 Ethical Statement

This study was reviewed and approved by the University of Pittsburgh Institutional Review Board.

5.3 RESULTS

5.3.1 Study Sample

Administrative shift scheduling and injury data was obtained from 14 EMS organizations. (Table 1) Data are representative of 4,382 employees and 966,082 total work shifts. (Figure 1)

5.3.2 Shift Length

The mean shift length overall was 12.6 hrs (SD 4.40), while the median length was 12 hrs (IQR 12, 12). (Table 1) The average shift length varied across agencies. (Figure 2)

5.3.3 Injury or Illness

The overall rate of OSHA reports in this sample was 5.36 per 100 FTE per year (Table 1). There were a total of 950 reports from 677 employees. Nearly ¾ (74.2%) of reports were categorized as injuries (Table 2). One in five injuries or illnesses resulted in the individual being restricted in their normal work activities (22.3%), while 12.7% resulted in time away from work.

5.3.4 Independent Variables

The greatest familiarity was observed for shifts >12 and ≤16 hrs duration, where partners had a median of 11 shifts together in the previous 8 weeks (Table 3). Consecutive shifts were most common for longer shift length categories. Over 20% of shifts longer than 24 hours began immediately following the end of the most recent previous shift. Hours of recovery were greatest for shifts 16-24 hours, with a median of 2 days off-work prior to those shifts in this cohort. Shifts 8-12 hours in duration had a median of 12 hours recovery. Although shifts longer than 24-hours were rare, over 15% of all workers in this sample worked at least one shift of this type during the study period.

5.3.5 Univariable Models

Shift length was associated with reported injury or illness without adjustment for confounding variables (p=0.003), while teammate familiarity was not (p=0.62). A quadratic term for shift-length was not significant, suggesting a linear relationship between shift length and the outcome. Other covariates of interest, including overnight shift, consecutive shift, hours of recovery, part-time worker status, and agency workforce size were not associated with the outcome.

5.3.6 Multivariable Models

Compared to shifts ≤8 hours in duration, shifts >8 & ≤12 hours increased the risk of occupational injury or illness by 43%, and shifts 12 & ≤16 hours increased the risk by 82%. Shifts greater than 16 hours and as long as 24 hours more than doubled the risk of injury or illness. (Table 4) Characterizing shift length in other ways yielded similar results. Shifts 12-hours in duration or greater increased the risk of occupational injury or illness by 49% (RR 1.49; 95% CI 1.18-1.88). For every additional hour of shift length, the risk of injury or illness increased by 4% (RR 1.04; 95% CI 1.02-1.06). (Figure 3)

Familiarity, agency workforce size, part-time status, and hours of recovery were not associated with occupational injury or illness. Consecutive shifts also did not significantly alter the risk of occupational injury or illness. Overnight shifts were safer, demonstrating a 22% decrease in risk compared to all other shifts. (Table 4)

5.3.7 Number Needed to Expose to Observe Harm

After adjustment for other potentially confounding variables, the number of shifts needed to result in harm decreased sequentially from shorter to longer shifts. (Figure 4)

5.4 DISCUSSION

The analysis suggests an increased risk of injury and illness sequentially with increased shift duration. The effect was statistically significant for 12-hour shifts compared to less than 12-hour shifts, and the greatest risk was observed for 24-hour shifts. Shift length appeared to have a linear relationship with the outcome. (Appendix B)

The relationship between shift length and safety outcomes is poorly understood and little data exists to guide decision-making.[7] The endotracheal intubation success rates of Air Medical providers was evaluated at one organization after a change in scheduling policies.[62] Success rates did not vary by increasing shift length from 12 to 24 hours. Thomas et al. similarly found no difference in cognitive performance for 12 vs. 18 hour shifts in a population of 10 flight nurses.[63] Another effort in Air Medical providers found no difference in cognitive performance between 12 and 24-hour shifts, and also reported reduced fatigue at the end of a 24-hour shift compared to the beginning.[158] A cross-sectional survey of 511 EMS providers nationally found the proportion of severely fatigued providers was highest among those working 24-hour shifts, and that severe mental or physical fatigue was associated with injury, medical errors, and safety-compromising behaviors. Shift length was not associated with these outcomes when fatigue was also included in the model.[6]

The rate of fatal injuries in EMS workers exceeds that of the general public and transportation crashes are the most common cause.[8,12] Driving emergently relies on reaction time and judgment for safety, both of which are impaired by fatigue.[69,171] Drowsiness increases the risk of a crash 8-fold.[47] Multiple studies have demonstrated similar impairment from alcohol intoxication and sustained wakefulness.[172] Williamson and Feyer showed that reaction time for subjects who slept adequately (7 hours) and then remained awake for approximately 18 hours was the same as when those subjects were legally intoxicated.[173] Our data suggest that EMS workers may not arrive to work fully rested – obtaining 6 hours of preshift sleep on average,[170] and shifts of 18 hours or more are common. These factors combined suggest that without restorative rest, impaired mental and physical performance may be present.

EMS agencies vary widely in terms of structure, coverage area, demands for service, monetary resources, available workforce, and other factors. There is no optimal schedule to meet the needs of all potential workplaces. In many cases, adequate staffing would not be possible without extended shifts. Extended shifts that allow for restorative sleep and rest may protect against the development of fatigue and sleepiness. Frakes showed EMS providers averaged 7 hours of sleep on 24-hr shifts[79], and Guyette observed improved performance on select tasks at the end of a 24-hour shift compared to the beginning, likely aided by on-shift sleep.[158] Studies of innovative scheduling practices among EMS providers in Japan suggest that protected inter-shift rest periods may alleviate perceived fatigue.[174] However, some workplaces do not permit sleep while employees are on shift, and calls for service may preclude rest opportunities.

The evidence provided by this study is not sufficient to change current practice. These findings are early observational evidence of a preventable exposure associated with injury and illness and should be tested in a randomized design.

5.4.1 Limitations

There are several important limitations that should be considered when interpreting our results. First, this is an observational study, and the neither the exposure nor the outcome was recorded in the interest of examining the hypothesized question. No agency-level demographic information was collected. Based on the number of active employees at each agency during the study period, our sample is not representative of agencies with workforces with less than 100 employees. There is no information on call volume, rurality, or existing fatigue management systems, important factors when interpreting these results. It is possible that this sample is composed entirely of high volume non-rural agencies, where rest on shift may be uncommon or not permitted.

The social norms at participating agencies regarding injury reporting are unknown. Safety culture has been associated with injury reporting in other settings, with a higher rate of underreporting in workplaces with negative safety culture.[175] In EMS, previous research suggests higher odds of self-reported occupational injury in agencies with negative safety culture.[176] Safety culture was not available as a covariate in this analysis.

Relevant individual characteristics, such as age, sex, medical conditions, and personal lifestyle habits, were not available. The sleep habits of individuals in the study could potentially explain our findings. The number of jobs that each individual worked was not known. Many EMS workers are employed at multiple agencies simultaneously,[6,79] and the likelihood of employment at more than 1 agency may be related to the most common shift length worked. Individuals who primarily work 24-hour shifts may have greater time availability with which to obtain other employment. Multiple job holders may be at increased risk of fatigue and injury due to a combination of factors, including reduced sleep, increased fatigue, long work hours, and increased commuting time.[54]

The use of OSHA 300 logs to capture occupational injury has limitations. OHSA logs are widely believed to underestimate the burden of injury and illness, somewhere between 20 and 70%.[159,160] Underreporting may be especially prevalent among healthcare workers.[27] Evidence suggests underreporting is particularly common in instances of musculoskeletal injury and needlestick injury, among the most common injuries sustained by EMS providers.[8] Any injuries related to shift length that occurred outside of work hours were not captured. There is an increased risk of motor vehicle crash commuting to and from the workplace for extended shifts, with a 9% increased crash risk for every 24-hour or longer shift.[50,177]

The dataset lacked granularity to examine the evolution of risk over successive hours on duty. The OSHA report was matched to a shift, with no knowledge of how many hours into the shift the injury or illness occurred. OSHA reports were also matched to the most recent shift within the previous 4 days. This method assumed that the event described occurred on the most recent shift. If reporting was delayed or inaccurate the report may not be matched to the shift on which it occurred.

5.5 CONCLUSION

Extended shifts are associated with occupational injury and illness. Findings may be interpreted as preliminary evidence for a randomized, controlled trial to guide policy-making.

