TOTAL WORKER HEALTH ON OCCUPATIONAL INJURY AMONG MALE AND FEMALE, CAREER AND VOLUNTEER FIREFIGHTERS

by

CHRISTOPHER M KAIPUST, BA, MPH

APPROVED:

R SUE DAY, BS, MS, PHD
CHAIR AND ACADEMIC ADVISOR

WENYAW CHAN, BS, MS, MS, PHD
COMMITTEE MEMBER

GEORGE DELCLOS, MD, MPH, PHD
COMMITTEE MEMBER

SARA A JAHNKE, PHD
COMMITTEE MEMBER

W S CARLOS POSTON, MPH, PHD
COMMITTEE MEMBER

DEAN, THE UNIVERSITY OF TEXAS
SCHOOL OF PUBLIC HEALTH

TOTAL WORKER HEALTH ON OCCUPATIONAL INJURY AMONG MALE AND FEMALE, CAREER AND VOLUNTEER FIREFIGHTERS

by

CHRISTOPHER M KAIPUST
BA, Rockhurst University, 2012
MPH, University of Texas School of Public Health, 2014

Presented to the Faculty of The University of Texas

School of Public Health

in Partial Fulfillment

of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF TEXAS
SCHOOL OF PUBLIC HEALTH
Houston, Texas
May, 2018

ACKNOWLEDGEMENTS

This dissertation was completed with funding from National Institute for Occupational Safety and Health (NIOSH) Southwest Center for Occupational and Environmental Health (SWCOEH) Education and Research Center Grant No. 5T42OH008421 through an Occupational Epidemiology Traineeship. Funding was also received from the Assistance to Firefighters Grants (AFG) program managed by the Federal Emergency Agency (FEMA) in the Department of Homeland Security (DHS) (EMW-2009-FP-01971 and EMW-2010-FP-01812), and (EMW-2013-FP-00983).

TOTAL WORKER HEALTH ON OCCUPATIONAL INJURY AMONG MALE AND FEMALE, CAREER AND VOLUNTEER FIREFIGHTERS

Christopher M Kaipust, BA, MPH, PhD
The University of Texas
School of Public Health, 2018

Dissertation Chair: R Sue Day, BS, MS, PhD

There are more than 1 million firefighters in the US, of which 70% are career, 30% are volunteer, and 5% of the entire fire service is female. Physical characteristics, health behaviors, and psychosocial factors have been explored in association with on-duty injury among male career firefighters, but never in volunteer firefighters or female firefighters. The aim of this study was to explore the role of obesity on the association between on-duty injury and physical characteristics, health behaviors, and psychosocial factors in male and female, career and volunteer firefighters.

Data for this cross-sectional study came from the Firefighter Injury and Risk Evaluation Study (2008-2010), the Fuel 2 Fight study (2010-2013), The First Twenty for Volunteer Firefighters study (2014-2017), and The Health of Women Firefighters study (2013-2014). Male career (n=1,419), male volunteer (n=533), and female career (n=1,817) firefighters were examined separately. On-duty injury was the dependent variable, obesity was the effect modifier among the male firefighters, and the following factors were explored as independent variables: sleep, total work hours, physical activity, depression, job stress, job satisfaction, anxiety, rank, and age. Mixed effect multivariable logistic regression models

stratified by obesity with a group level factor of department were conducted among male career and volunteer firefighters. A multivariable logistic regression model was conducted among female career firefighters since there was no department selection factor to consider. Potential confounders were evaluated using backward elimination approach and the change in estimate of 10% applied to determine model efficiency. The odds ratios, stratified odds ratio, 95% CI, and p-value ($p<0.05$) were used to evaluate results for significance and model fit was explored for models in each of the analyses.

Female career firefighters had the highest prevalence of on-duty injury, followed by male career firefighters, and male volunteer firefighters. Male volunteer firefighters had the highest prevalence of obesity compared to male career firefighters and female career firefighters. Obesity modified the association between on-duty injury and sleep, physical activity, depression, and job stress among male career firefighters. Among male volunteer firefighters, obesity modified the association between on-duty injury and total work hours, sleep, and depression. Depression and job stress were found to be significantly associated with on-duty injury among female firefighters. The results of the study as a whole suggest the risk profile for on-duty injury is different among non-obese and obese male firefighters, and different from the risk profile for female firefighters likely due to the lower prevalence of obesity among females.

Body composition should be examined as an effect modifier between on-duty injury and its predictors among male firefighters. Findings from this study highlight the need to address obesity, depression, job stress, sleep, and fitness to reduce the disproportionate burden of on-duty injuries in the fire service.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDICES

BACKGROUND

Literature Review

Total Worker Health

The National Institutes for Occupational Safety and Health Total Worker Health program is defined as, "policies, programs, and practices that integrate protection from work-related safety and health hazards with promotion of injury and illness prevention efforts to advance worker well-being" (CDC, 2017). Total Worker Health aims to advance worker health and safety beyond traditional occupational safety and health parameters by examining the interaction between personal health and occupational health. Personal and occupational health interact heavily in firefighting, particularly for those who are overweight or obese, work long hours, or experience depression given the physical and psychological demand of the occupation, possibly leading to injury. There is a clear need for research on this interaction to improve personal and occupational health of the nation's first responders.

Firefighter Occupation

Firefighters in the United States are the first responders to domestic crises, emergencies, and natural disasters. The more than one million volunteer and career firefighters in the US make up a major part of the public health safety framework. The physical and psychological challenges firefighters encounter while on-duty have the potential to put the people they serve, their fellow firefighters, and themselves in danger. Given the extreme demands of the occupation, thousands of on-duty injuries occur every year. Firefighters and emergency medical personnel have higher risk of non-fatal injury than most other occupations (Reichard & Jackson, 2010). Firefighter injuries resulting from overexertion cost $2.7-2.8 billion annually in the US (CDC, 2017; National Institutes of Standards and Technology (NIST), 2005; Walton, Conrad,

Furner, & Samo, 2003). The high incidence and related cost of on-duty injuries signal the need to explore the predictors of injury to improve occupational safety and prevention efforts and worker health. How personal and occupational factors impact injury risk is not well understood. Given the poor health of firefighters reported in numerous studies, a Total Worker Health approach is needed to gain a more comprehensive understanding of injury risk factors for prevention.

NFPA defines an injury as, "Physical damage suffered by a person that requires (or should require) treatment by a practitioner of medicine (physician, nurse, paramedic, EMT) within one year of the incident (regardless of whether treatment was actually received), or that results in at least one day of restricted activity immediately following the incident" (Haynes & Molis, 2016). The National Fire Protection Association (NFPA) provides annual statistics on injury incidence rates, injury mechanism, type, body part affected, and activity performed among career and volunteer firefighters.

Firefighter Injuries

In 2015, 68,085 on-duty firefighter injuries were reported to the NFPA during their annual survey, an increase of 7.5% from 2014 (Haynes & Molis, 2016). Of these injuries, 29,130 (42.8%) injuries occurred during fireground operations. Non-fire emergency incidents, other on-duty activities, training activities, and responding/returning from an incident accounted for the remaining types of injuries (Table 1). The leading cause of injuries during fireground operations were fall/slip/jump, followed by overexertion and strain. The leading types of injuries were strains and sprains (56%). The percentage of injuries due to smoke or gas inhalation and burns or smoke inhalation, the most common injury the public associates with firefighting, is

only about 3%. Thermal stress is also low at around 4%. The northeast region of the country reported the highest number of on-duty injuries, 2.1 per 100 fires.

Epidemiologic studies have been conducted to capture Occupational Safety and Health Administration (OSHA) reportable injuries and non-OSHA department mandated reportable injures due to potential for injury to progress to a repeated, more severe reportable injury. Injury definitions across epidemiologic studies vary from injuries requiring an accident report for the department, worker's compensation, or medical care (S. A. Jahnke, Poston, Haddock, & Jitnarin, 2013), injuries requiring worker compensation only (Kuehl et al., 2012; W. S. Poston, Jitnarin, Haddock, Jahnke, & Tuley, 2011), OSHA reportable injuries (requiring medical treatment, restricted work time, or lost work time), department internally documented injuries requiring no medical treatment, loss of job function, or capabilities, but were reported to document in the case of leading to a OSHA reportable injury (Poplin, Harris, Pollack, Peate, & Burgess, 2012), and injuries only treated in emergency rooms (Reichard & Jackson, 2010). While there is some overlap with the NFPA definition of injury, the differences in injury definitions from epidemiologic investigations can result in different conclusions.

Despite slightly different definitions of injury across epidemiologic studies, the pattern and location of injuries has been similar between studies. Reichard and Jackson (2010) examined NIOSH National Electronic Injury Surveillance System reportable injuries treated in emergency departments during 2000-2001 foe emergency medical services, firefighting, and police occupations (Reichard & Jackson, 2010). The majority (71%) of the 37,300 firefighter injuries occurred among career firefighters as compared to volunteer. They found career firefighters had an injury rate of 7.4 injuries per 100 full-time equivalent workers. The leading

type of injury among firefighters was sprain and strain (33%) and most were caused by bodily motions (20%), which included overexertion.

Among 433 male, career firefighters who participated in the PHLAME study in Oregon and Washington, 184 injuries occurred over five years after the wellness intervention (2001-2005) (Kuehl et al., 2012). Over a third (37%) of the injuries resulted in a worker's compensation claim. Sprains and strains were the leading cause of injury (16%), the back was the most common body part injured (35%).

Poplin et al. conducted a descriptive study of injuries among the Tucson Fire Department from 2004-2009 (Poplin et al., 2012). During this period 902 injuries occurred, of which 45.3% were repeated injuries. Approximately 67% were sprains and strains, 96% were classified as minor injuries, and 53.1% were due to overexertion. Most of these injuries occurred among firefighters and paramedics (52%), while 44% were incurred among recruits, engineers, and captains. About one-third of the injuries happened during physical exercise and about 30% of all injuries required lost time from work, with the median of 6 days lost.

In a population-based sample of 462 male, career firefighters from 11 departments from 2008-2010 in the Missouri Valley region of the US, which is comprised of seven states, almost 25% of the sample had at least one injury in the past 12 months requiring an accident report for the department, worker's compensation claim, or medical care (S. A. Jahnke et al., 2013). Most injuries occurred during training (33.3%) or fire and rescue activities (27.9%), and most of the training injuries happened during exercise (81.1%). Dislocation, sprains, and strains were the leading type of injury, accounting for 18.8% of all injuries. In a study examining 20 departments across the US (2011-2012), 11.4% of 522 male, career firefighters from departments engaging in some type of wellness and fitness activities, and 7.0% of 480 male, career firefighters at

departments not implementing wellness and fitness programs had injuries reported to worker's compensation in the past six months (W. S. Poston, Haddock, Jahnke, Jitnarin, & Day, 2013).

Data from NFPA and epidemiologic studies consistently show most injuries occur on the fireground or during training, are due to overexertion or slips, trips, and falls, and sprains and strains are the leading type of injury. Data from epidemiologic studies have the advantage of capturing risk factors for injury, which are not reported on NFPA OSHA reportable injury reports. Risk factors such as total work hours, unfavorable body composition, sleep, fitness, and psychosocial factors have been captured, but not evaluated, and will be utilized for this research.

Future examinations should investigate how the association between total work hours and injury is impacted by obesity, sleep, and fitness. When firefighters are working long hours across multiple jobs, they may have less time or opportunity to engage in healthy behaviors such as regular exercise, adequate sleep, and preparation and consumption of healthy foods. With less time and work stress, from consistently working long hours across multiple jobs, health behaviors may be modified negatively. For example, job strain can lead to reduced intake of fruits and vegetables, high levels of overtime work can act as a barrier to exercise, and long work hours are associated with short sleep hours (Taris et al., 2011; Van der Hulst, 2003). In firefighters, long work hours may lead to poor occupational fitness, inadequate sleep and disrupted sleep, and obesity which all may impact occupational injury.

Total Work Hours and Injuries

US firefighters have unique work hours, active work and rest times, and shift structures as compared to other occupations. The most common work schedules are 24-hours on-duty/48-hours off-duty, 48-hours on-duty/96-hours off-duty, or rotating 10-hour day shifts/14-hour night shifts (Haddock, Poston, Jitnarin, & Jahnke, 2013). These work schedules result in 8 to 12 shifts

of work per month for a full-time employee. Firefighters do not typically actively work the entire shift. They are allowed rest periods and to sleep while on-duty, unlike other shift work positions such as nurses and physicians. In addition, firefighters are only awake during the night for emergency calls. Because of the unique job demands, it is difficult to generalize other research on work hours and shift structures, such as overtime, extended or long work shifts, and hours per week to the firefighter population. In addition, career firefighters and especially volunteer firefighters often have additional jobs outside of the fire service. Thus, it is important to consider work hours from all jobs when examining the association between work hours and health or occupational outcomes.