5.6 FIGURES

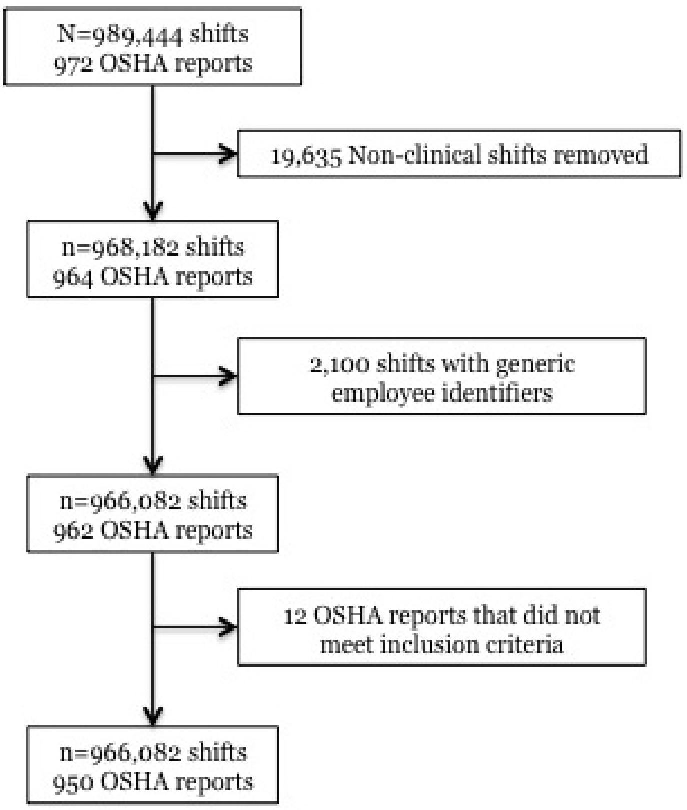


Figure 6. Data obtained and determination of inclusion in the final sample

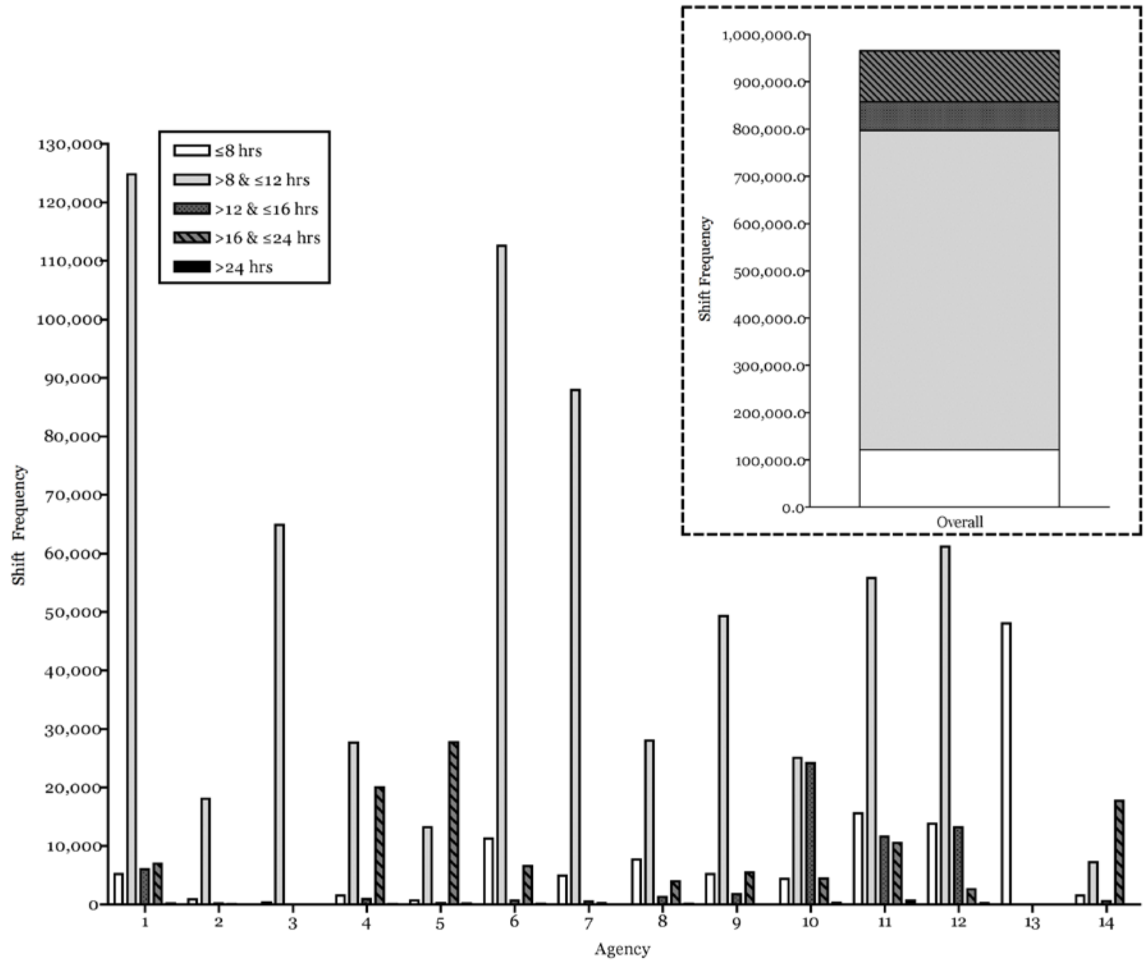
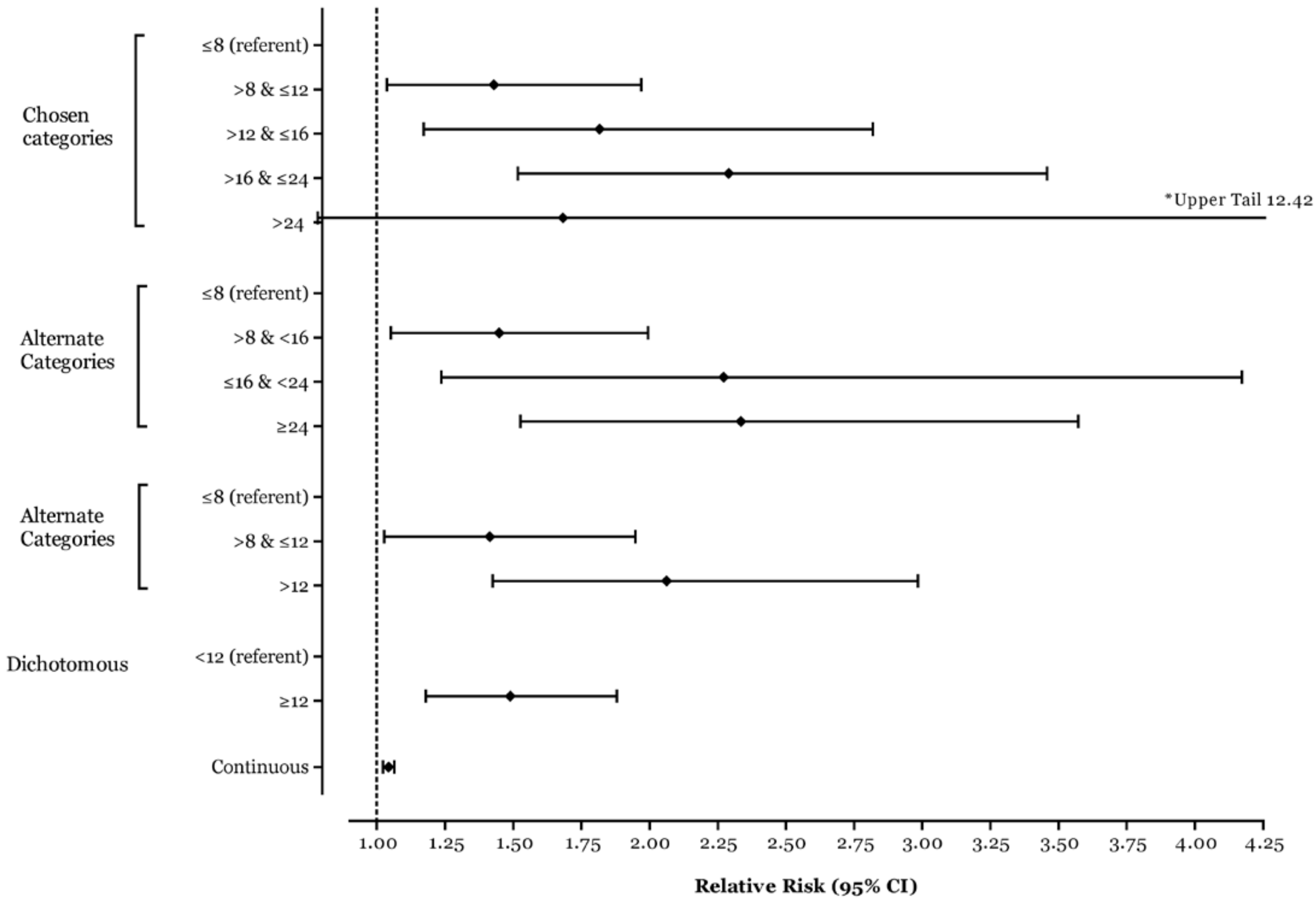


Figure 7. Frequency of shift length categories in the sample and across agencies



** Each estimate is from a separate mixed effects logistic model controlling for hours of recovery, night shift, part-time employment status, and agency workforce size, with random effects for agency and employee.

Figure 8. Results of sensitivity analysis testing different ways to characterize shift length

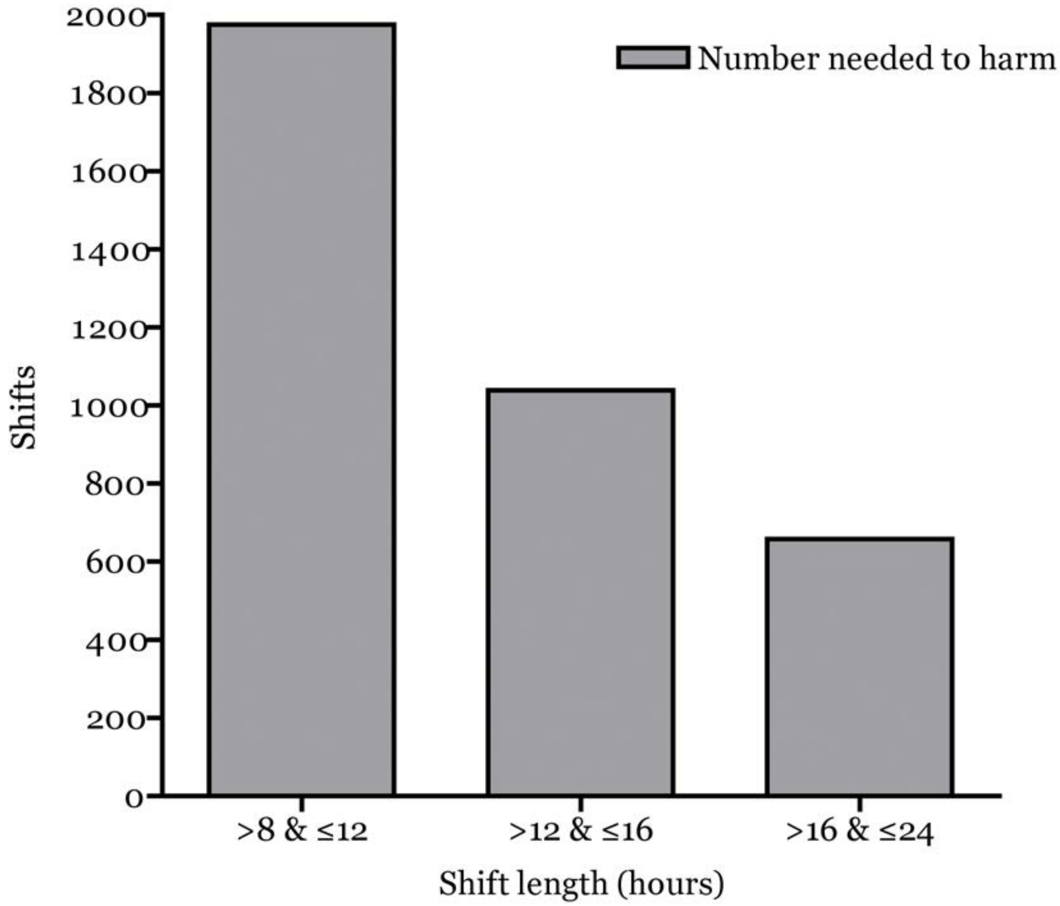


Figure 9. Number of shifts of a given length needed to observe harm

5.7 TABLES

Table 6. Agency level characteristics of study sample

Location	Number of Employees	Proportion Part-time Employees	Start Date	End Date	Number of Shifts n (%)	Shift Length (Mean, SD)	OSHA Report s	Rate (per 100 FTE per year)
Agency 1	545	30.17%	1/1/11	6/30/13	143,119 (14.81)	12.39 (2.90)	90	4.07
Agency 2	153	58.33%	11/1/12	11/29/13	19,190 (1.99)	11.45 (1.62)	23	19.42
Agency 3	231	68.24%	1/1/11	6/30/13	65,229 (6.75)	11.94 (0.66)	26	2.67
Agency 4	254	37.24%	2/27/11	11/29/13	50,237 (5.20)	16.32 (6.39)	68	6.02
Agency 5	170	14.53%	3/27/11	11/29/13	42,006 (4.25)	19.82 (5.94)	20	1.80
Agency 6	491	42.75%	1/1/11	11/29/13	131,182 (13.58)	12.20 (2.99)	136	5.84
Agency 7	314	41.40%	1/1/11	11/29/13	93,661 (9.69)	11.72 (1.40)	51	3.19
Agency 8	220	61.46%	5/21/11	11/29/13	41,061 (4.25)	11.25 (3.86)	40	6.87
Agency 9	387	78.04%	10/1/11	9/30/13	61,751 (6.39)	12.58 (3.99)	219	28.22
Agency 10	262	53.38%	1/1/11	11/29/13	58,247 (6.03)	12.33 (4.13)	36	3.44
Agency 11	447	48.64%	1/22/11	11/29/13	94,290 (9.76)	12.51 (4.96)	50	2.97
Agency 12	516	55.41%	1/1/11	11/29/13	90,988 (9.42)	11.16 (3.21)	23	1.56
Agency 13	154	94.20%	10/31/11	8/26/13	48,041 (4.97)	8.00 (0)	156	44.55
Agency 14	241	64.94%	10/1/11	7/31/13	27,080 (2.80)	19.38 (6.48)	12	2.49
Total	4,382	52.38%	1/1/11	11/29/13	966,082 (100)	12.61 (4.40)	950	5.36

Table 7. Work-related injuries and illnesses

	Total Reports (n=950, 100%)	Median (p25-P75)
Category		
Injury	705 (74.2)	---
Illness	245 (25.8)	---
Skin disease or disorder	4 (0.4)	---
Respiratory condition	16 (1.7)	---
Poisoning	2 (0.2)	---
Hearing loss	3 (0.3)	---
All other illnesses	169 (17.8)	---
Not specified	51 (5.4)	---
Severity		
Restricted work activity	212 (22.3)	8 (1-23)
Days away from work	121 (12.7)	8 (2-25)
Death	0 (0.0)	---
Other or unspecified	617 (64.9)	---

Table 8. Covariates of interest across exposure categories

	≤8 hrs (n=121,093)	>8 & ≤12 hrs (n=675,630)	>12 & ≤16 hrs (n=61,239)	>16 & ≥24 hrs (n=106,267)	>24 hrs (n=1,853)	Total (n=966,082)
Overnight shifts (n, %)	15,237 (12.58)	156,420 (23.15)	4,900 (8.00)	100,296 (94.38)	1,853 (100)	101,949 (95.49)
Partner familiarity (Median, IQR)	3 (0, 13)	8 (1, 21)	11 (1, 20)	4 (0, 11)	6 (2, 13)	7 (1, 19)
Consecutive shifts (n, %)	10,791 (8.91)	14,108 (2.09)	899 (1.47)	10,906 (10.26)	385 (20.78)	37,089 (3.84)
Hours of Recovery (Median, IQR)	16 (16, 46)	12 (12, 60)	24 (11-59)	48 (24, 73)	24 (7.5, 60)	16 (12, 60)
Number of shifts past 7 days (Median, IQR)	4 (3, 5)	3 (3, 4)	3 (2, 4)	2 (2, 3)	3 (2, 4)	3 (2, 4)
Unique workers (n, %)*	3,490 (79.64)	4,141 (94.50)	2,144 (48.93)	2,017 (46.03)	681 (15.54)	4,382 (100)
Total injuries and illnesses (n, %)	97 (0.16)	586 (0.09)	49 (0.08)	117 (0.11)	1 (0.05)	950 (0.10)
Resulting in work restriction	12 (0.01)	146 (0.02)	13 (0.02)	40 (0.04)	1 (0.05)	212 (0.02)
Resulting in time away from work	43 (0.04)	56 (0.01)	6 (0.01)	16 (0.02)	0 (0.00)	121 (0.01)

* Percentage calculated using denominator of 4,382 total unique EMS workers in study. All other percentages are column percentages.

Table 9. Multivariable model results

	Relative Risk (95% CI)	p-value
Shift Length (category)		
≤8 hrs	Referent	---
>8 & ≤12 hrs	1.43 (1.04-1.97)	0.03
>12 & ≤16 hrs	1.82 (1.17-2.82)	0.008
>16 and ≤24 hrs	2.29 (1.52-3.46)	<0.0001
>24 hrs	1.68 (0.23-12.42)	0.61
Overnight shift	0.78 (0.65-0.93)	0.005
Consecutive shift	0.84 (0.62-1.15)	0.29
Crew Familiarity		
0-1 shifts	Referent	---
2-7 shifts	1.05 (0.88-1.24)	0.59
8-19 shifts	1.08 (0.90-1.30)	0.39
≥20 shifts	1.14 (0.91-1.41)	0.25
Hours of recovery (4 hr units)	1.00 (1.00-1.00)	0.85
Employment Status		
Full-time	Referent	---
Part-time	0.91 (0.78-1.07)	0.26
Midpoint Agency Size (20 person units)	0.99 (0.86-1.13)	0.88

6.0 OVERARCHING DISCUSSION

Several themes emerged from the combined results of these efforts. First, shift length may be an important, modifiable risk factor for occupational injury and illness. Second, short-term familiarity alone does not seem to be an important factor for occupational injury or illness in EMS worker partnerships. Third, overnight work was protective in our dataset – an interesting finding which reinforces the unique nature of EMS work and the need for more targeted EMS occupational safety research. Finally, we observed substantial agency-level variation – suggesting that agency-level interventions may be promising and also that agency-level factors are important when considering relevant confounding factors.

Shift length was associated with occupational injury in our sample, while weekly work hours were not. This finding suggests that transient exposures isolated to the shift under study may be more important than long-term exposures thought to increase risk – such as weekly work hours. We hypothesize that the increased risk linked to extended shifts is attributable to fatigue-related performance deficit, but we did not directly directly address fatigue in our analyses. The results from the literature review suggest the methodology to test this hypothesis is currently lacking, but modern technologies may allow for more informed testing of this hypothesis in the near future.

One example is the SleepTrackTXT trial, whose design was published in the journal Trials.[170] The trial recruited individual EMS workers nationally to provide fatigue, sleepiness, and concentration measures at the beginning of each work shift, every 4 hours during the shift, and then again at the end of the shift using a text message data collection system. This form of momentary assessment represents a step forward in our understanding of the evolution of fatigue throughout a 6-month period of shiftwork. The SleepTrackTXT trial was an interventional trial designed to reduce reported fatigue, sleepiness, and difficulty concentrating using text message strategies. A similar trial powered to detect differences in fatigue across different shift length categories would be able to formally test our proposed mechanism.

The risk of occupational injury or illness increased in a linear fashion with increasing shift length. This finding was suggested by the similar increases in relative risk for each shift length category, with the exception of shifts longer than 24 hours, which were likely underpowered. (Appendix C) The presence of linearity was also formally tested in a mixed effects logistic model containing the continuous linear predictor as well as its quadratic equivalent. The linear predictor was significant (RR 1.14; 95% CI 1.02-1.28; p=0.02), while the quadratic term was not (RR 1.00; 95% CI 0.99-1.00; p=0.07).

An argument could be made that the increased risk observed with increasing shift length is strictly attributable to increased exposure – in other words, by working more, there is by definition a higher likelihood you will experience an injury. We cannot rule this out as a possibility in our study. In order to exclude this, we would need to be able to capture the moment in the shift during which the injury occurred. Our dataset only provides the detail necessary to link an injury to a shift as a whole. One way to investigate whether increased exposure has explanatory power could be to combine the exposures of interest – weekly work hours and shift length – in a single model. This would inform whether individuals who worked more reported more injuries. The results of a model containing shift length, weekly work hours, overnight shift, and familiarity are below. (Table 10)

Table 10. Combined model

	Relative Risk (95% CI)	p-value
Shift Length (category)		
≤8 hrs	Referent	---
>8 & ≤12 hrs	1.47 (1.07-2.03)	0.02
>12 & ≤16 hrs	1.88 (1.21-2.91)	0.005
>16 and ≤24 hrs	2.52 (1.67-3.80)	<0.0001
>24 hrs	1.72 (0.23-12.67)	0.60
Overnight shift	0.78 (0.65-0.93)	0.005
Weekly Work Hours		
<48 hrs	Referent	---
48-59 hrs	0.89 (0.76-1.05)	0.18
≥60 hrs	0.99 (0.80-1.23)	0.96
Familiarity (quartiles)		
0-1 shifts	Referent	---
2-7 shifts	1.04 (0.88-1.23)	0.68
8-19 shifts	1.09 (0.91-1.30)	0.36
≥20 shifts	1.16 (0.94-1.44)	0.15

After controlling for weekly work hours (hours of work in the 7 days preceding the shift), shift length becomes an even stronger predictor of injury than in a model without weekly work hours. This provides some evidence to suggest that increased risk with extended shifts is not attributable to increased time at risk in the work environment.

Familiarity between partners did not significantly impact injury risk in our data. We examined familiarity as a short-term exposure – specifically within the 8-weeks prior to the shift of interest. We chose this approach based on literature suggesting periods longer than 8 weeks may introduce difficulty in recall for teamwork interactions.[148,149] However, many individuals in our study likely had long-term exposures to one another via work prior to the start of the study. Short-term familiarity does not give a complete picture of the extent of crew familiarity, which may be several years removed. It is also possible that intangibles not captured in this study are more important than familiarity alone. For example, positive teamwork behaviors are desirable, and they are not necessarily created with increased familiarity. Familiarity can promote trust and communication through shared experiences, but effective teamwork is complex and requires additional elements as well.[178]

The database of shift schedules analyzed in this dissertation represents the largest database of its kind to be reported in the literature. Overwhelming, the most common shift length among agencies in this study was 12 hours. Prior to this report, we have relied on self-reported data from EMS providers, who were asked to report the shift length that they most commonly worked.[6,7,83,173] Previous self-reported data suggested the most common shift lengths in our industry were 12 and 24 hours. We now know, at least among agencies similar to those described in our study, the distribution of shifts is heavily skewed toward 12-hour shifts. The most common shift length also varied across agency.