Lusa et al. examined firefighter work hours, stress, sleep disturbance, and injuries among Finnish firefighters (Lusa, Häkkänen, Luukkonen, & Viikari-Juntura, 2002). They found those working 70 to 100 hours per week had a 3.9 (95%CI: 1.6, 9.2) times higher odds of injury than those working less than 50 hours per week, but those working 51-69 hours per week did not have statistically significant higher odds of injury. The Lusa et al. study was conducted during a strike, and therefore in understaffed situations. A direct comparison of these results to a staffed fire station under normal working stressors may not be appropriate, but it does highlight the impact working long hours can have on occupational injury among firefighter populations.

Dembe and colleagues investigated 110,236 employee job records among a nationally representative sample of US working adults from the National Longitudinal Survey of Youth (Dembe, Erickson, Delbos, & Banks, 2005). They found employees who worked extended work hours every week (≥60 hours) had 1.23 (95% CI: 1.05, 1.45) times higher risk of occupational injury or illness than those who worked less than 60 hours a week. Those who worked ≥12 hours per day had 1.37 (95% CI: 1.16, 1.59) times higher risk of occupational injury or illness as

those who worked less than 12 hours. Those who reported working any overtime had 1.61 (95% CI: 1.43, 1.79) times the risk of occupational injury or illness than those who did not work over time. Those who had extended hours per week, per day, overtime, or extended commute time had 1.38 (95% CI: 1.25, 1.51) times the risk of occupational injury or illness than those who did not report extended hours per week, per day, overtime, or extended commute time. This study covered a large variety of jobs, controlled for age, gender, occupation, industry, and region among a large cohort.

Working long hours was significantly associated with occupational injury among firefighters as well as over 100,000 US workers in other occupations. Because there was only one study directly examining work hours and injury among firefighters, future research needs to examine this association among normal working conditions.

Injury Risk Factors

Evidence exists for potential fireground-specific injury risks and potential non-fireground injury risks, which may be divided into fireground characteristics and worker health characteristics. The main worker health characteristic associated with risk for injury among firefighters is unfavorable body composition. Depression also has been positively associated with risk for injury, although not as consistently associated with injury as body composition (S. A. Jahnke et al., 2013). Total work hours, sleep, fitness, and psychosocial factors have been associated with injury among firefighters and other occupational populations.

Obesity and Injury

The prevalence of overweight and obesity among firefighters is higher than that of the general US population. The prevalence of BMI-defined overweight and obesity was 79.5% and the prevalence of obesity was 33.5% among 478 male, career firefighters in the Missouri Valley.

The prevalence of overweight and obesity was 78.4% and the prevalence of obesity was 43.2% among 199 male, volunteer firefighters in the Missouri Valley region (W. S. Poston et al., 2011). The prevalence of overweight was 53% and the prevalence of obesity was 35% among 358 Massachusetts firefighters (Soteriades, Hauser, Kawachi, Christiani, & Kales, 2008). Among over 1,000 male, career firefighters from 20 departments across the US, the prevalence of BMI-defined obesity was 25% and 36%, body fat percentage-defined obesity was 33% and 44%, and waist circumference-defined obesity was 23% and 33% depending on the presence of a wellness and fitness program (W. S. Poston et al., 2013).

Total Work Hours and Body Composition

Choi et al. examined the association between the number of 24-hour work shifts in the past month and obesity status among 308 male firefighters in a single department in Southern California (Choi, Dobson, Schnall, & Garcia-Rivas, 2016). They found those who worked 15, 16, and 17-21 24-hour work shifts in the past month had 4.57 (95%CI: 1.06, 19.68), 4.38 (95%CI: 1.01, 18.90), and 6.03 (95%CI: 1.31, 27.78) higher prevalence ratios for BMI-based obesity compared to those working 8-11 shifts in adjusted models. The results were similar for 17-21 24-hour shifts and waist circumference and skin-fold thickness based obesity, although not statistically significant ($p=0.054$).

Luckhaupt et al. examined 15,121 working US adults from the 2010 National Health Interview Survey (Luckhaupt, Cohen, Li, & Calvert, 2014). They found individuals working more than 40 hours per week had 1.08 (95%CI: 1.01, 1.17) times higher prevalence of obesity than those working 35-40 hours per week. The authors suggest there may be other work related variables such as occupational physical activity or sedentariness contributing to obesity, although not examined.

Long work hours have been associated with increased odds of obesity among coal mine and university employees (Di Milia & Mummery, 2009), Korean workers (Jang, Kim, Lee, Myong, & Koo, 2013), and commercial truck drivers (Lemke, Hege, Perko, Sönmez, & Apostolopoulos, 2015). Solovieva et al conducted a systematic review on the association between long work hours and obesity. They reviewed four studies and concluded there was a positive association of long work hours and weight gain among men and women (Solovieva, Lallukka, Virtanen, & Viikari-Juntura, 2013).

Long work hours are positively associated with obesity and weight gain among adults in many occupations. Only one study has examined this association in firefighters from only one career department (Choi, Dobson, Schnall, & Garcia-Rivas, 2016) . This association needs to be examined among larger, more representative samples of career and volunteer firefighters from multiple departments across the country. No study has investigated obesity's role in the association between work hours and injuries among firefighters.

Body Composition and Injury

Lombardi et al (2012) examined the effect of BMI on injury risk among 101, 891 working adults in the US form the National Health Interview Survey (Lombardi, Wirtz, Willetts, & Folkard, 2012). They found only obese individuals had 1.34 (95%CI: 1.09, 1.66) higher odds of injury than normal weight individuals, not overweight individuals ($p>0.05$). Younger age was protective of injury, females had lower injury risks, and work hours were positively associated with injury.

Obesity has been a significant predictor of injury and injury related outcomes in firefighters in cross-sectional and prospective studies (S. Jahnke, Poston, Haddock, & Jitnarin, 2013; S. A. Jahnke et al., 2013; Kuehl et al., 2012; W. S. Poston et al., 2011; Smith, DeBlois,

Haller, Lefferts, & Fehling, 2015; Soteriades et al., 2008). Male firefighters with BMI-defined obesity were 5.2 (95% CI: 1.1, 23.4) times more likely to experience a musculoskeletal injury than normal weight firefighters in the Missouri Valley (S. Jahnke et al., 2013). Class II and III BMI defined obese male firefighters in the same cohort had nearly 5 (95% CI: 3.63, 6.58) times the odds of missed work days due to injury than normal weight firefighters. Obese class I male firefighters had 2.7 (95% CI: 2.01, 3.65) times higher odds than normal weight firefighters, and overweight male firefighters had 2.6 (95% CI: 1.90, 3.41) times higher odds of having missed work days due to injury compared to normal weight firefighters (W. S. Poston et al., 2011). Male firefighters had 1.04 (95% CI: 1.00, 1.07) times the rate of self-reported poor physical health days, which included injury and sickness, with every increase in one unit of BMI among a national sample of male firefighters (Brown et al., 2014).

In an examination of obesity and firefighters' worker's compensation claims in Oregon and Washington state, obese firefighters had 3 (95% CI: 1.17, 3.30) times the odds of filing an injury claim than normal weight firefighters (Kuehl et al., 2012). Finally, in an examination of obesity and job disability, every 1 kg/m^2 increase in BMI was associated with a 5% increased risk of job disability among male firefighters in Massachusetts (Soteriades et al., 2008). Current studies show obese male firefighters experience more injuries, miss more work days due to injury, are more likely to file worker's compensation claims, report more poor health days, and have an increased risk of job disability as compared to normal weight firefighters. Unfortunately, these studies utilized small samples in the limited geographic areas, limiting generalizability and strength of evidence.

Obesity is significantly associated with injury among firefighters and working adults in the United States. However, previous studies have been limited to specific geographic areas and only included career firefighters.

Total Work Hours, Obesity, and Injury

In the Lombardi et al (2012) examination of the association between obesity and injury, work hours was controlled for as a confounder (Lombardi et al., 2012). While both obesity and work hours were positively associated with injury, obesity was not examined as an effect modifier of work hours and injury. So, total work hours are significantly associated with obesity and injury, and obesity is significantly associated with injury, but no study has examined the role obesity plays in the relationship between total work hours and injury among any working population.

Sleep and Injuries

Firefighting is a unique occupation requiring firefighters to sleep at the station while on-duty. While on-duty, firefighters may be awoken for an emergency call, limiting the amount and quality of sleep. Among a convenience sample of 112 career firefighters, 59% were classified as sleep deprived (Carey, Al-Zaiti, Dean, Sessanna, & Finnell, 2011). Among 522 male, career firefighters from 10 departments, 5.6% of departments with wellness and fitness programs had doctor diagnosed sleep apnea and 5.1% of 480 male, career firefighters from 10 departments which did not have wellness and fitness programs had sleep apnea (W. S. Poston et al., 2013). Among 431 firefighters from the Columbus Ohio Division of Fire who participated in a sleep intervention, 42% screened positive for at least one sleep disorder at baseline (J. P. Sullivan et al., 2017a).

Total Work Hours and Sleep

Haddock et al. examined excessive daytime sleepiness (EDS) among male, career firefighters from the Missouri Valley region and found firefighters have a similar prevalence of unadjusted EDS rates (13.7% on-duty, 14.02% off-duty) as compared to the general population and other occupational populations (Haddock et al., 2013). Working a second job outside of the fire service was significantly associated with off-duty EDS (EDS rate with second job 17.1%, without 10.5%), as was working more hours outside of the fire service ($P<0.05$). Haddock et al. call for future research on the impact of having a second job outside of the fire service, which adds to the total burden of work hours on sleep related outcomes.

Lusa et al examined stress, work hours, and sleep disturbance among the Finnish firefighters during a strike (Lusa et al., 2002). They found those working 51-69 hours per week had 2.4 (95%CI: 1.4, 4.2) times higher odds of sleep disturbance than those working less than 50 hours, and those working 70-100 hours had 3.7 (95% CI: 2.4, 5.9) times the odds of sleep disturbance. Again, a direct comparison of these results may not be appropriate due to the understaffed setting, and there more demand placed on the firefighters, but it does highlight the impact working long hours can have on sleep among firefighter populations. Total work hours was positively associated with sleep disturbances in both these career firefighter studies. However, these study groups are limited to the Missouri Valley area and Finland, and do not include volunteer firefighters or women.

Sleep and Injury

Lombardi et al (2012) examined the effect of sleep and BMI on injury risk among 101, 891 working adults in the US form the National Health Interview Survey (Lombardi et al., 2012). They found poor sleep and obesity were significant independent predictors of injury, but there

was not a significant interaction between them. Those who usually slept less than 6 hours per night had 1.86 (95%CI: 1.37, 2.52) higher odds of injury than those who slept 7-7.9 hours, and those who usually slept 6-6.9 hours had 1.46 (95%CI: 1.18, 1.80) higher odds of injury. Obese individuals had 1.34 (95%CI: 1.09, 1.66) higher odds of injury than normal weight individuals, but overweight individuals did not have significantly higher odds of injury than normal weight individuals ($p>0.05$). Younger age was protective of injury, females had lower injury risks, and work hours were positively associated with injury.

In the fire service, Jahnke et al. did not find daytime sleepiness to be significantly associated with injury among 462 male, career firefighters from the Misssouri Valley region (S. A. Jahnke et al., 2013). Looking at incident injuries only, daytime sleepiness was not a significant predictor of incident injury among the same cohort (S. Jahnke et al., 2013). Sullivan et al conducted a randomized clinical trial of a sleep health program on firefighter injury and disability (J. P. Sullivan et al., 2017b). The study did not find significant differences in their key outcomes, self-reported sleep or sleepiness. However, firefighters who attended at least one education session had 24% (OR: 0.76; 95%CI: 0.60, 0.98) lower odds of filing an injury report than those who did not attend any sessions. In addition, those completing the intervention had 46% fewer disability days than those in the control stations ($p<0.05$).

The current evidence does not provide strong support of a positive association between sleep and injury (J. P. Sullivan et al., 2017a). These studies are not representative of the fire service due to only career, Midwest firefighters explored in one study and one Midwest career department explored in the other. Further investigation in broader samples among career and volunteer firefighters with consistent measures is needed.

Total Work Hours, Sleep, and Injury

Lombardi et al used National Health Interview Survey data to examine the association between sleep, work hours, and occupational injury among 74, 415 working adults (Lombardi, Folkard, Willetts, & Smith, 2010). They found compared with those who usually slept 7-7.9 hours, those who slept <5 hours had 2.65 higher odds of injury, those who usually slept 5-5.9 hours had 1.79 higher odds of injury, and those who usually slept 6-6.9 hours had 1.40 higher odds of injury. Younger age was protective of injury, females had lower injury risks, and BMI was positively associated with injury. Work hours were also significantly associated with occupational injury (OR=1.10).

Sleep and work hours are independently significantly associated with occupational injury. Lombardi also tested the interaction between daily sleep and work hours, but did not find a significant interaction. However, the lack of an interaction may be due the variety of occupations included in the analysis, which may diminish an association in a unique occupation, such as firefighting. No study has examined the role sleep plays in the relationship between total work hours and injury among any firefighters, career or volunteer.

Fitness and Injuries

One estimation of fitness used in the fire service is VO_{2max}. VO_{2max} is the maximal rate of oxygen consumption during exercise. The NFPA standard states firefighters should at minimum meet the criterion of 12.0 metabolic equivalent (42 mL/kg/minute) (Donovan et al., 2009; National Fire Protection Association, 2006; Poston et al., 2011). Physical activity level, along with BMI, age, and gender can be used to estimate VO_{2max} in a non-exercise model in epidemiologic studies (A. S. Jackson et al., 1990; A. S. Jackson & Ross, 1997; A. S. Jackson et

al., 1995; A. S. Jackson et al., 1996; Jurca et al., 2005; Wier, Jackson, Ayers, & Arenare, 2006). An individual with a low physical activity level will have lower fitness.

Among firefighters from 11 departments in the Missouri Valley region, only 38.7% of career and 23.6% of volunteer male firefighters met the minimal criterion of 12.0 METs regardless of their weight (W. S. Poston et al., 2011). Obese male, career firefighters had 96% higher odds of not meeting the NFPA standard than normal weight firefighters, and male, volunteer firefighters had 99% higher odds of not meeting the standard than normal weight firefighters. Among male, career firefighters from 10 departments across the US who had a health and fitness program, only 46.8% of firefighters met the NFPA standard and only 43% of career firefighters from 10 departments across the US who do not have a health and fitness program met the NFPA standard (W. S. Poston et al., 2013).

Total Work Hours and Fitness

Taris et al. examined the association between overtime, health behaviors, and subjective health among 649 Dutch working adults (Taris et al., 2011). They authors report overtime lead to lower levels of physical activity. They suggest this is because individuals do not have the opportunity nor the energy to engage in physical activity. Van der Hulst found physical exercise was not associated with extended work hours among the three studies reviewed, but all three studies were among Japanese populations working in various occupations (Van der Hulst, 2003). There is a limited amount of research on total work hours and fitness among working populations and no research among firefighting. This association needs to be explored further among a large, diverse sample of firefighters in the US.

Fitness and Injury

Poplin et al. conducted a retrospective cohort to examine the association between aerobic fitness and risk of injury among 799 fire service employees in a fire department in Tucson, Arizona (Poplin, Roe, Peate, Harris, & Burgess, 2014). The mean VO_{2max} among the firefighters was 49.6 mL/kg/minute and 773 injuries were reported over the 5-year study period. A 1 unit increase in VO_{2max} decreased risk of injury 0.041 times (HR: 0.953; 95%CI: 0.939, 0.968), which means improving a firefighter's metabolic equivalent of a task (MET) (1 MET=3.5 mL/kg/minute) would reduce the risk of any injury by 14%. Those in the middle fitness category (43-48 mL/kg/minute) were 1.38 (95%CI: 1.06, 1.78) times more likely to sustain an injury than those in the highest fitness category (>48 mL/kg/minute). Those in the lowest fitness category (<43 mL/kg/minute) were 2.22 (95%CI: 1.71, 2.88) times more likely to sustain an injury than those in the highest fitness category (>48 mL/kg/minute). Hazard ratios for risk of injury also were increased significantly for both levels of fitness for sprains and strains, and for the lowest level of fitness for exercise injuries. Poplin et al. also found age modified the association between aerobic fitness and injuries. Specifically, firefighters less than 30 years of age in the middle (HR: 2.28; 95%CI: 1.41, 3.71) and lower (HR: 3.43; 95%CI: 2.10, 5.58) levels of aerobic fitness were at higher risk of injury than those greater than 30 years of age in the middle (HR: 1.15; 95%CI: 0.85, 1.57) and lower (HR: 1.86; 95%CI: 1.36, 2.53) levels of aerobic fitness.

Poplin et al. used the same data to examine a more comprehensive measure of fitness in relation to injury (Poplin, Roe, Burgess, Peate, & Harris, 2016). The comprehensive fitness score, calculated for each person-year, was comprised of VO_{2max}, resting heart rate, total grip strength, flexibility, percent body fat, sit-ups, and push-ups. The study results were similar to the VO_{2max} measure in that those with lower comprehensive fitness levels had increased risk of

injury compared to those with higher comprehensive fitness levels, and age modified this association.

Fitness interventions have been conducted in the fire service to lower injury rates. Griffin et al. conducted a pilot intervention among recruits and found a significant difference in overall injury, injury during probationary year, claims frequency, and claims costs compared to historical controls (Griffin et al., 2016). The return on investment for the intervention was 2.4%. Damrongsak did not find an association between fitness and ever having lower back pain among a convenience sample of firefighters from one department (Damrongsak, Prapanjaroensin, & Brown, 2017). However, the measures of fitness used in this study were not as sensitive or comprehensive as those in other studies such as Poplin et al.

Aerobic capacity is one measurement of fitness, and planned physical activity, or exercise, helps achieve or maintain fitness. Jahnke et al. found participants who engaged in on-duty exercise had 4 times the odds of being injured as compared to those who did not exercise and most of those were exercise related. However, those who engaged in on-duty exercise had half the odds of sustaining non-exercise injuries among 462 male career firefighters from 11 departments in the Missouri Valley region (S. A. Jahnke et al., 2013). VO_{2max} was not significantly associated with injury. Looking at incident injuries only, self-reported physical activity was not a significant predictor of incident injury among the same cohort (S. Jahnke et al., 2013). Overall, the research among career firefighters shows a significant association between fitness and injury, but not physical activity.

Total Work Hours, Fitness, and Injuries

Fitness is significantly associated with injuries among firefighters, but the association between total work hours and fitness is less clear due to the limited amount of research

conducted. Further no study has examined the role fitness may play in the relationship between total work hours and injury among firefighters. This association should be examined in a large, geographically diverse sample, among both career and volunteer firefighters.

Psychosocial Factors and Injuries

Psychosocial factors such as depression, anxiety, stress, family stress, job satisfaction, firefighter self-efficacy, and work discrimination and harassment may lead to occupational injury.

Job stress and Injury

Poston et al. found perceived stress was not a significant predictor of missed work days due to injury among 478 male, career firefighters from 11 departments in the Missouri Valley region (W. S. Poston et al., 2011). Poston et al. also found that among over 1,000 male, career firefighters from 20 departments, most firefighters disagreed to the statement "I have had stress at work while carrying out duties during the last six months," and strongly disagreed to "stress at work interfered with performing duties during the last six months" on a scale from strongly disagree to strongly agree (W. S. Poston et al., 2013).

Kim et al. conducted a national survey among Korean firefighters to examine the association between job stress and occupational injuries (Kim, Ahn, Kim, Yoon, & Roh, 2016). For firefighters whose primary responsibility was fire suppression, high job demand (OR 1.49; 95%CI: 1.25, 1.77), high interpersonal conflicts (OR 1.18; 95%CI: 1.02, 1.37), poor organizational support (OR 1.33; 95%CI: 1.14, 1.55), and negative workplace environment (OR 1.41; 95%CI: 1.21, 1.64) were all significantly associated with injury. For EMS personnel, high job demand (OR 1.26; 95%CI: 1.03, 1.54), high interpersonal conflicts (OR 1.40; 95%CI: 1.19, 1.66), poor organizational support (OR 1.55; 95%CI: 1.33, 1.85), low rewards (OR 1.43; 95%CI: 1.21, 1.69), and negative workplace environment (OR 1.30; 95%CI: 1.10, 1.54) were all

significantly association with injury. For officers, a high job demand (OR 1.96; 95%CI: 1.35, 2.85) and a negative workplace environment (OR 1.54; 95%CI: 1.13, 2.10) were all significantly associated with injury. Damrongsak did not find an association between occupational stress and ever having lower back pain among a convenience sample of firefighters from one department (Damrongsak et al., 2017).

Male, career, firefighters in the US self-report low levels of job stress, even though they were high stress jobs, suggesting they manage it well. Poston et al. found stress not to be associated with missed work days due to injury, but stress was not examined in association with occurrence of injury. Their results suggest stress was not associated with severe injuries which would require missed days of work, but do not indicate if it is associated with injury itself. Job stress was found to be significantly associated with injury among Korean firefighters. Job stress needs to be examined with injury among a large, diverse sample of US male, career and volunteer firefighters and female firefighters.

Job Satisfaction and Injury

Poston et al. found the 10 departments with a wellness and fitness program were significantly more likely to report greater optimism (4.1 vs 3.7), job satisfaction (4.2 vs 3.8), satisfaction with morale of coworkers (3.6 vs 2.9), better morale of the fire department (3.6 vs 3.1), and a sense of accomplishment (4.2 vs 3.9) than the 10 departments without a wellness and fitness program (W. S. Poston et al., 2013). But, overall the scores for job satisfaction were high. Poston et al. also examined job satisfaction and missed work days among 478 male, career firefighters from 11 departments in the Missouri Valley region. Job satisfaction was not a significant predictor of missed work days (W. S. Poston et al., 2011). Damrongsak did not find

an association between job satisfaction and ever having lower back pain among a convenience sample of firefighters from one department (Damrongsak et al., 2017).

Firefighters have high job satisfaction, but the ratings differ among career departments with and without a wellness and fitness program. Job satisfaction was not a significant predictor of injury among male, career firefighters from the Midwest or a significant predictor of low back pain among a convenience sample from a single department. This association needs to be explored among a large, geographically diverse sample of firefighters, including volunteer and female firefighters.

Depression and Injury

Poston et al. found the prevalence of physician diagnosed depressive disorder among firefighters was 6.2% among 10 departments (522 firefighters) with a wellness and fitness program and 6.8% among 10 departments (480 firefighters) without a wellness and fitness program, and the mean CESD-10 scores were low in both (1.7 and 1.8, respectively) (W. S. Poston et al., 2013).

In the Jahnke et al. study on injuries among career firefighters in the Missouri Valley region, those scoring in the range of concern for symptoms for depression had 2.33 times the odds of injury than those not scoring in the range of concern for depression (S. A. Jahnke et al., 2013). Looking at incident injuries only, depression was not a significant predictor of incident injury among the same cohort (S. Jahnke et al., 2013). Depression also was not a significant predictor of missed work days among the same population (W. S. Poston et al., 2011).

Tiesman et al. conducted the first prospective analysis of depression as a risk factor for injury among a cohort of 1,493 men and women in rural Iowa (Tiesman et al., 2006). They found those who had depressive symptoms had a 41% (95%CI: 1.10, 1.80) higher risk of injury

than those who did not, after controlling for antidepressant medication use, gender, previous injury, income, and sleepiness. The prevalence of those scoring in the range of concern for depressive symptoms was 17%. While this was a general population-based study, it did include workers and occupational injuries. Overall, depression appears to be significantly associated with occupational injury, although there were conflicting results. This association needs to be better understood among a larger, more geographic sample of career firefighters, and among volunteer and female firefighters.

Anxiety and Injury

Poston et al. found the prevalence of physician diagnosed anxiety disorder among firefighters was 3.2% among 10 departments (522 firefighters) with a wellness and fitness program and 10.7% among 10 departments (480 firefighters) without a wellness and fitness program (W. S. Poston et al., 2013). Anxiety needs to be explored as a predictor of injury among all firefighter populations given the associations found for other mental health factors such as stress and depression.

Female Firefighters

The percentage of females in the US fire service is estimated to be between 3.7% and 5.1% of the US fire service is female (S. A. Jahnke et al., 2012). This is extremely low compared to similar occupations such as the military and police force, which have about 17% females. The psychological and physical strain of firefighting, along with gender-based harassment and a male dominated culture not accepting of females has been posited as the explanations for the very low proportions of females in the fire service. A court decision set a target goal of 16-22% women in the fire service, yet there are no efforts to track any potential progress on this goal. An abysmal amount of research on female firefighters has been conducted

in the fire service, and this has been acknowledged by Federal Emergency Management Agency (FEMA), United States Fire Administration (USFA), and National Fallen Firefighters Foundation (NFFF).

Murphy et al. utilized a cross-sectional design to described gender differences of job stressors and symptoms of stress in firefighters in 1994 among 670 males and 41 females with 10 years or less experience firefighting (Murphy, Beaton, Cain, & Pike, 1995). They found female firefighters reported significantly higher scores regarding job skill concerns, job discrimination, and depression than males.