Night work hours and night shifts as a whole were found to be protective against OSHA reports in both analyses. This is in contrast to previous work in police officers, which suggests a substantial increase in injury risk on night shifts.[45] It seems that fatigue would be most prevalent on night shifts,[74,179] and also that staffing levels would be lowest during off-peak hours, reducing the availability of backup when lifting and moving patients. These factors may be outweighed by the reduced call volume on night shifts, and perhaps the increased likelihood of recent rest to mitigate fatigue.

This project enhanced our understanding of the rate of occupational injury experienced by EMS providers. Previous research either utilized government databases that were unable to inform at the employee-shift level,[8,9,11,12,180] or were limited to a single city's perspective.[14,148] The overall rate of OSHA reporting observed in our study is similar to the rate of injuries resulting in lost work time in these previous works, confirming that EMS does have an elevated safety risk in comparison to the general workforce. One of the most interesting findings from our more detailed database was the variation in OSHA reporting rate that exists across different EMS agencies.

A nearly 30-fold variation in injury rate was observed across participating agencies. We attempted to minimize agency-level confounding by introducing a random-effect for agency in the multivariate model, but the effect of workplace cannot be entirely removed in the analysis phase. We did explore removing agencies with the highest injury rates from the analysis (Figure 13), and observed in one case our conclusions remained entirely the same, and in the other statistical significance did not remain for some comparisons, while the direction of the association remained the same.

Our data source to capture occupational injury is the OSHA 300 log. In the United States, most employers are required to maintain records of work-related injuries and illnesses. (OSHA Regulation 29 CFR Part 1904) Exceptions are granted if you employ 10 or fewer personnel at all times, or if you are on a small list of low hazard industries. Certainly, agency-level factors could play a large role in recording the outcome. Agency size, availability and training of support staff, and workplace safety culture are all relevant factors that could account for some agency-level variation.[151]

Underreporting of injuries is a concern, and one that is difficult to quantify. One large Canadian study of 20,000 workers estimated that 50% of injuries go unreported to their employer.[159] This estimate, 50%, has been reported in other studies as well, but noted to vary widely across occupational setting.[161] Previous studies have found that organizational safety culture is associated with injury reporting. Specifically, organizations with negative safety climate had significantly higher rates of underreporting of OSHA eligible injuries.[162] We have previously found wide variation in safety climate scores and safety culture as a whole across EMS agencies nationally.[123] These characteristics could potentially impact agency-level injury rates, however, we also found that EMS providers who report more negative perceptions of safety climate were more likely to report occupational injuries – not less.[176] These injuries were obtained by self-report, not by collection of OSHA 300 logs. If our estimates of injury are biased by using this data source to capture our outcome, we anticipate the bias to manifest in calculated injury rates that are lower than actual injury rates. We have little reason to expect differential reporting across exposure categories (shift length and other characteristics of shift work). If agencies systematically fail to report serious injuries, and the agency does not have a random distribution of shift lengths and weekly work hours, our estimates will be biased toward the null for the shift length and weekly work hours that are most commonly represented at those agencies. We can only address this bias through statistical methods.

There is also the possibility of over-reporting. If there were agencies or individuals who submit minor injury or illness reports that do not meet the threshold for injury reporting by our definition, they would bias our results away from the null for the shift length or weekly work hours that they most commonly work. We attempted to minimize some of the reporting biases across agencies and individuals by reviewing all the OSHA reports and excluding reports which did not meet the OSHA required recording standard. We excluded 12 minor reports (Appendix C, Table 11), which were distributed across different shift lengths but were isolated to the two agencies with the highest rate of reporting.

There is an adage commonly heard among peers, *If you have seen one EMS agency, you have seen one EMS agency*. It seems particularly relevant to the work described here. At the time of this writing, there are 65 EMS agencies in Allegheny County alone (the county which houses the City of Pittsburgh, Pennsylvania and its surrounding area). Each of them is truly unique. The findings and associations observed in our study do not generalize to all of them. For example, by many metrics, this is an urban area. However, there are surely many agencies that can and do safely deploy 24-hour shifts with a leisurely workload. In order to understand the intricacies of shift work and safety, we must have more finely textured datasets with information on both individual-level workload and agency policies. The work must be carried forward prospectively to confirm or reject our conclusions.

This project is significant to public health. While the findings should not be used in isolation to change policy, they are compelling initial data and present a foundation for future work. Future work is imperative because the health and safety of EMS workers concerns not only that specific worker population – but also the residents of the communities where those EMS workers serve. EMS workers are the safety net for all public citizens, and it is likely that their role in the healthcare system will only increase in the future.[177] The health and safety of the EMS workforce must be prioritized in order to ensure a healthy safety net for the public.

APPENDIX A: WEEKLY WORK HOURS

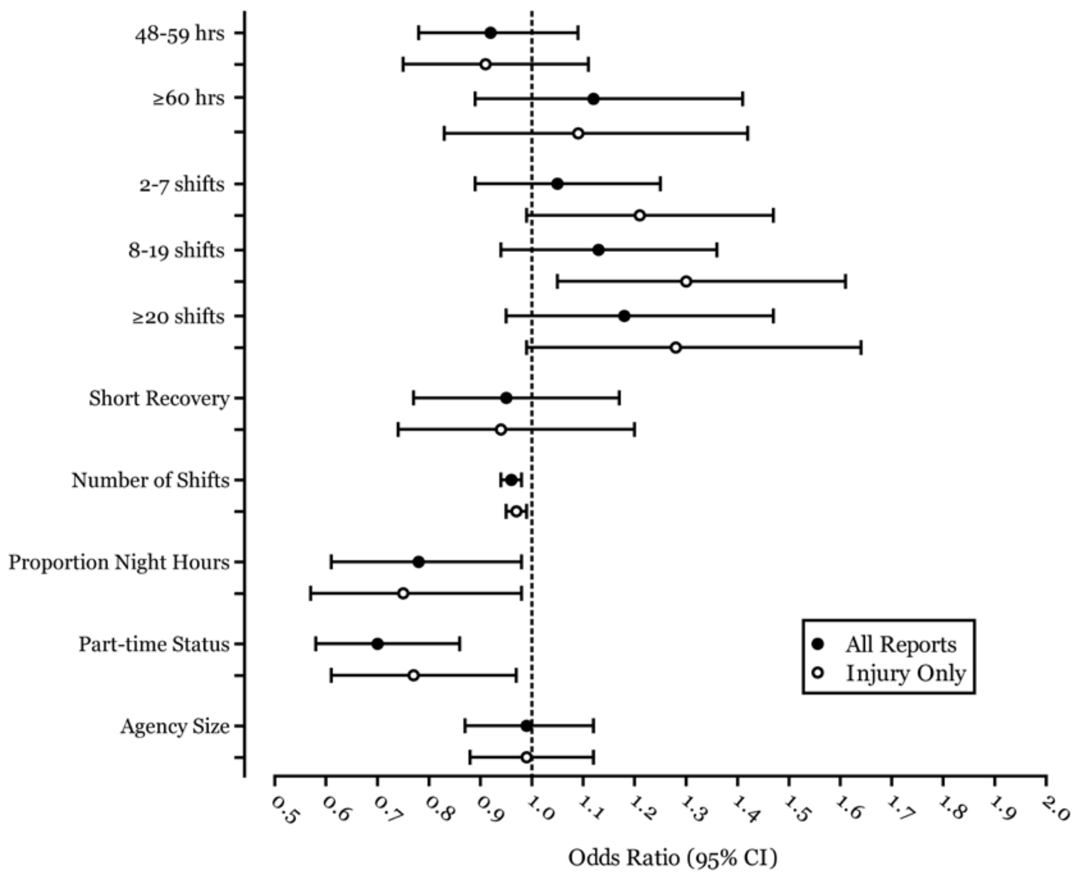


Figure 10. Weekly work hours sensitivity analysis comparing models of all OSHA reports and with illnesses excluded