The International Association of Women in Fire and Emergency Services published "A National Report Card on Women in Firefighting" in 2008 (Hulett, Bendick, Thomas, & Moccio, 2008). In this report, they found discrimination or harassment are prevalent in the fire service. About 85% of women reported having experienced different treatment because of their gender, while only about 12% of men reported unequal treatment. Additionally, as compared to less than 3% of men: 51% of women experienced shunning/isolation because of their gender, 46% experienced negative incidents of privacy in showers, dormitories, or when changing clothes, 43% experienced verbal harassment issues, almost a third experienced pornography issues, 30% experienced unwanted sexual advances, and 28% experienced incidents with dormitory accommodations all because of their gender. Further, 30% said these incidents continue today. In regards to addressing discrimination complaints, 65% of female firefighters and 43% of male firefighters said their department has no procedure for addressing discrimination complaints.

Jahnke et al. in 2012 reported on 18 career and 13 volunteer female firefighters from the Midwest (S. A. Jahnke et al., 2012). The prevalence of percent body fat defined obesity among female career firefighters was 38.9% (47.7% among male) and 46.2% among female volunteer

firefighters (54.3% among male). Almost 28% of female career firefighters reported an injury in the past month and only 7.7% of female volunteer firefighters reported injuries. Mental health and job satisfaction were also examined. About one-quarter of female career firefighters (22.2%) and 38.5% of female volunteer firefighters reported CESD scores in the range of concern for depression. Approximately 28% of female career firefighters and 31% of volunteer firefighters reported feeling nervous and stressed fairly often or very often. About 22% of female career firefighters reported feeling angered because things were outside of their control fairly often or very often. Overall, female career and volunteer firefighters reported strong perceived coping skills.

Career female firefighters were satisfied with their job at their fire department but only about half of volunteers were satisfied. Female volunteer firefighters reported a slightly higher sense of accomplishment from work than career females (85% vs 77%). Female career firefighters were more optimistic about their success with the fire department than female volunteers (82% vs 54%). Female volunteer firefighters were more satisfied with the personal morale at the fire department than female career firefighters (69% vs 53%), and were slightly more satisfied with the morale of the crew than female career firefighters (62% vs 53%).

It is abundantly clear there are issues in the workplace for female firefighters which need to be addressed to improve life for current and future female firefighters. Most of the current research done among female firefighters has been descriptive. Therefore, it is unknown how these psychosocial factors are associated with occupational injury among female firefighters.

Public Health Significance

According to the NFPA one firefighter injury occurs every 7 minutes and 43 seconds (Haynes & Molis, 2016). Qualitative research among fire service personnel has emphasized concerns about

obesity, fitness, mental health, and injuries (S. A. Jahnke, Poston, Jitnarin, & Haddock, 2012). Further, US Fire service leadership has raised concerns about having a second job outside of the fire service, and therefore total work hours, is an issue potentially related to health and sleep (Elliot & Kuehl, 2007).

The role of obesity, sleep, and fitness on total work hours and occupational injury among career and volunteer firefighters is unknown. Further, the impact of psychosocial factors on occupational injury among male and female, career and volunteer firefighters is largely unknown. Previous examinations of injuries among firefighters have primarily been conducted among male career firefighters in the Midwest or single departments, with no ability to compare predictors of injury by region, career or volunteer, or gender. The proposed research is indeed novel and is expected to provide evidence of the interaction between personal and occupation health on occupational safety. In doing so, the proposed research will inform Total Worker Health personal and occupation health and safety prevention programs. *This contribution will be significant because it will pool data from four of the largest epidemiologic studies in the fire service to date to create the largest, most representative, geographically diverse sample of career, volunteer, male, and female firefighters to explore occupational health and safety in the United States.*

This project will elucidate the predictors of injuries among US career and volunteer firefighters, and male and female firefighters, including two underserved occupational sub-populations, volunteers and females. In the long term, this study will provide information to inform prevention strategies and policies to reduce the incidence of on-duty injuries and improve health of male and female career and volunteer firefighters.

Hypothesis, Research Question, Specific Aims or Objectives

Aim 1a: To determine the role of body composition on the association between sleep and on-duty injury among male, career firefighters from the FIRE (2008-2010) and Fuel 2 Fight (2010-2013) cohorts.

> **Hypothesis Aim 1a**: Firefighters in the obese stratum with poor sleep will have higher odds of on-duty injury as compared to those in the normal weight stratum with no sleep problems.

Aim 1b: To determine the role body composition and sleep have on the association between total work hours and on-duty injury among male, volunteer firefighters from FIRE (2008-2010) and The First Twenty (2014-2017) cohorts.

> **Hypothesis Aim 1b**: Firefighters in the obese stratum, with poor sleep, and with higher total work hours will have higher odds of on-duty injury as compared to those in the normal weight stratum, no sleep problems, and with lower total work hours.

Aim 2: Identify psychosocial predictors of on-duty injury among male, career and volunteer firefighters.

> **Sub Aim 2a**: Identify psychosocial predictors (stress and depression) of on-duty injury among male, career firefighters from the FIRE (2008-2010) and Fuel 2 Fight (2010-2013) cohorts.
>
> > **Hypothesis Sub Aim 2a**: Firefighters reporting job stress and depression will have higher odds of on-duty injury as compared to those without stress or depression.

Sub Aim 2b: Identify psychosocial predictors (depression) of on-duty injury among male, volunteer firefighters from the FIRE (2008-2010) and The First Twenty (2014-2017) cohorts.

Hypothesis Sub Aim 2a: Firefighters reporting depression will have higher odds of on-duty injury as compared to those with no depression.

Aim 3: Identify psychosocial predictors (stress, job satisfaction, depression, and anxiety) of on-duty injury among female firefighters from the Health of Women Firefighters (2013-2014).

Hypothesis Aim 3: Firefighters reporting job stress, job dissatisfaction, depression or anxiety will have higher odds of on-duty injury as compared to those without job stress, job satisfaction, no depression or anxiety.

JOURNAL ARTICLE

Sleep, Obesity, and Injury Among US Male Career Firefighters

Journal of Occupational and Environmental Medicine

Introduction

The US fire service has an alarmingly high prevalence of overweight and obesity. The prevalence of BMI-defined overweight and obesity among male firefighters is around 80%, which 25-36% are obese[1-3]. In the general population, the prevalence of overweight and obesity among US adults is 70.7%, which 37.9% are obese[4]. Obesity is a risk factor for many poor health outcomes including high blood pressure, coronary heart disease, stroke, diabetes, sleep apnea, and mental illness[5]. Obesity is of particular concern to the fire service because cardiac death, which obesity is a risk factor, is the leading cause of line-of-duty deaths in the fire service. Obesity can also lead to difficulty with physical functioning[5]. Obesity has been a significant predictor of on-duty injury and injury-related outcomes in firefighters in cross-sectional and prospective studies[1, 6-9]. The proposed mechanism for obesity on injury centers on excess fat adding extra load and altering mechanics while performing locomotor tasks, stressing connective tissue structures[10].

Beyond obesity, investigations into other personal health factors, such as physical activity, associated with on-duty injury have been conducted across many occupations. Looking at incident on-duty injury only, self-reported physical activity done anywhere was not a significant predictor among firefighters[9]. On-duty exercise, a component of physical activity, has been associated with on-duty injury among career firefighters. Engaging in on-duty exercise has been associated with higher odds of on-duty injury, but firefighters who engaged in on-duty exercise had half the odds of sustaining non-exercise injuries[7].

Sleep has been less explored than obesity and exercise with on-duty injury. Career firefighters typically work in 24-hour shifts requiring them to stay overnight at the fire station while on-duty. Overnight, firefighters often are allowed to sleep between calls, but may be awoken for calls which reportedly limits the amount and quality of their sleep. Long work hours, which can lead to decreased sleep quantity, are also associated with greater on-duty injury in firefighters and other occupations[11, 12]. Among a convenience sample of 112 career firefighters from a single department, 59% were classified as sleep deprived[13]. Among 431 firefighters from a Midwest fire department, 42% screened positive for at least one sleep disorder[14]. In the fire service, self-reported quantity of sleep or sleepiness and daytime sleepiness have not been found to be associated with on-duty injury[7, 9, 14]. Only a handful of studies have been done, in the same Midwest region, of which two used daytime sleepiness, a result of poor sleep, rather than a measure of sleep quantity or quality. The proposed mechanism for sleep on injury draws from short sleep or poor sleep leading to sleepiness and fatigue, which results in impaired performance and safety[11, 15-18]. Investigations outside the fire service among US working adults report poor sleep and obesity are significant independent predictors of occupational injury[19]. The interaction between sleep and BMI on on-duty injury has not been examined in the fire service, a physical demanding occupation where poor sleep and obesity are both prevalent.

In 2015, 68,085 on-duty firefighter injuries were reported to the National Fire Protection Association (NFPA) during their annual survey, an increase of 7.5% from 2014[20]. Data from the NFPA and epidemiologic studies consistently show most injuries occur on the fireground or during training or exercise. The leading causes of firefighter on-duty injuries are overexertion, slips, trips, or falls, and sprains or strains are the leading types of injury[6-8, 20-22]. Firefighters and emergency medical personnel have higher risk of non-fatal injury than most other occupations[21].

Poston et al. estimated the cost of absenteeism from on-duty injury due to excess weight among a cohort of firefighters[8]. The attributable per capita costs for obesity-related absenteeism was $74.41 per overweight firefighter over the last year, $254.00 per obese class I firefighter, and $1,682.90 per class II and III obese firefighter over the last year[8].

The high incidence and related cost of on-duty injuries, and the high prevalence of obesity and poor sleep signal the need to explore the predictors of on-duty injury beyond traditional occupational factors to improve occupational safety and prevention efforts as well as worker health. Previous examinations of injuries in the fire service have primarily been conducted among Midwest departments or single departments across the nation, which may not be representative of the US fire service as a whole. How personal and occupational factors interact to impact firefighters' injury risk is not fully understood. The aim of this study is to determine the role of obesity on the association between sleep and on-duty injury among male career firefighters using two studies, the largest national cohort of over 1,000 firefighters and 478 firefighters from eight Midwest states.

Methods

Participants and Procedures

Data for this cross-sectional study are from the baseline assessments of the Firefighter Injury and Risk Evaluation (FIRE) study and the Fuel 2 Fight (F2F) study. The longitudinal FIRE cohort study was conducted in the US Midwest from 2008-2010. A list of fire departments was obtained from all eight International Association of Fire Chiefs Missouri Valley region states (Kansas, Missouri, Iowa, Nebraska, North Dakota, South Dakota, Colorado, and Wyoming) using the U.S. Fire Department Census Database. Fire departments were randomly selected and then contacted for participation. Details of the sampling strategy and recruitment

have been published [2]. There were 11 career and 13 volunteer departments (N=736) in the IAFC Missouri Valley region selected for participation, and 97% (N=714 total) of all firefighters solicited from the departments consented to participate. For this study, only data from male, career firefighters (n=478) were used. There were low numbers of female firefighters (n=21), typical of the overall fire service; thus, females were excluded due to the inability to make gender comparisons.

The F2F study was a longitudinal cohort study conducted from 2010-2013. The F2F study used a purposive sampling approach to select 10 heterogeneous fire departments from across the US self-reporting having implemented key aspects of the Fire Service Joint Labor Management Wellness-Fitness Initiative (WFI)[3]. These departments were matched by size, call volume, staffing, and catchment area to 10 standard departments not implementing the WFI. The list of potential standard departments from across the country was generated from a solicitation posted in Chief Billy Goldfeder's "Secret List" (a popular, worldwide listserv for firefighters). Departments were screened and selected by the research team and approved by an Expert Fire Service Panel. Detailed information on sampling strategy and recruitment have been published[3]. Overall, 94.4% (N=1,035) of firefighters solicited consented to participate. For this study, only male firefighters (n=941) with complete data were included in the analyses and the small number of female firefighters (n=33) in this career sample were also excluded.

In total there were 1,419 eligible male firefighters for this analysis. Institutional Review Boards approved the FIRE and F2F study protocols prior to onset of the studies. Investigators traveled to all fire departments in both studies for 2-8 days depending on department size and shift structure to maximize participation. Interested firefighters were consented in person using written consents for both studies.

Measures

The same investigators conducted both studies coordinating with the department chiefs to schedule data collection meetings to explain the study and complete consents for on-duty firefighters. Firefighters in both studies were asked to complete paper questionnaires using similar questions. The same trained investigators conducted the physical measurements (height, weight, waist circumference, body fat) using identical protocols. Self-report demographic (age, race/ethnicity, education) and occupational (years in fire service, rank, total work hours, fitness using estimated VO_{2max} in a non-exercise model[3]) information was collected along with the following measures.

Injury

Injuries were assessed using questions based on the National Health Interview Survey (CDC) and firefighter-specific questions modeled on wording from the National Institute of Standards and Technology[23, 24]. The injury section began with the instruction, "The following questions are about injuries you have incurred in the past 12 months. An injury is anything for which you have or should have received medical care (by a physician or other medical professional) whether you reported the injury or not." The firefighters indicated the number of on-duty injuries in the past 12 months for the FIRE study and in the past 6 months for the F2F study. Responses from both studies were dichotomized as no injuries or one or more injuries.