APPENDIX B: SHIFT LENGTH

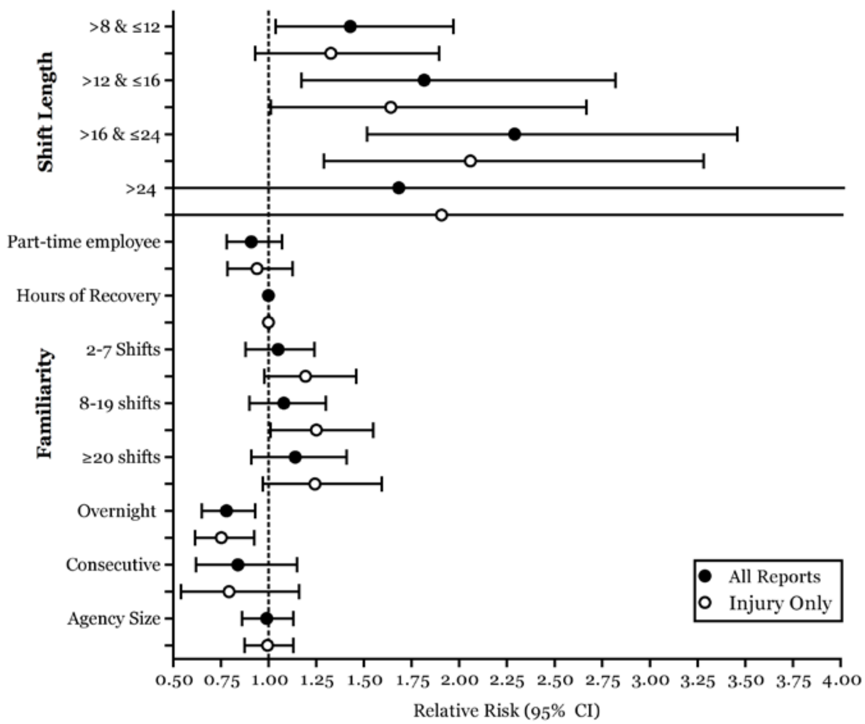


Figure 11. Sensitivity analysis of all OSHA reports vs injury alone

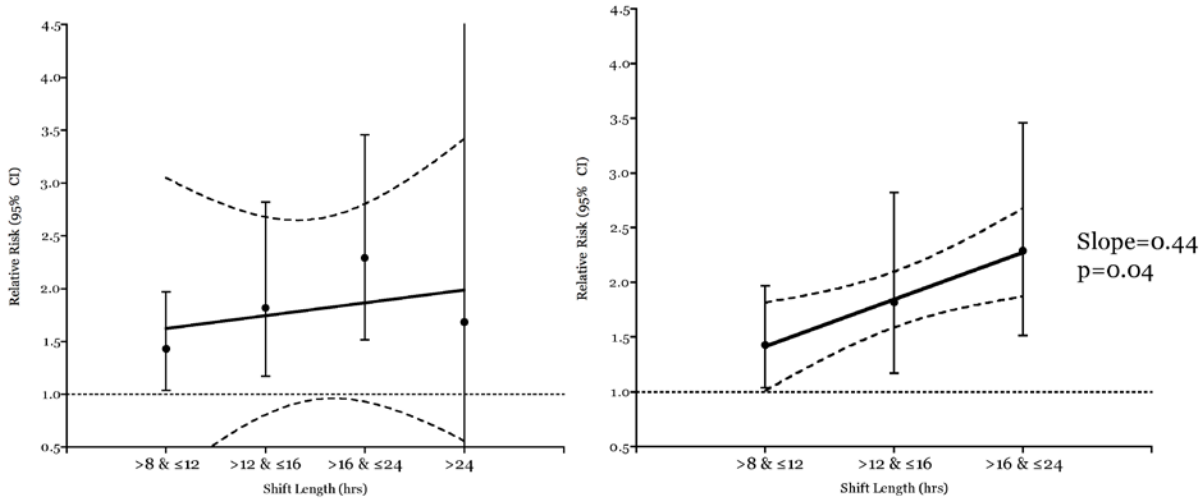
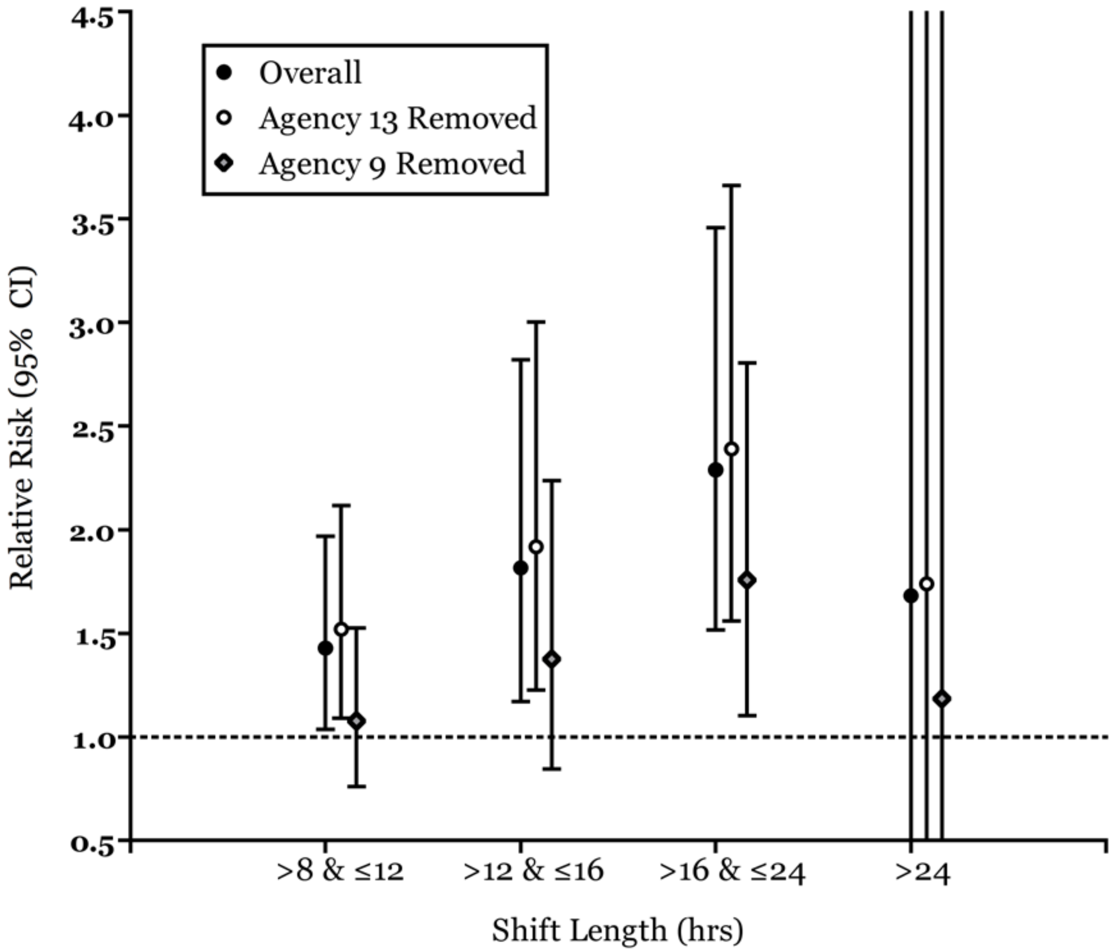


Figure 12. Linearity of shift length predictor with and without shifts longer than 24 hours



The overall n is 966,082, with 950 OSHA reports. Removal of agency 13 excludes 48,041 shifts and 156 OSHA reports. Removal of agency 9 excludes 61,751 shifts and 219 OSHA reports.

Figure 13. Sensitivity analysis demonstrating change in results with exclusion of highest OSHA reporting agencies

Table 11. Description of excluded OSHA reports (n=12)

	Description	Agency	Shift length (hrs)
1	Ache/discomfort/strain/sprain of back when putting stretcher back into ambulance - report that pain subsided by next call and didn't have trouble repeating the task	9	24
2	Potential for contamination – coworker contacted medic stating she was diagnosed with Pertussis	9	16
3	Possible exposure to TB - unknowingly in contact with patient being treated for TB for a short period of time	9	16
4	Struck parked car while driving golf cart - no major damages	9	12
5	Possible exposure to TB -transporting patient that had been continually treated for TB	9	12
6	No observable condition - precaution of chemical exposure to lungs from contact with patients exposed to Hydrofluoric Acid	9	12
7	Possible exposure to TB or Meningitis from direct care of very sick patient - precaution (full PPT worn)	9	12
8	Possible Contamination Exposure - response to call for sick male with neck pain, so precautionary measures were taken - hospital later confirmed patient had infectious disease	9	12
9	Possible raw sewage exposure when station flooded	13	8
10	Possible raw sewage exposure when station flooded	13	8
11	Possible environmental exposure from a house with urine and trash present	13	8
12	Bed bugs exposure when transporting infested patient to hospital	13	8

BIBLIOGRAPHY

1. Ruutiainen AT, Durand DJ, Scanlon MH, Itri JN. Increased error rates in preliminary reports issued by radiology residents working more than 10 consecutive hours overnight. *Acad Radiol.* Mar 2013;20(3):305-311.

2. Mansukhani MP, Kolla BP, Surani S, Varon J, Ramar K. Sleep deprivation in resident physicians, work hour limitations, and related outcomes: a systematic review of the literature. *Postgrad Med.* Jul 2012;124(4):241-249.

3. West CP, Tan AD, Habermann TM, Sloan JA, Shanafelt TD. Association of resident fatigue and distress with perceived medical errors. *JAMA : the journal of the American Medical Association.* Sep 23 2009;302(12):1294-1300.

4. Lockley SW, Barger LK, Ayas NT, Rothschild JM, Czeisler CA, Landrigan CP. Effects of health care provider work hours and sleep deprivation on safety and performance. *Jt Comm J Qual Patient Saf.* Nov 2007;33(11 Suppl):7-18.

5. Dembe AE, Delbos R, Erickson JB. Estimates of injury risks for healthcare personnel working night shifts and long hours. *Qual Saf Health Care.* Oct 2009;18(5):336-340.

6. Patterson PD, Weaver MD, Frank RC, et al. Association between poor sleep, fatigue, and safety outcomes in emergency medical services providers. *Prehosp Emerg Care.* Jan-Mar 2012;16(1):86-97.

7. Patterson PD, Weaver MD, Hostler D, Guyette FX, Callaway CW, Yealy DM. The shift length, fatigue, and safety conundrum in EMS. *Prehosp Emerg Care.* Oct-Dec 2012;16(4):572-576.

8. Reichard AA, Marsh SM, Moore PH. Fatal and nonfatal injuries among emergency medical technicians and paramedics. *Prehosp Emerg Care.* Oct-Dec 2011;15(4):511-517.

9. Maguire BJ, Hunting KL, Smith GS, Levick NR. Occupational fatalities in emergency medical services: a hidden crisis. *Ann Emerg Med.* Dec 2002;40(6):625-632.

10. McGonigal M. Helicopter EMS: The Risks. 2013; The Trauma Professional's Blog. Available at: http://regionstraumapro.com/post/66781604470. Accessed 11/18, 2013.

11. Maguire BJ, Hunting KL, Guidotti TL, Smith GS. Occupational injuries among emergency medical services personnel. *Prehosp Emerg Care.* Oct-Dec 2005;9(4):405-411.

12. Maguire BJ, Smith S. Injuries and Fatalities among Emergency Medical Technicians and Paramedics in the United States. *Prehosp Disaster Med.* Aug 2013;28(4):376-382.

13. Leigh JP. Economic burden of occupational injury and illness in the United States. *Milbank Q.* Dec 2011;89(4):728-772.

14. Suyama J, Rittenberger JC, Patterson PD, Hostler D. Comparison of public safety provider injury rates. *Prehosp Emerg Care.* Oct-Dec 2009;13(4):451-455.

15. Federal Interagency Committee on Emergency Medical Services 2011 National EMS Assessment National Highway Traffic Safety Administration; 2011.

16. Caruso CC. Negative impacts of shiftwork and long work hours. *Rehabil Nurs.* Jan-Feb 2014;39(1):16-25.

17. Drake CL, Wright KP. Shift work, shift work disorder, and jet lag. In: Kreiger MH, Roth T, Dement WC, eds. *Principles and practice of sleep medicine.* 5 ed. St Louis, MO: Elsevier; 2011.

18. Kryger MH, Roth T, Dement WC. *Principles and practice of sleep medicine.* 4th ed. Philadelphia, PA: Elsevier/Saunders; 2005.

19. Knutsson A. Health disorders of shift workers. *Occup Med (Lond).* Mar 2003;53(2):103-108.

20. Charles LE, Gu JK, Fekedulegn D, Andrew ME, Violanti JM, Burchfiel CM. Association between shiftwork and glomerular filtration rate in police officers. *J Occup Environ Med.* Nov 2013;55(11):1323-1328.