Sleep

Sleep was assessed in the same manner in both studies by response to the following two questions, "Most nights when I am on duty at the fire station, I get enough sleep" and "Most nights when I am not on duty at the fire station and I am at home, I get enough sleep." Firefighters responded using a 5-point Likert scale from strongly disagree to strongly agree.

Responses from these two variables were dichotomized into not enough sleep at the fire station and/or at home, or enough sleep. Firefighters responding strongly disagree or disagree were grouped to "not enough sleep," and firefighters responding strongly agree, agree, and no opinion were grouped to "enough sleep."

Body Composition

Body Mass Index (BMI), waist circumference, and body fat percentage were measured by study personnel. Height was measured using a stadiometer and weight using a Tanita 300. BMI was categorized using standard CDC cut points for underweight (<18.5 kg/m^2), normal weight (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2), and obese (>30 kg/m^2)[23]. Waist circumference was measured using a spring-loaded tape measure following standard procedures. Measures were dichotomized using standard CDC cut points for high risk for developing obesity related conditions (high risk male, >102cm)[25]. Body fat percentage was measured using foot-to-foot bioelectrical impedance Tanita 300 and was dichotomized using CDC cut points (unhealthy male, >25%)[25].

All three measures of body composition were evaluated to determine the best single measure for inclusion in statistical analyses. Obesity prevalence was similar across body composition measurements, and BMI was chosen due to its ease for comparability to other studies, its accuracy in defining obesity in this population (false positive 9.2% and false negative 14.6% compared to waist circumference)[26], and its ability to distinguish normal, overweight, and obese firefighters.

Physical Activity

The Self-Report of Physical Activity (SRPA) questionnaire used in FIRE and F2F measured physical activity pattern during the past 30 days[27]. Firefighters chose their physical

activity patterns by selecting a response from a range from 0 (Avoids walking or exertion) to 7 (>3 hours/week of vigorous activity). SRPA categories were collapsed to provide adequate cell sizes during analyses.

Total Work Hours

Total work hours at the fire department and from employment outside the fire house were assessed in the same manner in both studies by the following two questions: "Most weeks, I work __ hours for the fire department" and "Most weeks, I work __ hours OUTSIDE of the fire department" requiring firefighters to write in the hours for both questions. The hours per week were combined from both questions to create a total work hours per week variable, and then categorized into "<50 hours per week," "50-69 hours per week," "70-89 hours per week," and ">=90 hours per week."

Statistical Analyses

Statistical analyses were performed with Stata version 15[28]. The association between on duty injury, sleep, and the potential confounders age, rank, total work hours, physical activity, obesity, and years in fire service was evaluated using logistic regression. Potential confounders were evaluated using backward elimination approach and the change in estimate of 10% applied to determine model efficiency. Age was forced into the final model.

To account for sampling, a group level factor of "department" was entered as a random effect in all multivariable models. A multivariable mixed effect logistic regression model was created with the confounders. A multivariable, mixed effect logistic regression model stratified by BMI categories was created to examine the presence of effect measure modification comparing stratified odds ratios. The stratified odds ratio, 95% CI, and p-value ($p<0.05$) were used to evaluate results for significance and model fit was explored.

Results

Firefighter demographics stratified by BMI defined obesity are presented in Aim 1a Table 1. In this large cohort of firefighters 81.4% were overweight or obese. Approximately 25% of the sample experienced one or more injuries in the previous six months to twelve months. Obese firefighters reported less vigorous physical activity, and fewer obese (11.5%) firefighters met the NFPA fitness standard of 12 metabolic equivalents than normal (77.5%) and overweight (50.5%) firefighters. Obese firefighters were slightly older, worked the most hours per week, were a greater percentage minority, and had more years of service compared to those normal and overweight.

In model building, years in the fire service was dropped due to collinearity with age. In this cross-sectional study, the odds of reporting not getting enough sleep versus getting enough sleep among male career firefighters who had an on-duty injury was 1.62 (95% CI: 1.21, 2.16) times more likely than among uninjured firefighters after adjusting for confounding (Aim 1a Table 2). The odds of vigorous physical activity >3 hours per week versus avoiding exertion among firefighters who had an on-duty injury was 1.76 (95% CI: 1.06, 2.92) as compared to uninjured firefighters.

Results from effect measure modification analyses necessitated presenting stratified results (Aim 1a Table 3). Among obese firefighters, the odds of not getting enough sleep versus getting enough sleep among firefighters indicating an on-duty injury was twice the odds of the uninjured. The odds of not getting enough sleep among normal weight firefighters who had an on-duty injury was 1.59, and among overweight was 1.39, although neither were significant ($p>0.05$). Obese firefighters who had an on-duty injury had double to triple the odds of increasing duration and intensity of physical activity versus avoiding exertion among the

uninjured. The association between on-duty injury and sleep appears to be modified by body composition, and obese firefighters who had an on-duty injury had the highest odds of not getting enough sleep compared to the uninjured.

Discussion

Firefighters are an occupational group with one of the highest prevalence of obesity[29]. Previous investigations have found obesity to be a significant predictor of on-duty injury, but this is the first investigation in the fire service to examine body composition as an effect modifier between other health behaviors (sleep) and the occupational outcome, on-duty injury.

Prior to our study, the association between sleep and on-duty injury has been relatively unexplored in the fire service. Further, the effect of BMI on injury and sleep had not been examined in the fire service, a physical demanding occupation where poor sleep and obesity are prevalent. This study found obese firefighters with an on-duty injury have twice the odds of not getting enough sleep than uninjured obese firefighters. The effect modification was not significant for normal or overweight firefighters. Given the cross-sectional design of this study and the measures used, we assumed the sleep reported was habitual and did not change before or after the injury. The Lombardi et al. examination of sleep effects and BMI on injury risk among working adults in the US found poor sleep and obesity were significant independent predictors of injury, but effect modification was not significant[19]. Effect modification may have been found among firefighters because they may have interrupted sleep while on-duty or undiagnosed sleep disorders but are expected to be alert and complete physically demanding tasks in high stress situations. Further, short sleep is a risk factor for obesity, and obesity is a risk factor for sleeping disorders. The interaction between sleep and BMI on injury is biologically plausible in this occupation. Considering the proposed mechanisms, the extra weight altering mechanics placing

stress on soft connective tissues, combined with fatigue due to poor sleep, potentially places obese firefighters at high risk for impaired performance and safety.

Interestingly, significantly increased odds of increasing duration and intensity physical activity versus avoiding exertion among firefighters indicating on-duty injury compared to those uninjured were only more likely among the obese. Jahnke et al. used only the FIRE data included in this study to examine physical activity and on-duty incident injury but did not find a significant association, however they did not stratify by obesity. These findings suggest obese firefighters are suffering on-duty exercise injuries, however this cannot be confirmed in this larger population because F2F did not collect information on type of injury, therefore non-exercise injuries cannot be singled out.

Brown et al. found overall 25% of firefighters reported receiving weight loss advice from a health care professional in the F2F cohort used in this study[30], and Wilkinson et al. found 48% of obese firefighters received no weight loss advice[31]. Given the high prevalence of obesity in the fire service and its impact on on-duty injury, health care professionals should discuss weight management with firefighters, especially with obese firefighters. Likewise, they should discuss healthy sleep habits with firefighters and screen for sleep disorders.

Results from this study have implications for fire departments looking to implement health and wellness programs. Fire departments should promote sleep hygiene, and ensure sleeping quarters are set up optimally. Fire service leadership should promote safe and effective exercise for obese firefighters to prevent on-duty injuries.

There are limitations to acknowledge. First, on-duty injury, sleep, physical activity, and total work hours were all self-reported. However, using self-report injury data has been found to be more sensitive to injuries less severe and not reported to the department or through worker's

compensation[32]. The duration for the reference time frame for self-reporting on-duty injuries differed by 6 months for the FIRE and F2F cohorts, which may introduce bias, however there is no reason to expect it to be differential because departments were assessed throughout the year across the US and we are unaware of any major events impacting these study departments during the timeframe of the study. Injuries were dichotomized at none or one or more, so numbers of injuries greater than one were not impacted by the different reporting periods. F2F did not collect information on types of on-duty injuries, so more specific analyses into predictors of exercise and non-exercise injuries could not be conducted. This is a cross-sectional study, so only associations between factors can be investigated.

Despite the limitations, this study combined the two largest national cohorts of firefighters to date to examine prevalent on-duty injuries spanning over 5 years. Body composition measurements were conducted in person by the same investigative team using validated protocols, and the results were compared to waist circumference and body fat percentage with no discernable differences. This study is the first to examine sleep both on and off duty and its association with occupational injury.

Conclusion

Body composition should be examined as an effect modifier in future examinations into on-duty injury and sleep amongst career firefighters because of the elevated odds among obese firefighters. Findings from this study highlight the need to address obesity, improve sleep and fitness to reduce the disproportionate burden of on-duty injuries in the fire service.

Aim 1a Table 1: Characteristics of US Male, Career Firefighters Stratified by Body Mass Index (BMI), FIRE (2008-2010) & Fuel 2 Fight (2010-2013)

	BMI Normal[a] n=261 (18.6%) n (%)	BMI Overweight[a] n=710 (50.6%) n (%)	BMI Obese[a] n=433 (30.8%) n (%)
Injury			
≥1 Injury	65 (25.6)	173 (25.0)	103 (25.1)
Physical Activity			
≤1hr Moderate/wk	20 (8.1)	66 (9.9)	75 (18.8)
>1hr Moderate/wk	27 (10.9)	81 (12.1)	90 (22.6)
≤1hr Vigorous/wk	77 (31.2)	204 (30.5)	129 (32.4)
1-3hr Vigorous/wk	62 (25.1)	155 (23.2)	64 (16.1)
>3hr Vigorous/wk	61 (24.7)	163 (24.3)	40 (10.1)
Fitness[b]			
Meet NFPA	193 (77.5)	340 (50.5)	46 (11.5)
Don't Meet NFPA	56 (22.5)	333 (49.5)	354 (88.5)
Rank[c]			
FF/Medic/Driver	178 (72.4)	502 (73.3)	290 (71.4)
LT/CPT/Chief	68 (27.6)	183 (26.7)	116 (28.6)
Education			
High School or Less	24 (9.6)	62 (9.0)	42 (10.5)
Some College	157 (63.1)	462 (67.0)	282 (70.5)
College/Grad Degree	68 (27.3)	166 (24.0)	76 (19.0)
Minority			
White non-Hispanic	203 (80.9)	506 (73.3)	267 (65.3)
Minority	48 (19.1)	184 (26.7)	142 (34.7)
	Mean (SD)	Mean (SD)	Means (SD)
Total Work Hours	67.4 (17.3)	67.1 (17.7)	70.5 (20.2)
Age (years)	35.4 (9.4)	38.7 (8.9)	40.8 (9.0)
Years of Service	11.5 (8.0)	13.9 (8.6)	15.8 (8.9)

[a]BMI normal weight (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2), and obese (>30 kg/m^2); [b]NFPA Fitness cutoff: 12 METS; [c]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any type of Chief;
Missing: BMI (n=15); Injury (n=52); Physical Activity (n=94); Fitness (n=97); Rank (n=71); Education (n=69); Minority (n=58); Total Work Hours (n=70); Age (n=8); Years of Service (n=64)

Aim 1a Table 2: Mixed Effects Logistic Regression for Injury on Sleep, FIRE (2008-2010) & Fuel 2 Fight (2010-2013)

	OR (95% CI)
Sleep	
Get Enough Sleep	Ref.
Not Enough Sleep	**1.62 (1.21, 2.16)**[b]
BMI[a]	
Normal	Ref.
Overweight	0.98 (0.69, 1.39)
Obese	1.04 (0.70, 1.56)
Physical Activity	
≤1hr Moderate	Ref.
>1hr Moderate	1.43 (0.84, 2.44)
≤1hr Vigorous	1.30 (0.80, 2.10)
1-3hr Vigorous	1.62 (0.98, 2.67)
>3hr Vigorous	**1.76 (1.06, 2.92)**
Total Work Hours	
<50 hours/week	Ref.
50-69 hours/week	0.93 (0.59, 1.46)
70-89 hours/week	0.85 (0.53, 1.35)
90+ hours/week	0.95 (0.55, 1.63)
Age (years)	
<30	Ref.
30-39	1.16 (0.79, 1.72)
40-49	1.35 (0.89, 2.05)
50+	0.95 (0.55, 1.63)
Rank[c]	
FF/Medic/Driver	Ref.
LT/CPT/Chief	0.84 (0.61, 1.15)

[a]BMI normal weight (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2), and obese (>30 kg/m^2)
[b]bold indicates significance p<0.05**;** [c]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any type of Chief

Aim 1a Table 3: Mixed Effects Logistic Regression for Injury on Sleep Stratified by BMI, FIRE (2008-2010) & Fuel 2 Fight (2010-2013)

	BMI Normal[a] OR (95% CI)	BMI Overweight[a] OR (95% CI)	BMI Obese[a] OR (95% CI)
Sleep			
Get Enough Sleep	Ref.	Ref.	Ref.
Not Enough Sleep	1.59 (0.78, 3.21)	1.39 (0.94, 2.06)	**2.00**[b] (1.16, 3.43)
Physical Activity			
≤1hr Moderate	Ref.	Ref.	Ref.
>1hr Moderate	1.73 (0.41, 7.23)	0.87 (0.39, 1.94)	**2.44** (1.03, 5.81)
≤1hr Vigorous	1.19 (0.34, 4.16)	0.81 (0.41, 1.60)	**2.49** (1.09, 5.68)
1-3hr Vigorous	1.29 (0.36, 4.57)	1.17 (0.59, 2.34)	**2.59** (1.05, 6.41)
>3hr Vigorous	1.64 (0.45, 5.90)	1.23 (0.62, 2.43)	**3.05** (1.12, 8.31)
Total Work Hours			
<50 hours/week	Ref.	Ref.	Ref.
50-69 hours/week	0.53 (0.20, 1.39)	1.27 (0.67, 2.43)	1.00 (0.44, 2.30)
70-89 hours/week	0.57 (0.21, 1.56)	1.06 (0.54, 2.08)	0.87 (0.37, 2.05)
90+ hours/week	0.27 (0.07, 1.09)	1.75 (0.83, 3.72)	0.72 (0.27, 1.93)
Age (years)			
<30	Ref.	Ref.	Ref.
30-39	1.12 (0.52, 2.42)	1.04 (0.60, 1.78)	1.19 (0.53, 2.67)
40-49	1.29 (0.55, 3.07)	1.28 (0.72, 2.28)	1.30 (0.60, 3.00)
50+	1.44 (0.40, 5.02)	0.99 (0.46, 2.12)	1.26 (0.50, 3.21)
Rank[c]			
FF/Medic/Driver	Ref.	Ref.	Ref.
LT/CPT/Chief	0.99 (0.47, 2.07)	0.84 (0.54, 1.32)	0.77 (0.43, 1.40)

[a]BMI normal weight (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2), and obese (>30 kg/m^2)
[b]bold indicates significance $p<0.05$; [c]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any type of Chief

References

1. Soteriades, E S, Hauser, R, Kawachi, I, Christiani, D C and Kales, S N. Obesity and risk of job disability in male firefighters. *Occup Med (Lond).* 2008;58:245-250.

2. Poston, W S, Haddock, C K, Jahnke, S A, Jitnarin, N, Tuley, B C and Kales, S N. The prevalence of overweight, obesity, and substandard fitness in a population-based firefighter cohort. *J Occup Environ Med.* 2011;53:266-273.

3. Poston, W S, Haddock, C K, Jahnke, S A, Jitnarin, N and Day, R S. An examination of the benefits of health promotion programs for the national fire service. *BMC Public Health.* 2013;13:805.

4. National Center for Health Statistics. Health, united states, 2016: With chartbook on long-term trends in health. 2017.

5. CDC. Adult obesity causes & consequences. 2018.

6. Kuehl, K S, Kisbu-Sakarya, Y, Elliot, D L, Moe, EL; Defrancesco, C A.; Mackinnon, D P.; Lockhart, G.; Goldberg, L.; Kuehl, H E. Body mass index as a predictor of firefighter injury and workers' compensation claims. *J Occup Environ Med.* 2012;54:579-582.

7. Jahnke, S A, Poston, W S, Haddock, C K and Jitnarin, N. Injury among a population based sample of career firefighters in the central USA. *Inj Prev.* 2013;19:393-398.

8. Poston, W S, Jitnarin, N, Haddock, C K, Jahnke, S A and Tuley, B C. Obesity and injury-related absenteeism in a population-based firefighter cohort. *Obesity.* 2011;19:2076-2081.

9. Jahnke, S, Poston, W, Haddock, C and Jitnarin, N. Obesity and incident injury among career firefighters in the central United States. *Obesity.* 2013;21:1505-1508.

10. Wearing, S C, Hennig, E M, Byrne, N M, Steele, J R and Hills, A P. Musculoskeletal disorders associated with obesity: A biomechanical perspective. *Obesity Reviews.* 2006;7:239-250.

11. Dembe, A E, Erickson, J B, Delbos, R G and Banks, S M. The impact of overtime and long work hours on occupational injuries and illnesses: New evidence from the United States. *Occup Environ Med.* 2005;62:588-597.

12. Lusa, S, Häkkänen, M, Luukkonen, R and Viikari-Juntura, E. Perceived physical work capacity, stress, sleep disturbance and occupational accidents among firefighters working during a strike. *Work & Stress.* 2002;16:264-274.

13. Carey, M G, Al-Zaiti, S S, Dean, G E, Sessanna, L and Finnell, D S. Sleep problems, depression, substance use, social bonding, and quality of life in professional firefighters. *J Occup Environ Med.* 2011;53:928-933.

14. Sullivan, J P, O'Brien, C S, Barger, L K, et al. Randomized, prospective study of the impact of a sleep health program on firefighter injury and disability. *Sleep.* 2017;40:10.1093/sleep/zsw001.

15. Williamson, A, Lombardi, D A, Folkard, S, Stutts, J, Courtney, T K and Connor, J L. The link between fatigue and safety. *Accident Analysis & Prevention.* 2011;43:498-515.

16. Fafrowicz, M, Oginska, H, Mojsa-Kaja, J, Marek, T, Golonka, K and Tucholska, K. Chronic sleep deficit and performance of a sustained attention task—an electrooculography study. *Chronobiol Int.* 2010;27:934-944.

17. Kronholm, E, Sallinen, M, Era, P, Suutama, T, Sulkava, R and Partonen, T. Psychomotor slowness is associated with self-reported sleep duration among the general population. *J Sleep Res.* 2011;20:288-297.

18. Lombardi, D A, Folkard, S, Willetts, J L and Smith, G S. Daily sleep, weekly working hours, and risk of work-related injury: US national health interview survey (2004–2008). *Chronobiol Int.* 2010;27:1013-1030.

19. Lombardi, D A, Wirtz, A, Willetts, J L and Folkard, S. Independent effects of sleep duration and body mass index on the risk of a work-related injury: Evidence from the US national health interview survey (2004–2010). *Chronobiol Int.* 2012;29:556-564.

20. Haynes, H J G and Molis, J L. NFPA's "U.S. firefighter injuries-2015". 2016.

21. Reichard, A A and Jackson, L L. Occupational injuries among emergency responders. *Am J Ind Med.* 2010;53:1-11.

22. Poplin, G S, Harris, R B, Pollack, K M, Peate, W F and Burgess, J L. Beyond the fireground: Injuries in the fire service. *Inj Prev.* 2012;18:228-233.

23. CDC. National health interview survey (NHIS). Retrieved from http://www.cdc.gov.utsph.idm.oclc.org/nchs/nhis.htm.

24. National Institutes of Standards and Technology (NIST). The economic consequences of firefighter injuries and their prevention. Final Report. 2005;NIST GCR 05-874.

25. CDC. About adult BMI. 2015. Retrieved from http://www.cdc.gov.utsph.idm.oclc.org/healthyweight/assessing/bmi/adult_bmi/index.html.

26. Jitnarin, N, Poston, W S, Haddock, C K, Jahnke, S A and Day, R S. Accuracy of body mass index-defined obesity status in US firefighters. *Safety and Health at Work.* 2014;5:161-164.

27. Jackson, A S, Blair, S N, Mahar, M T, Wier, L T, Ross, R M and Stuteville, J E. Prediction of functional aerobic capacity without exercise testing. *Med Sci Sports Exerc.* 1990;22:863-870.

28. StataCorp. *Stata statistical software: Release 15*. College Station, TX: StataCorp LLC. 2017.

29. Gu, J K, Charles, L E, Bang, K M, et al. Prevalence of obesity by occupation among US workers: The national health interview survey 2004-2011. *J Occup Environ Med.* 2014;56:516-528.

30. Brown, A L, Poston, W S, Jahnke, S A, Haddock, C K; Luo, S.; Delclos, G L; Day, RS. Weight advice associated with male firefighter weight perception and behavior. *Am J Prev Med.* 2015;49:589-593.

31. Wilkinson, M L, Brown, A L, Poston, W S, Haddock, C K, Jahnke, S A and Day, R S. Physician weight recommendations for overweight and obese firefighters, united states, 2011-2012. *Prev Chronic Dis.* 2014;11:E116.

32. Pole, J D, Franche, R L, Hogg-Johnson, S, Vidmar, M and Krause, N. Duration of work disability: A comparison of self-report and administrative data. *Am J Ind Med.* 2006;49:394-401.

JOURNAL ARTICLE

Total Work Hours, Sleep, Obesity, and Injury in the Volunteer Fire Service

Journal of Occupational and Environmental Medicine

Introduction

There were 1,160,450 firefighters in the United States in 2015, of which 70% were volunteer firefighters (814,850)[1]. Further, 67% of the 29,727 US fire departments were completely volunteer. The volunteer fire service is aging: 42% of volunteer firefighters have been firefighting for at least 10 years. Volunteer firefighters typically do not consider firefighting their occupation. However, they are often on call 24 hours a day and complete the same tasks required of a career firefighter.

The average annual number of on-duty injuries in the volunteer fire service from 2012-2014 was 14,870[2]. According to the National Fire Protection Association, most volunteer firefighter on-duty injuries occur on the fireground or during training. Compared to career firefighters, volunteer firefighters experience a higher proportion of fireground injuries and a lower proportion of non-fire emergencies, partly because many volunteer fire departments do not run emergency medical service calls.

To date, predictors of on-duty injury among volunteer firefighters have remained unexplored in epidemiologic research. Difficulties accessing volunteer firefighters may be part of the reason there is limited epidemiologic data. About 95% of volunteer firefighters work in departments serving less than 25,000 people and half are with rural departments serving less than 2,500 people. Most volunteer firefighters are spread throughout the US in small departments serving small communities[1], making it a challenge for investigators to reach large amounts of volunteers efficiently. At this time epidemiologic investigations into factors associated with on-

duty injury among career firefighters provide the only data to inform investigations among volunteers.

Among career firefighters, self-reported physical activity was not a significant predictor of incident injury[4]. On-duty exercise, a component of physical activity, was a significant predictor of on-duty injury among career firefighters, although on-duty exercise was protective against non-exercise injuries[3, 4]. Volunteer firefighters had slightly lower metabolic equivalents, or estimated amount of oxygen consumed at rest, than career firefighters among a cohort in the US Midwest, suggesting a lower level of physical activity and fitness[5].

Obesity is the most studied personal health factor in association with on-duty injury and injury-related outcomes and has been consistently associated with on-duty injury among career firefighters[3, 4, 6-8]. The prevalence of obesity in the volunteer fire service is 43%, as compared to 34% among career firefighters[5]. The proposed mechanism for obesity on injury centers on excess fat adding extra load and altering mechanics while performing locomotor tasks, adding stress to connective-tissue structures[9]. Other personal health factors, including total work hours and sleep, have been less explored in association with on-duty injury in the fire service.

Most volunteer firefighters have day jobs outside of the fire service and may be working long hours. Long work hours have been found to increase risk for on-duty injury among Finnish career firefighters working during a strike and among employees in the US general population[10, 11]. Working long hours have been associated with sleep disturbance and short sleep[10, 12, 13], and with obesity and weight gain among adults in many occupations, including firefighting[14-19].

About 42% of career firefighters in one Midwest department screened positive for a sleep disorder and 59% of a convenience sample of career firefighters from a single department were classified as sleep deprived[20, 21]. Investigations into sleep and on-duty injury in the fire service

have not found self-reported quantity of sleep or sleepiness and daytime sleepiness to be associated with on-duty injury[3, 4, 20]. Lombardi et al. (2012) found poor sleep is associated with occupational injury among the general US working population using more direct measures of sleep quality and quantity, rather than effects of poor sleep used in a previous study in the fire service[22]. The proposed mechanism for sleep on injury draws from short sleep or poor sleep leading to sleepiness and fatigue, which results in impaired performance and safety[11, 23-26].

Sleep, obesity, and work hours are independently associated with occupational injury. Lombardi (2010) tested the interaction between daily sleep and work hours but did not find a significant interaction[26]. The lack of an interaction between sleep and work hours may be due to the variety of occupations included in the analysis, diminishing an association in a unique occupation, such as firefighting. In another study by Lombardi et al (2012), work hours were controlled for as a confounder in the examination of the association between obesity and injury[22]. While both obesity and work hours were positively associated with injury, obesity was not examined as an effect modifier of work hours and injury. No study has examined the role sleep or obesity play in the relationship between total work hours and on-duty injury among any firefighters, career or volunteer. The aim of the current study is to determine the role sleep and obesity have on the association between total work hours and on-duty injury among 201 male volunteer firefighters from 13 departments across eight Midwest states coupled with 332 male volunteer firefighters from ten departments located in ten states across the USA.