21. Caruso CC. Negative Impacts of Shiftwork and Long Work Hours. *Rehabil Nurs.* Jun 18 2013.

22. Monk TH, Buysse DJ, Billy BD, et al. Shiftworkers report worse sleep than day workers, even in retirement. *J Sleep Res.* Apr 2013;22(2):201-208.

23. Frank AL. Injuries related to shiftwork. *Am J Prev Med.* May 2000;18(4 Suppl):33-36.

24. Finsterer J, Mahjoub SZ. Fatigue in Healthy and Diseased Individuals. *Am J Hosp Palliat Care.* Jul 26 2013.

25. National Occupational Research Agenda (NORA) 29 October 2013 Revision 2013.

26. NEMSAC. Fatigue in Emergency Medical Services. *NEMSAC*: National EMS Advisory Council Quarterly Meeting; 2013.

27. Bledsoe BE, Porter RS, Cherry RA. *Essentials of paramedic care : principles & practice.* 2nd ed. Upper Saddle River, NJ: Pearson Prentice Hall; 2011.

28. Alterman T, Luckhaupt SE, Dahlhamer JM, Ward BW, Calvert GM. Prevalence rates of work organization characteristics among workers in the U.S.: data from the 2010 National Health Interview Survey. *Am J Ind Med.* Jun 2013;56(6):647-659.

29. Spiegel U, Gonen L, Weber M. Duration and optimal number of shifts in the labour market. *Applied Economics Letters.* 2014;21(6).

30. Dembe AE. Ethical Issues Relating to the Health Effects of Long Working Hours - Springer. *Journal of Business Ethics.* 2009.

31. Rosenbluth G, Landrigan CP. Sleep science, schedules, and safety in hospitals: challenges and solutions for pediatric providers. *Pediatr Clin North Am.* Dec 2012;59(6):1317-1328.

32. Radstaak M, Geurts SA, Beckers DG, Brosschot JF, Kompier MA. Recovery and well-being among Helicopter Emergency Medical Service (HEMS) pilots. *Appl Ergon.* Jul 2014;45(4):986-993.

33. Brown DL, Feskanich D, Sanchez BN, Rexrode KM, Schernhammer ES, Lisabeth LD. Rotating night shift work and the risk of ischemic stroke. *Am J Epidemiol.* Jun 1 2009;169(11):1370-1377.

34. Frost P, Kolstad HA, Bonde JP. Shift work and the risk of ischemic heart disease - a systematic review of the epidemiologic evidence. *Scand J Work Environ Health.* May 2009;35(3):163-179.

35. Fritschi L, Glass DC, Heyworth JS, et al. Hypotheses for mechanisms linking shiftwork and cancer. *Med Hypotheses.* Sep 2011;77(3):430-436.

36. Ha M, Park J. Shiftwork and metabolic risk factors of cardiovascular disease. *J Occup Health.* Mar 2005;47(2):89-95.

37. Knutsson A, Boggild H. Shiftwork and cardiovascular disease: review of disease mechanisms. *Rev Environ Health.* Oct-Dec 2000;15(4):359-372.

38. Monk TH, Buysse DJ. Exposure to shift work as a risk factor for diabetes. *Journal of biological rhythms.* Oct 2013;28(5):356-359.

39. Shapiro CM. Chronic fatigue--chronically confusing but growing information. *J Psychosom Res.* Feb 2004;56(2):153-155.

40. Hossain JL, Reinish LW, Kayumov L, Bhuiya P, Shapiro CM. Underlying sleep pathology may cause chronic high fatigue in shift-workers. *J Sleep Res.* Sep 2003;12(3):223-230.

41. Rogers A, Holmes S, Spencer M. The effect of shiftwork on driving to and from work. *Journal of human ergology*. Dec 2001;30(1-2):131-136.

42. Stutts JC, Wilkins JW, Scott Osberg J, Vaughn BV. Driver risk factors for sleep-related crashes. *Accid Anal Prev*. May 2003;35(3):321-331.

43. Fransen M, Wilsmore B, Winstanley J, et al. Shift work and work injury in the New Zealand Blood Donors' Health Study. *Occup Environ Med.* May 2006;63(5):352-358.

44. Wong IS, McLeod CB, Demers PA. Shift work trends and risk of work injury among Canadian workers. *Scand J Work Environ Health.* Jan 2011;37(1):54-61.

45. Violanti JM, Fekedulegn D, Andrew ME, et al. Shift work and the incidence of injury among police officers. *Am J Ind Med.* Mar 2012;55(3):217-227.

46. Folkard S, Lombardi DA. Modeling the impact of the components of long work hours on injuries and "accidents". *Am J Ind Med.* Nov 2006;49(11):953-963.

47. Folkard S, Tucker P. Shift work, safety and productivity. *Occup Med (Lond).* Mar 2003;53(2):95-101.

48. Rosa RR. Extended workshifts and excessive fatigue. *J Sleep Res.* Dec 1995;4(S2):51-56.

49. Vegso S, Cantley L, Slade M, et al. Extended work hours and risk of acute occupational injury: A case-crossover study of workers in manufacturing. *Am J Ind Med.* Aug 2007;50(8):597-603.

50. Institute of Medicine (U.S.). Committee on Optimizing Graduate Medical Trainee (Resident) Hours and Work Schedules to Improve Patient Safety., Ulmer C, Wolman DM, Johns MME. *Resident duty hours : enhancing sleep, supervision, and safety*. Washington, D.C.: National Academies Press; 2009.

51. Landrigan CP, Rothschild JM, Cronin JW, et al. Effect of reducing interns' work hours on serious medical errors in intensive care units. *N Engl J Med.* Oct 28 2004;351(18):1838-1848.

52. Moonesinghe SR, Lowery J, Shahi N, Millen A, Beard JD. Impact of reduction in working hours for doctors in training on postgraduate medical education and patients' outcomes: systematic review. *Bmj.* 2011;342:d1580.

53. Estabrooks CA, Cummings GG, Olivo SA, Squires JE, Giblin C, Simpson N. Effects of shift length on quality of patient care and health provider outcomes: systematic review. *Qual Saf Health Care.* Jun 2009;18(3):181-188.

54. Stimpfel AW, Sloane DM, Aiken LH. The longer the shifts for hospital nurses, the higher the levels of burnout and patient dissatisfaction. *Health affairs.* Nov 2012;31(11):2501-2509.

55. Barger LK, Cade BE, Ayas NT, et al. Extended work shifts and the risk of motor vehicle crashes among interns. *The New England journal of medicine.* Jan 13 2005;352(2):125-134.

56. Horwitz IB, McCall BP. The impact of shift work on the risk and severity of injuries for hospital employees: an analysis using Oregon workers' compensation data. *Occup Med (Lond).* Dec 2004;54(8):556-563.

57. de Castro AB, Fujishiro K, Rue T, Tagalog EA, Samaco-Paquiz LP, Gee GC. Associations between work schedule characteristics and occupational injury and illness. *International nursing review.* Jun 2010;57(2):188-194.

58. Eldevik MF, Flo E, Moen BE, Pallesen S, Bjorvatn B. Insomnia, excessive sleepiness, excessive fatigue, anxiety, depression and shift work disorder in nurses having less than 11 hours in-between shifts. *PloS one.* 2013;8(8):e70882.

59. Brown WE, Jr., Dickison PD, Misselbeck WJ, Levine R. Longitudinal Emergency Medical Technician Attribute and Demographic Study (LEADS): an interim report. *Prehosp Emerg Care.* Oct-Dec 2002;6(4):433-439.

60. Beaton RD, Murphy SA. Sources of occupational stress among firefighter/EMTs and firefighter/paramedics and correlations with job-related outcomes. *Prehosp Disaster Med.* Apr-Jun 1993;8(2):140-150.

61. Chng CL, Collins J, Eaddy S. A comparison of rural and urban Emergency Medical System (EMS) personnel: a Texas study. *Prehosp Disaster Med.* Jul-Sep 2001;16(3):159-165.

62. Allen TL, Delbridge TR, Stevens MH, Nicholas D. Intubation success rates by air ambulance personnel during 12-versus 24-hour shifts: does fatigue make a difference? *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors.* Oct-Dec 2001;5(4):340-343.

63. Thomas F, Hopkins RO, Handrahan DL, Walker J, Carpenter J. Sleep and cognitive performance of flight nurses after 12-hour evening versus 18-hour shifts. *Air Med J.* Sep-Oct 2006;25(5):216-225.

64. Boudreaux E, Mandry C, Brantley PJ. Emergency medical technician schedule modification: impact and implications during short- and long-term follow-up. *Acad Emerg Med.* Feb 1998;5(2):128-133.

65. Brachet T, David G, Duseja R. *The Effect of Shift Structure on Performance: The Role of Fatigue for Paramedics.* Cambridge, MA: National Bureau of Economic Research;2010.

66. Pirrallo RG, Loomis CC, Levine R, Woodson T. The prevalence of sleep problems in emergency medical technicians. *Sleep and Breathing.* 2012;16(1):149-162.

67. Sofianopoulos S, Williams B, Archer F. Paramedics and the effects of shift work on sleep: a literature review. *Emerg Med J.* Feb 2012;29(2):152-155.

68. Crill MT, Hostler D. Back strength and flexibility of EMS providers in practicing prehospital providers. *J Occup Rehabil.* Jun 2005;15(2):105-111.

69. Cone DC, Brice JH, Delbridge TR, Myers JB. *Emergency medical services : clinical practice and systems oversight.* Second edition. ed. Chichester, West Sussex ; Hoboken: John Wiley & Sons Inc.; 2015.

70. Boal WL, Leiss JK, Ratcliffe JM, et al. The national study to prevent blood exposure in paramedics: rates of exposure to blood. *International Archives of Occupational and Environmental Health.* Feb 2010;83(2):191-199.

71. Corbett SW, Grange JT, Thomas TL. Exposure of prehospital care providers to violence. *Prehosp Emerg Care.* Apr-Jun 1998;2(2):127-131.

72. Grange JT, Corbett SW. Violence against emergency medical services personnel. *Prehosp Emerg Care.* Apr-Jun 2002;6(2):186-190.

73. Mock EF, Wrenn KD, Wright SW, Eustis TC, Slovis CM. Prospective field study of violence in emergency medical services calls. *Ann Emerg Med.* Jul 1998;32(1):33-36.

74. Flo E, Pallesen S, Akerstedt T, et al. Shift-related sleep problems vary according to work schedule. *Occup Environ Med.* Apr 2013;70(4):238-245.

75. Studnek JR, Ferketich A, Crawford JM. On the job illness and injury resulting in lost work time among a national cohort of emergency medical services professionals. *Am J Ind Med.* Dec 2007;50(12):921-931.

76. Studnek JR, Fernandez AR. Characteristics of emergency medical technicians involved in ambulance crashes. *Prehosp Disaster Med.* Sep-Oct 2008;23(5):432-437.

77. Pitts SR, Lord G. Demographic Trends in Ambulance Use. Poster presented at Public Health Emergency Preparedness Summit; April 2013, 2013; Atlanta, GA.

78. BureauOfLaborStatistics USD. Occupational Outlook Handbook, 2014-2015 Edition, EMTs and Paramedics. 2014; http://www.bls.gov/ooh/healthcare/emts-and-paramedics.htm. Accessed Thursday, January 9, 2014.

79. Frakes MA, Kelly JG. Sleep debt and outside employment patterns in helicopter air medical staff working 24-hour shifts. *Air Med J.* Jan-Feb 2007;26(1):45-49.

80. Brice JH, Studnek JR, Bigham BL, et al. EMS Provider and Patient Safety during Response and Transport: Proceedings of an Ambulance Safety Conference. *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors.* Jan-Mar 2012;16(1):3-19.

81. Patterson PD, Arnold RM, Abebe K, et al. Variation in emergency medical technician partner familiarity. *Health services research.* Aug 2011;46(4):1319-1331.

82. Bigham BL, Buick JE, Brooks SC, Morrison M, Shojania KG, Morrison LJ. Patient safety in emergency medical services: a systematic review of the literature. *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors.* Jan-Mar 2012;16(1):20-35.

83. Patterson PD, Suffoletto BP, Kupas DF, Weaver MD, Hostler D. Sleep quality and fatigue among prehospital providers. *Prehosp Emerg Care.* Apr-Jun 2010;14(2):187-193.

84. Shen J, Barbera J, Shapiro CM. Distinguishing sleepiness and fatigue: focus on definition and measurement. *Sleep Med Rev.* Feb 2006;10(1):63-76.

85. Van Dongen HP, Maislin G, Mullington JM, Dinges DF. The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep.* Mar 15 2003;26(2):117-126.

86. Raslear TG, Hursh SR, Van Dongen HP. Predicting cognitive impairment and accident risk. *Prog Brain Res.* 2011;190:155-167.

87. Basner M, Rubinstein J, Fomberstein KM, et al. Effects of night work, sleep loss and time on task on simulated threat detection performance. *Sleep.* Sep 2008;31(9):1251-1259.

88. Akerstedt T. Consensus statement: fatigue and accidents in transport operations. *J Sleep Res.* Dec 2000;9(4):395.

89. Nasca TJ, Day SH, Amis ES, Jr. The new recommendations on duty hours from the ACGME Task Force. *N Engl J Med.* Jul 8 2010;363(2):e3.

90. Gander P, Purnell H, Garden A, Woodward A. Work patterns and fatigue-related risk among junior doctors. *Occup Environ Med.* Nov 2007;64(11):733-738.

91. Becker TK, Gausche-Hill M, Aswegan AL, et al. Ethical challenges in Emergency Medical Services: controversies and recommendations. *Prehospital and disaster medicine.* Oct 2013;28(5):488-497.

92. Blau G. Perceived health as a robust correlate of perceived sleepiness in an emergency medical services (EMS) sample. *Journal of Workplace Behavioral Health.* 2011;26(1):59-69.

93. Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep.* Dec 1991;14(6):540-545.

94. Mullington JM, Czeisler CA, Goel N, et al. Panel discussion: current status of measuring sleepiness. *J Clin Sleep Med.* Oct 15 2011;7(5 Suppl):S22-25.

95. Johns M. Rethinking the assessment of sleepiness. *Sleep Med Rev.* Feb 1998;2(1):3-15.

96. Vercoulen JH, Alberts M, Bleijenberg G. The Checklist Individual Strength (CIS). *Gedragstherapie.* 1999;32:131-136.

97. Beurskens AJHM, Bültmann U, Kant I, Vercoulen JHMM, Bleijenberg G, Swaen GMH. Fatigue among working people: validity of a questionnaire measure. 2000.

98. Chalder T, Berelowitz G, Pawlikowska T, et al. Development of a fatigue scale. *J Psychosom Res.* 1993;37(2):147-153.

99. Pawlikowska T, Chalder T, Hirsch SR, Wallace P, Wright DJ, Wessely SC. Population based study of fatigue and psychological distress. *Bmj.* Mar 19 1994;308(6931):763-766.

100. Sofianopoulos S, Williams B, Archer F, Thompson B. The exploration of physical fatigue, sleep and depression in paramedics: a pilot study. *Journal of Emergency Primary Health Care.* 2011;9(1):1-33.

101. Buysse DJ, Reynolds I, C F, Monk TH, Berman SR. The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. *Psychiatry* …. 1989.

102. Motohashi Y. Alteration of circadian rhythm in shift-working ambulance personnel. Monitoring of salivary cortisol rhythm. *Ergonomics.* Nov 1992;35(11):1331-1340.

103. Motohashi Y, Takano T. Effects of 24-hour shift work with nighttime napping on circadian rhythm characteristics in ambulance personnel. *Chronobiology international.* Dec 1993;10(6):461-470.

104. Braude D, Goldsmith T, Weiss SJ. Assessing air medical crew real-time readiness to perform critical tasks. *Prehospital emergency care : official journal of the*

National Association of EMS Physicians and the National Association of State EMS Directors. Apr-Jun 2011;15(2):254-260.

105. Courtney JA, Francis AJ, Paxton SJ. Caring for the country: fatigue, sleep and mental health in Australian rural paramedic shiftworkers. *Journal of Community Health.* Feb 2013;38(1):178-186.

106. Courtney JA, Francis AJ, Paxton SJ. Caring for the Carers: Fatigue, Sleep, and Mental Health in Australian Paramedic Shiftworkers. *The Australian and New Zealand Journal of Organisational Psychology*. 2010;3:32-41.

107. van der Ploeg E, Kleber RJ. Acute and chronic job stressors among ambulance personnel: predictors of health symptoms. *Occup Environ Med.* Jun 2003;60 Suppl 1:i40-46.

108. Hardy GE, Shapiro DA, Borrill CS. Fatigue in the workforce of National Health Service Trusts: levels of symptomatology and links with minor psychiatric disorder, demographic, occupational and work role factors. *J Psychosom Res.* Jul 1997;43(1):83-92.

109. Bos J, Mol E, Visser B, Frings-Dresen M. Risk of health complaints and disabilities among Dutch firefighters. *International Archives of Occupational and Environmental Health.* 2004;77(6):373-382.

110. Carey MG, Al-Zaiti SS, Dean GE, Sessanna L, Finnell DS. Sleep problems, depression, substance use, social bonding, and quality of life in professional firefighters. *J Occup Environ Med.* Aug 2011;53(8):928-933.

111. Haddock CK, Poston WSC, Jitnarin N, Jahnke SA. Excessive daytime sleepiness in firefighters in the central united states. *Journal of Occupational and Environmental Medicine.* 2013;55(4):416-423.

112. Knauth P, Keller J, Schindele G, Totterdell P. A 14-h night-shift in the control room of a fire brigade. *Work & Stress.* 1995;9(2/3):176-186.

113. Paley MJ, Price JM, Tepas DI. The impact of a change in rotating shift schedules: A comparison of the effects of 8, 10 and 14 h work shifts. *International Journal of Industrial Ergonomics.* 1998;21(3-4):293-305.

114. Paley MJ, Tepas DI. Fatigue and the shiftworker: Firefighters working on a rotating shift schedule. *Human Factors.* 1994;36(2):269-284.

115. Takeyama H, Itani T, Tachi N, et al. Effects of shift schedules on fatigue and physiological functions among firefighters during night duty. *Ergonomics.* 2005;48(1):1-11.

116. Motohashi Y. Alteration of circadian rhythm in shift-working ambulance personnel. Monitoring of salivary cortisol rhythm. *Ergonomics.* Nov 1992;35(11):1331-1340.

117. Motohashi Y, Takano T. Effects of 24-hour shift work with nighttime napping on circadian rhythm characteristics in ambulance personnel. *Chronobiology international.* Dec 1993;10(6):461-470.

118. Manacci C, Rogers K, Martin G, Kovach B, Mancuso C, Fallon W. Efficacy of 24-hour shifts: prepared or impaired? A prospective study. *Air Medical Journal.* Feb 1999;18(1):20-25.

119. Van Der Ploeg E, Kleber RJ. Acute and chronic job stressors among ambulance personnel: predictors of health symptoms. *Occup Environ Med.* Jul 2003;60 Suppl 1(SUPPL. 1):i40-i46.

120. Thomas F, Hopkins RO, Handrahan DL, Walker J, Carpenter J. Sleep and cognitive performance of flight nurses after 12-hour evening versus 18-hour shifts. *Air Medical Journal.* Sep 2006;25(5):216-225.

121. Witteveen AB, Bramsen I, Twisk JWR, et al. Psychological distress of rescue workers eight and one-half years after professional involvement in the Amsterdam air disaster. *Journal of Nervous and Mental Disease.* 2007;195(1):31-40.

122. Takeyama H, Itani T, Tachi N, et al. Effects of a modified ambulance night shift system on fatigue and physiological function among ambulance paramedics. *J Occup Health.* 2009;51(3):204-209.

123. Patterson PD, Huang DT, Fairbanks RJ, Simeone S, Weaver M, Wang HE. Variation in emergency medical services workplace safety culture. *Prehosp Emerg Care.* Oct-Dec 2010;14(4):448-460.

124. Blau G. Exploring the impact of sleep-related impairments on the perceived general health and retention intent of an Emergency Medical Services (EMS) sample. *Career Development International.* 2011;16(3):238-253.

125. Sofianopoulos S, Williams B, Archer F, Thompson B. The exploration of physical fatigue, sleep and depression in paramedics: a pilot study. *Journal of Emergency Primary Health Care.* Apr 01 2011;9(1):1-33.

126. Patterson PD, Weaver MD, Frank RC, et al. Association between poor sleep, fatigue, and safety outcomes in emergency medical services providers. *Prehospital Emergency Care.* Feb 2012;16(1):86-97.

127. Pirrallo RG, Loomis CC, Levine R, Woodson BT. The prevalence of sleep problems in emergency medical technicians. *Sleep & breathing = Schlaf & Atmung.* Apr 2012;16(1):149-162.