Methods

Participants and Procedures

Data for this cross-sectional study are from the baseline assessments of the Firefighter Injury and Risk Evaluation (FIRE) study and The First Twenty study (TF20). Due to the

challenges of accessing large numbers of volunteer firefighters, combining FIRE and TF20 study cohorts provides a unique opportunity to have high quality data on a large sample from across the US. Data from these studies were easy to combine as they were conducted by the same research team utilizing the same measurements, questions, and protocols.

The longitudinal FIRE cohort study was conducted from 2008-2010 in the US Midwest. A list of fire departments was obtained from all eight International Association of Fire Chiefs Missouri Valley region states (Kansas, Missouri, Iowa, Nebraska, North Dakota, South Dakota, Colorado, and Wyoming) using the U.S. Fire Department Census Database. Fire departments were randomly selected and contacted about potential interest in study participation. Details of the sampling strategy and recruitment have been published [5]. There were 11 career and 13 volunteer departments in the IAFC Missouri Valley region selected for participation. A total of 736 firefighters were approached about participating in this study, and 97% (N=714) of all firefighters consented to participate. For this study, only data from male volunteer firefighters (n=201) were used. There were low numbers of female firefighters, typical of the overall fire service, thus they were excluded due to an inability to explore differences in gender.

The TF20 study was a cluster-randomized controlled trial conducted from 2014-2017. Primary recruitment was achieved by soliciting interest from volunteer fire departments utilizing the email listserv Chief Billy Goldfeder's "Secret List" and the list serve of the National Volunteer Fire Council. A list of interested fire departments across the nation was compiled and every fire department underwent a telephone screening interview. Departments were selected based on size, call volume, region, and interest in the study. Ten departments were selected to participate and were randomized: five in the wait-list control arm and five in the treatment arm. The departments were located in ten different states (Missouri, New Jersey, New Mexico, North

Carolina, Ohio, Oregon, Texas, Utah, Virginia, and Washington), with at least one department in each of the four major US Census Bureau Regions. For this study, only data from male firefighters (n=332) were used due to the low number of females and an inability to make statistical comparisons based on gender.

The combination of the two studies resulted in 533 volunteer firefighters eligible for analysis. The FIRE and TF20 study protocols were approved by Institutional Review Boards prior to onset of the studies. Consent for interested firefighters was done in person using written consents for both studies.

Measures

The same investigative team conducted both studies and coordinated with the department chiefs to schedule data collection meetings for on-duty firefighters. Investigators traveled to each department for 1-8 days depending on the size and structure of the department. Self-report questionnaires in both studies used like or similar questions. Physical measurements (height, weight, waist circumference, body fat) using the same protocols were conducted by trained investigators in both studies. Self-report occupational (rank, years in fire service, fitness) and demographic (age, race/ethnicity, education, physical activity) information was collected in addition to the following measures.

Injury

Questions based on the National Health Interview Survey (CDC) and firefighter specific questions based on work from the National Institute of Standards and Technology were used to asses injuries[27, 28]. The injury section began with the instruction, "*The following questions are about injuries you have incurred in the past 12 months. An injury is anything for which you have or should have received medical care (by a physician or other medical professional) whether you*

reported the injury or not." Firefighters indicated the number of injuries they had in the past 12 months for the FIRE study and in the past 6 months for the TF20 study. Responses from both studies were dichotomized as having incurred an injury or not.

Total Work Hours

Work hours outside of the fire department for FIRE was assessed by "*Most weeks, I work __ hours outside of the fire department*" requiring firefighters to write in the number of hours. For TF20, work hours were assessed by "*About how many hours do you work at a job aside from being a volunteer firefighter*" with response options "*<20 hours per week*," "*20-39 hours per week*," and "*40+ hours per week*." To create a comparable variable to FIRE, the TF20 response "*about <20 hours per week*" was assigned the median value 10 hours per week, the option "*20-39 hours per week*" was assigned the median value 30 hours per week, and the option "*40+ hours per week*" was assigned the most conservative value, 40 hours per week.

For both the FIRE and TF20 studies, volunteer hours for the fire department was assessed by "*On average, I spend __ hours each month volunteering for the fire department*" requiring firefighters to write in the hours. This value was divided by 4 to create a hours volunteering per week for the fire department variable. The hours per week from all questions were combined to create a continuous variable, total work hours per week. The total work hours (work hours outside plus volunteer hours) were then categorized into "*<40 hours per week*," "*40-49 hours per week*," "*50-59 hours per week*," and "*60+ hours per week*."

Sleep

Sleep was assessed by the response to the following question in FIRE, "*Most nights, I get enough sleep*." Firefighters responded using a Likert scale from strongly disagree to strongly agree. Responses were dichotomized so firefighters responding strongly disagree or disagree

were grouped to "inadequate sleep," and firefighters responding strongly agree, agree, and no opinion were grouped to "adequate sleep."

Sleep was assessed by response to the following questions in TF20, "*How many hours do you typically need during the night to feel rested the following day?*" and "*Over the past week, how many hours on average did you typically sleep per day?*" Firefighters' average hours of sleep over the past week was subtracted from the average hours of sleep they typically need to feel rested the following day. Firefighters whose sleep hours were less than their hours needed were categorized as "inadequate sleep," while firefighters whose average sleep equaled or exceeded needed sleep hours were categorized as "adequate sleep." Responses from FIRE and TF20 variables were dichotomized into one sleep variable, "adequate or inadequate sleep."

Body Composition

Trained study personnel measured Body Mass Index (BMI), waist circumference, and body fat percentage using the same protocols in both studies. Height was measured using a stadiometer and weight using a Tanita 300. BMI was categorized using standard CDC cut points for not obese (<30 kg/m^2) and obese (≥30 kg/m^2)[29]. Waist circumference was measured using a spring-loaded tape measure following standard procedures. Measures were dichotomized using standard CDC cut points for high risk for developing obesity related conditions (high risk male >102cm)[29]. Body fat percentage was measured using foot-to-foot bioelectrical impedance Tanita 300 and was dichotomized using CDC cut points (unhealthy male >25%)[29].

All three measures of body composition were examined to determine the best single measure for inclusion in statistical analyses. BMI was chosen due to its ease for comparability to other studies and its accuracy in defining obesity in this population (false positive 9.2% and false negative 14.6% compared to waist circumference)[30].

Statistical Analyses

Statistical analyses were performed with Stata version 15[31]. The association between injury, total work hours, sleep, obesity, and the potential confounders physical activity, age, rank, and years in fire service was evaluated using logistic regression. A backward elimination approach was used to evaluate confounders, and the change in estimate of 10% was applied to determine model efficiency. A group level factor of "department" was entered as a random effect in all multivariable models to account for sampling. A multivariable mixed effect logistic regression model, with the confounders age and rank forced in the model, was used to assess the role of total work hours and injury. To examine for the presence of effect measure modification by sleep and obesity, multivariable mixed effect logistic regression models stratified by sleep and another stratified by obesity were created. The stratified odds ratios, 95% CIs, and p-values ($p<0.05$) were used to evaluate results for significance and model fit was explored.

Results

Overall**,** 44% of volunteer firefighters from both studies reported inadequate sleep and 80% were overweight or obese, of which 46% were obese. Approximately 11% of volunteer firefighters experienced an on-duty injury in the past six months to a year. About 91% of volunteer firefighters were non-Hispanic white, and the mean years of service was approximately 12 years.

Firefighter demographics stratified by sleep are presented in Aim 1b Table 1 and stratified by obesity in Aim 1b Table 2. Volunteer firefighters with adequate sleep were more obese (49.5%) than volunteer firefighters with inadequate sleep (41.6%). Volunteer firefighters with adequate sleep were also a few years older and had a few more years of experience than those with inadequate sleep. Obese volunteer firefighters did less physical activity (679 minutes)

than non-obese (841 minutes), reported less inadequate sleep, on average worked a few hours more per week, and had a few years less experience than non-obese volunteer firefighters.

Years in the fire service was dropped from the regression models due to collinearity with age. In the full multivariable mixed effect logistic regression model, no predictors were associated with injury ($p>0.05$) (Aim 1b Table 3). Results from effect measure modification analyses necessitated presenting stratified results (Aim 1b Tables 4 & 5). Among volunteer firefighters with adequate sleep, the odds of working/volunteering 40-49 hours per week compared to <40 hours per week among injured firefighters was 0.19 (95% CI: 0.05, 0.70) as compared to uninjured firefighters (Aim 1b Table 4). Among those with adequate sleep, the adjusted odds of working/volunteering 50-59 hours per week compared to <40 hours per week among those with an injury was 0.07 (0.01, 0.60) as compared to those uninjured firefighters. Among volunteer firefighters with adequate sleep, the odds of being obese compared to not obese was 3 (95% CI: 1.03, 8.86) times more likely than among uninjured firefighters. The association between total work hours and prevalent injury appears to be modified by sleep. Sleep also appears to modify the association between obesity and prevalent injury.

Among obese firefighters, the odds of working/volunteering 40-49 hours per week compared to <40 hours per week among injured firefighters was 0.05 (95% CI: 0.01, 0.45) times less likely than among uninjured firefighters (Aim 1b Table 5). Among non-obese volunteer firefighters, the odds of inadequate versus adequate sleep was 2.8 (95% CI: 1.06, 7.86) times more likely among injured firefighters than uninjured firefighters. The association between total work hours and prevalent injury also appears to be modified by obesity. Obesity is also modifying the association between sleep and prevalent injury.

Discussion

While volunteer firefighters make up the majority of the US fire service, limited research is available to guide prevention and intervention efforts to reduce injury. The present study is the first epidemiologic investigation into potential personal health predictors of on-duty injury among volunteer firefighters. This is also the first exploration of sleep or obesity as effect modifiers of the association between on-duty injury and total work hours in the fire service.

In the sleep stratified analyses, this study found volunteer firefighters with adequate sleep who had an on-duty injury were less likely to work/volunteer between 40 and 59 hours per week compared to <40 hours per week than uninjured firefighters . No association between total work hours and on-duty injury among those reporting inadequate sleep were found. Among obese volunteer firefighters, those with an on-duty injury were less likely to work/volunteer 40-49 hours per week compared to <40 hours per week. No association was found between total work hours and sleep among the non-obese. Interestingly, non-obese firefighters who had an on-duty injury were more likely to report inadequate sleep than uninjured firefighters. The results from this study suggest volunteer firefighters who get adequate sleep, are obese, and work/volunteer hours for a full-time job may be less prone to injury than those working/volunteering less than full-time. Firefighters working/volunteering between 40-59 hours are perhaps more physically active throughout their day or could be spending more time at the department training or have more regular activity than those working/volunteering <40 hours.

Lombardi et al. did not find a significant interaction between daily sleep and work hours among US working adults[26]. The lack of an interaction in the general US working population may be due the variety of occupations included in the analysis. The effects specific to firefighting may have been unmeasurable due to the inclusion of so many occupations with

varying levels of physical demands. Firefighting is a unique and physically demanding occupation requiring a high level of fitness which puts them at higher risk for injury. Lombardi et al. also used working 31-40 hours per week as the referent category. Among volunteer firefighters with adequate sleep, the odds of being obese or not was 3 times more likely among injured versus uninjured firefighters. This finding suggests being obese is associated with on-duty injury, even among those who get enough sleep.

Collectively, the findings of both stratified analyses suggest sleep, obesity, and total work hours interact in association with on-duty injury among volunteer firefighters. This study highlights obese firefighters may have different risks for injury than non-obese firefighters, and adequate sleep may impact the association of total work hours and injury. The fatigue due to poor sleep and decreased opportunity for sleep due to longer work hours[11, 23-26], and the extra weight altering mechanics placing stress on soft connective tissues[9], each place firefighters at high risk for injury. Findings from this study have implications for volunteer fire departments and health care professionals. Health care professionals should screen firefighters for sleep disorders, discuss healthy sleep habits, and discuss weight management with volunteer firefighters. Volunteer fire departments should promote healthy sleep habits, and weight management through healthy eating and exercise.

The limitations of this study should be acknowledged. Total work hours and sleep were measured differently for FIRE and TF20, and therefore the categorizing and combining of these variables from each study may have biased study results. However, a conservative approach was used for categorizing, thus any associations are likely minimized not exacerbated by this approach. The duration for the reference time frame for self-reporting injury differed by 6 months for FIRE and TF20, and could bias results. However, differential bias is unlikely given

that injuries were dichotomized as none vs any, so any additional injuries developed in the longer time frame would not bias results, and the prevalence of injury is high in this occupation. This study was cross-sectional, so only associations can be explored. Given the study design and the measures used, we assumed the sleep reported was habitual and did not change before or after the injury. Finally, injury, sleep, total work hours, and physical activity were self-report and are subject to potential memory lapse. Self-report injury data may have the advantage of capturing less severe injuries not reported in department records[32].