128. Guyette FX, Morley JL, Weaver MD, Patterson PD, Hostler D. The effect of shift length on fatigue and cognitive performance in air medical providers. *Prehospital Emergency Care.* 2012;17(1):23-28.

129. Courtney J, Francis A, Paxton S. Caring for the Country: Fatigue, Sleep and Mental Health in Australian Rural Paramedic Shiftworkers. *Journal of Community Health.* Mar 01 2013;38(1):178-186.

130. Bureau of Labor Statistics Series Report. United States Department of Labor; 2014. http://data.bls.gov/cgi-bin/srgate. Accessed 10/12/2014.

131. Sallinen M, Kecklund G. Shift work, sleep, and sleepiness - differences between shift schedules and systems. *Scandinavian journal of work, environment & health.* Apr 2010;36(2):121-133.

132. Virtanen M, Ferrie JE, Gimeno D, et al. Long working hours and sleep disturbances: the Whitehall II prospective cohort study. *Sleep.* Jun 2009;32(6):737-745.

133. Caruso CC. Negative impacts of shiftwork and long work hours. *Rehabil Nurs.* 2014;39(1):16-25.

134. Williamson A, Lombardi DA, Folkard S, Stutts J, Courtney TK, Connor JL. The link between fatigue and safety. *Accid Anal Prev.* 2011;43(2):498-515.

135. Brown W, Dickison P, Misselbeck W, Levine R. Longitudinal Emergency Medical Technician Attribute and Demographic Study (LEADS): An interim report. *Prehosp Emerg Care.* 2002;6(4):433-439.

136. Maguire BJ, Hunting KL, Guidotti TL, Smith GS. Occupational injuries among emergency medical services personnel. *Prehospital Emergency Care.* Oct 2005;9(4):405-411.

137. Reichard AA, Marsh SM, Moore PH. Fatal and nonfatal injuries among emergency medical technicians and paramedics. *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors.* Oct 2011;15(4):511-517.

138. Maguire BJ, Smith S. Injuries and Fatalities among Emergency Medical Technicians and Paramedics in the United States. *Prehospital and disaster medicine.* Jun 09 2013:1-7.

139. Suyama J, Rittenberger JC, Patterson PD, Hostler D. Comparison of public safety provider injury rates. *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors.* Oct 2009;13(4):451-455.

140. Salas E, Fiore SM. *Team cognition : understanding the factors that drive process and performance.* 1st ed. Washington, DC: American Psychological Association; 2004.

141. Salas E, Sims DE, Burke CS. Is there a "Big Five" in Teamwork? *Small Group Research.* 2005;36(5):555-599.

142. Baker DP, Salas E, Barach P, Battles J, King H. The relation between teamwork and patient safety. In: Carayon P, ed. *Handbook of Human Factors and Ergonomics in Health Care and Patient Safety*. Mahwah, New Jersey: Lawrence Erlbaum Associates (LEA); 2007:259-271.

143. Anderson C, Dickinson DL. Bargaining and trust: the effects of 36-h total sleep deprivation on socially interactive decisions. *J Sleep Res.* 2010;19(1 Pt 1):54-63.

144. Patterson PD, Weaver MD, Weaver SJ, et al. Measuring teamwork and conflict among emergency medical technician personnel. *Prehosp Emerg Care.* Jan-Mar 2012;16(1):98-108.

145. NTSB. *A Review of Flightcrew-Involved Major Accidents of U.S. Air Carriers, 1978 through 1990.* Washington, D.C.: National Transportation Safety Board;1994. PB94-917001.

146. Thomas MJ, Petrilli RM. Crew familiarity: operational experience, non-technical performance, and error management. *Aviat Space Environ Med.* 2006;77(1):41-45.

147. Foushee HC, Lauber JK, Baetge MM, Acomb DB. *Crew Factors in Flight Operations: III. The Operational Significance of Exposure to Short-Haul Air Transport Operations.* Moffett Field, California: National Aeronautics and Space Administration;1986.

148. Gershon RR, Vlahov D, Kelen G, Conrad B, Murphy L. Review of accidents/injuries among emergency medical services workers in Baltimore, Maryland. *Prehosp Disaster Med.* Jan-Mar 1995;10(1):14-18.

149. Mock EF, Wrenn KD, Wright SW, Eustis TC, Slovis CM. Anxiety levels in EMS providers: effects of violence and shifts schedules. *The American journal of emergency medicine.* Oct 1999;17(6):509-511.

150. Labor Force Statistics from the Current Population Survey. *Labor Force Characteristics (CPS)* 2014; http://www.bls.gov/cps/lfcharacteristics.htm. Accessed October 23, 2014.

151. Azaroff LS, Levenstein C, Wegman DH. Occupational injury and illness surveillance: conceptual filters explain underreporting. *American journal of public health.* Sep 2002;92(9):1421-1429.

152. Oleinick A, Gluck JV, Guire KE. Establishment size and risk of occupational injury. *Am J Ind Med.* Jul 1995;28(1):1-21.

153. Lombardi DA, Folkard S, Willetts JL, Smith GS. Daily sleep, weekly working hours, and risk of work-related injury: US National Health Interview Survey (2004-2008). *Chronobiology international.* Jul 2010;27(5):1013-1030.

154. Olds DM, Clarke SP. The effect of work hours on adverse events and errors in health care. *J Safety Res.* Apr 2010;41(2):153-162.

155. Oginski A, Oginska H, Pokorski J, Kmita W, Gozdziela R. Internal and external factors influencing time-related injury risk in continuous shift work. *International journal of occupational safety and ergonomics : JOSE.* 2000;6(3):405-421.

156. James M, Tremea MO, Jones JS, Krohmer JR. Can melatonin improve adaptation to night shift? *The American journal of emergency medicine.* Jul 1998;16(4):367-370.

157. Kilpatrick K, Lavoie-Tremblay M. Shiftwork: what health care managers need to know. *Health Care Manag (Frederick).* Apr-Jun 2006;25(2):160-166.

158. Guyette FX, Morley JL, Weaver MD, Patterson PD, Hostler D. The effect of shift length on fatigue and cognitive performance in air medical providers. *Prehosp Emerg Care.* Jan-Mar 2013;17(1):23-28.

159. Tucker S, Diekrager D, Turner N, Kelloway EK. Work-related injury underreporting among young workers: Prevalence, gender differences, and explanations for underreporting. *J Safety Res.* 2014.

160. Ruser JW. Examining evidence on whether BLS undercounts workplace injuries and illnesses. *Mon Labor Rev.* Aug 2008;131(8):20-32.

161. Fan ZJ, Bonauto DK, Foley MP, Silverstein BA. Underreporting of work-related injury or illness to workers' compensation: individual and industry factors. *J Occup Environ Med.* Sep 2006;48(9):914-922.

162. Probst TM, Brubaker TL, Barsotti A. Organizational injury rate underreporting: the moderating effect of organizational safety climate. *J Appl Psychol.* Sep 2008;93(5):1147-1154.

163. Boal WL, Leiss JK, Ratcliffe JM, et al. The national study to prevent blood exposure in paramedics: rates of exposure to blood. *Int Arch Occup Environ Health.* 2010;83(2):191-199.

164. Pollack KM, Agnew J, Slade MD, et al. Use of employer administrative databases to identify systematic causes of injury in aluminum manufacturing. *Am J Ind Med.* Sep 2007;50(9):676-686.

165. Extended Unusual Work Shifts. Occupational Safety and Health Administration; https://http://www.osha.gov/OshDoc/data_Hurricane_Facts/faq_longhours.html. Accessed June 1, 2014.

166. Barger LK, Ayas NT, Cade BE, et al. Impact of extended-duration shifts on medical errors, adverse events, and attentional failures. *PLoS medicine.* Dec 2006;3(12):e487.

167. Kirkwood S. Studies Prove 24-Hour Shifts Unsafe: Another ethical dilemma for EMS leaders. *JEMS*. San Diego, CA: PennWell Corporation; 2012.

168. Smith-Jentsch KA, Kraiger K, Cannon-Bowers JA, Salas E. Do familiar teammates request and accept more backup? Transactive memory in air traffic control. *Hum Factors.* 2009;51(2):181-192.

169. Harrison DA, Mohammed S, McGrath JE, Florey AT, Vanderstoep SW. Time matters in team performance: effects of member familiarity, entrainment, and task discontinuity on speed and quality. *Personnel Psychology.* 2003;56(3):633-669.

170. Patterson PD, Moore CG, Weaver MD, et al. Mobile phone text messaging intervention to improve alertness and reduce sleepiness and fatigue during shiftwork among emergency medicine clinicians: study protocol for the SleepTrackTXT pilot randomized controlled trial. *Trials.* 2014;15:244.

171. Bender R, Blettner M. Calculating the "number needed to be exposed" with adjustment for confounding variables in epidemiological studies. *Journal of clinical epidemiology*. May 2002;55(5):525-530.

172. Lamond N, Dawson D. Quantifying the performance impairment associated with fatigue. *J Sleep Res.* Dec 1999;8(4):255-262.

173. Ragone M. Are we ready for the future? Where EMS stands now & where it's prepared to go. *JEMS : a journal of emergency medical services.* Feb 2011;36(2):38-43.

174. Takeyama H, Itani T, Tachi N, et al. Effects of a modified ambulance night shift system on fatigue and physiological function among ambulance paramedics. *J Occup Health.* 2009;51(3):204-209.

175. Probst TM, Estrada AX. Accident under-reporting among employees: testing the moderating influence of psychological safety climate and supervisor enforcement of safety practices. *Accid Anal Prev*. Sep 2010;42(5):1438-1444.

176. Weaver MD, Wang HE, Fairbanks RJ, Patterson D. The association between EMS workplace safety culture and safety outcomes. *Prehospital emergency care : official journal of the National Association of EMS Physicians and the National Association of State EMS Directors.* Jan-Mar 2012;16(1):43-52.

177. Kellermann AL, Hsia RY, Yeh C, Morganti KG. Emergency care: then, now, and next. *Health affairs.* Dec 2013;32(12):2069-2074.

178. Salas E. *Developing and enhancing teamwork in organizations : evidence-based best practices and guidelines.* 2013.

179. Winwood PC, Winefield AH, Lushington K. Work-related fatigue and recovery: the contribution of age, domestic responsibilities and shiftwork. *J Adv Nurs.* Nov 2006;56(4):438-449.

180. Reichard AA, Jackson LL. Occupational injuries among emergency responders - Reichard - 2009 - American Journal of Industrial Medicine - Wiley Online Library. *American journal of industrial ….* 2010.