This study examined on-duty injuries among volunteer firefighters for the first time in an epidemiologic study, in a population of firefighters relatively unexplored in the literature. This study was conducted among the largest sample of volunteer firefighters by combining two cohorts. Body composition measurements following valid protocols were conducted in person by the same investigative team for this study, and the results were compared to waist circumference and body fat percentage without major differences.

Conclusion

This is the first study to examine personal health characteristics and their association with on-duty injury in the volunteer fire service, and to explore any effect modification in the association. Total work hours, sleep, and body composition should be examined in future investigations into on-duty injuries among volunteer firefighters. Risk factors for injury should be explored among the not obese and obese separately in future investigations, and amongst firefighters who get adequate sleep versus those who don't get inadequate sleep. These findings can be used to inform health promotion and prevention plans to mitigate occurrence of injuries among volunteers and the need to address obesity and sleep issues.

Aim 1b Table 1: Characteristics of US Male, Volunteer Firefighters Stratified by Sleep, FIRE (2008-2010) & TF20 (2014-2017)

	Adequate Sleep n=295 (55.8%) n (%)	Inadequate Sleep n=234 (44.2%) n (%)
Injury		
≥1 Injury	26 (9.2)	29 (12.7)
BMI[a]		
Not Obese	144 (50.5)	132 (58.4)
Obese	141 (49.5)	94 (41.6)
Rank[c]		
FF/Medic/Driver	205 (72.2)	159 (72.6)
LT/CPT/Chief	79 (27.8)	60 (27.4)
Education		
High School or Less	74 (25.5)	60 (25.6)
Some College	146 (50.3)	117 (50.0)
College/Grad Degree	70 (24.1)	57 (24.4)
Minority		
White non-Hispanic	263 (91.3)	210 (89.7)
Minority	25 (8.7)	24 (10.3)
	Mean (SD)	Mean (SD)
Physical Activity Minutes[b]	759.2 (1160.7)	739.1 (1189.9)
Total Work Hours	47.0 (20.6)	47.7 (21.2)
Age (years)	40.6 (12.6)	36.6 (11.4)
Years of Service	12.8 (11.0)	10.5 (9.3)

[a]BMI not obese (18.5-29.9 kg/m^2) and obese (≥30 kg/m^2); [b]Total minutes of moderate and vigorous physical activity per week; [c]FF/Medic/Driver=Firefighter, Emergency Medical Services, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any Type of Chief;

Missing: Sleep (n=4); Injury (n=20); BMI (n=22); Rank (n=30); Education (n=9); Minority (n=11); Physical Activity (n=46); Total Work Hours (n=13); Age (n=8); Years of Service (n=11)

Aim 1b Table 2: Characteristics of US Male, Volunteer Firefighters Stratified by Obesity, FIRE (2008-2010) & TF20 (2014-2017)

	Not Obese[a] n=276 (54.0%) n (%)	Obese[a] n=235 (46.0%) n (%)
Injury		
≥1 Injury	27 (10.0)	26 (11.6)
Sleep		
Adequate Sleep	144 (52.2)	141 (60.0)
Inadequate Sleep	132 (47.8)	94 (40.0)
Rank[c]		
FF/Medic/Driver	197 (73.5)	156 (70.6)
LT/CPT/Chief	71 (26.5)	65 (29.4)
Education		
High School or Less	70 (25.5)	61 (26.2)
Some College	133 (48.4)	124 (53.2)
College/Grad Degree	72 (26.2)	48 (20.6)
Minority		
White non-Hispanic	247 (90.2)	211 (91.0)
Minority	27 (9.9)	21 (9.1)
	Mean (SD)	Mean (SD)
Physical Activity Minutes[b]	841.2 (1292.8)	678.8 (1049.3)
Total Work Hours	45.9 (22.4)	49.2 (18.9)
Age (years)	37.3 (12.9)	40.2 (11.1)
Years of Service	10.4 (9.6)	13.2 (10.5)

[a]BMI not obese (18.5-29.9 kg/m^2) and obese (≥30 kg/m^2); [b]Total minutes of moderate and vigorous physical activity per week; [c]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any Type of Chief;
Missing: Sleep (n=4); Injury (n=20); BMI (n=22); Rank (n=30); Education (n=9); Minority (n=11); Physical Activity (n=46); Total Work Hours (n=13); Age (n=8); Years of Service (n=11)

Aim 1b Table 3: Mixed Effects Logistic Regression for Injury on Total Work Hours, FIRE (2008-2010) & TF20 (2014-2017)

	OR (95% CI)
Total Work Hours	
<40 hours/week	Ref.
40-49 hours/week	0.50 (0.20, 1.28)
50-59 hours/week	0.42 (0.14, 1.23)
60+ hours/week	0.86 (0.34, 2.20)
Sleep	
Adequate Sleep	Ref.
Inadequate Sleep	1.51 (0.75, 3.04)
BMI[a]	
Not Obese	Ref.
Obese	1.23 (0.61, 2.48)
Physical Activity (minutes)	
<58 minutes/week	Ref.
58-180 minutes/week	1.14 (0.42, 3.12)
181-385 minutes/week	1.55 (0.55, 3.39)
386-1260 minutes/week	0.72 (0.22, 2.31)
1261+ minutes/week	0.66 (0.18, 2.38)
Age (years)	
<30	Ref.
30-39	0.44 (0.16, 1.21)
40-49	1.46 (0.61, 3.51)
50+	0.71 (0.22, 2.23)
Rank[b]	
FF/Medic/Driver	Ref.
LT/CPT/Chief	0.69 (0.31, 1.57)

[a]BMI not obese (18.5-29.9 kg/m^2) and obese (≥30 kg/m^2); [b]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any Type of Chief

Aim 1b Table 4: Mixed Effects Logistic Regression for Injury on Total Work Hours Stratified by Sleep, FIRE (2008-2010) & TF20 (2015-2017)

	Adequate Sleep OR (95% CI)	Inadequate Sleep OR (95% CI)
Total Work Hours		
<40 hours/week	Ref.	Ref.
40-49 hours/week	**0.19 (0.05, 0.70)[b]**	0.79 (0.21, 2.90)
50-59 hours/week	**0.07 (0.01, 0.60)**	1.12 (0.27, 4.55)
60+ hours/week	0.58 (0.16, 2.13)	1.23 (0.24, 4.44)
BMI[a]		
Not Obese	Ref.	Ref.
Obese	**3.02 (1.03, 8.86)**	0.79 (0.30, 2.07)
Physical Activity (minutes)		
<58 minutes/week	Ref.	Ref.
58-180 minutes/week	0.96 (0.22, 4.16)	1.93 (0.44, 8.53)
181-385 minutes/week	0.95 (0.24, 3.86)	2.84 (0.57, 14.31)
386-1260 minutes/week	0.26 (0.04, 1.66)	1.43 (0.29, 7.10)
1261+ minutes/week	0.30 (0.05, 1.94)	1.00 (0.17, 5.77)
Age (years)		
<30	Ref.	Ref.
30-39	0.37 (0.08, 1.72)	0.46 (0.13, 1.70)
40-49	0.53 (0.13, 2.21)	2.34 (0.79, 6.95)
50+	0.42 (0.09, 1.88)	0.40 (0.04, 3.66)
Rank[c]		
FF/Medic/Driver	Ref.	Ref.
LT/CPT/Chief	1.93 (0.60, 6.15)	0.48 (0.14, 1.60)

[a]BMI not obese (18.5-29.9 kg/m^2) and obese (≥30 kg/m^2); [b]bold indicates significance $p<0.05$; [c]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any Type of Chief

Aim 1b Table 5: Mixed Effects Logistic Regression for Injury on Total Work Hours Stratified by Obesity, FIRE (2008-2010) & TF20 (2014-2017)

	Not Obese[a] OR (95% CI)	Obese[a] OR (95% CI)
Total Work Hours		
<40 hours/week	Ref.	Ref.
40-49 hours/week	1.27 (0.36, 4.41)	**0.05 (0.01, 0.45)[b]**
50-59 hours/week	0.75 (0.15, 3.63)	0.22 (0.04, 1.35)
60+ hours/week	1.31 (0.34, 5.02)	0.80 (0.14, 4.46)
Sleep		
Adequate Sleep	Ref.	Ref.
Inadequate Sleep	**2.84 (1.06, 7.86)**	0.74 (0.19, 2.95)
Physical Activity (minutes)		
<58 minutes/week	Ref.	Ref.
58-180 minutes/week	0.97 (0.22, 4.25)	1.77 (0.31, 9.97)
181-385 minutes/week	2.15 (0.52, 8.90)	1.31 (0.21, 8.40)
386-1260 minutes/week	0.49 (0.09, 2.50)	1.89 (0.21, 16.85)
1261+ minutes/week	0.95 (0.20, 4.54)	0.18 (0.01, 4.72)
Age (years)		
<30	Ref.	Ref.
30-39	0.81 (0.24, 2.72)	0.12 (0.01, 1.34)
40-49	1.62 (0.48, 5.45)	3.12 (0.42, 23.07)
50+	0.46 (0.08, 2.60)	1.50 (0.18, 12.79)
Rank[c]		
FF/Medic/Driver	Ref.	Ref.
LT/CPT/Chief	1.07 (0.36, 3.19)	0.30 (0.06, 1.45)

[a]BMI not obese (18.5-29.9 kg/m^2) and obese (≥30 kg/m^2); [b]bold indicates significance $p<0.05$; [c]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any Type of Chief

References

1. Haynes, H J G and Stein, G P. U.S. fire department profile-2015. 2017.

2. Haynes, H. U.S. volunteer firefighter injuries 2012-2014. 2016.

3. Jahnke, S A, Poston, W S, Haddock, C K and Jitnarin, N. Injury among a population based sample of career firefighters in the central USA. *Inj Prev.* 2013;19:393-398.

4. Jahnke, S, Poston, W, Haddock, C and Jitnarin, N. Obesity and incident injury among career firefighters in the central United States. *Obesity.* 2013;21:1505-1508.

5. Poston, W S, Haddock, C K, Jahnke, S A, Jitnarin, N, Tuley, B C and Kales, S N. The prevalence of overweight, obesity, and substandard fitness in a population-based firefighter cohort. *J Occup Environ Med.* 2011;53:266-273.

6. Kuehl, K S, Kisbu-Sakarya, Y, Elliot, D L, Moe, EL; Defrancesco, C A.; Mackinnon, D P.; Lockhart, G.; Goldberg, L.; Kuehl, H E. Body mass index as a predictor of firefighter injury and workers' compensation claims. *J Occup Environ Med.* 2012;54:579-582.

7. Poston, W S, Jitnarin, N, Haddock, C K, Jahnke, S A and Tuley, B C. Obesity and injury-related absenteeism in a population-based firefighter cohort. *Obesity.* 2011;19:2076-2081.

8. Soteriades, E S, Hauser, R, Kawachi, I, Christiani, D C and Kales, S N. Obesity and risk of job disability in male firefighters. *Occup Med (Lond).* 2008;58:245-250.

9. Wearing, S C, Hennig, E M, Byrne, N M, Steele, J R and Hills, A P. Musculoskeletal disorders associated with obesity: A biomechanical perspective. *Obesity Reviews.* 2006;7:239-250.

10. Lusa, S, Häkkänen, M, Luukkonen, R and Viikari-Juntura, E. Perceived physical work capacity, stress, sleep disturbance and occupational accidents among firefighters working during a strike. *Work & Stress.* 2002;16:264-274.

11. Dembe, A E, Erickson, J B, Delbos, R G and Banks, S M. The impact of overtime and long work hours on occupational injuries and illnesses: New evidence from the United States. *Occup Environ Med.* 2005;62:588-597.

12. Taris, T W, Ybema, J F, Beckers, D G, Verheijden, M W, Geurts, S A and Kompier, M A. Investigating the associations among overtime work, health behaviors, and health: A longitudinal study among full-time employees. *Int J Behav Med.* 2011;18:352-360.

13. Van der Hulst, M. Long work hours and health. *Scand J Work Environ Health.* 2003:171-188.

14. Luckhaupt, S E, Cohen, M A, Li, J and Calvert, G M. Prevalence of obesity among US workers and associations with occupational factors. *Am J Prev Med.* 2014;46:237-248.

15. Di Milia, L and Mummery, K. The association between job related factors, short sleep and obesity. *Ind Health.* 2009;47:363-368.

16. Jang, T, Kim, H, Lee, H, Myong, J and Koo, J. Long work hours and obesity in Korean adult workers. *Journal of Occupational Health.* 2013;55:359-366.

17. Lemke, M, Hege, A, Perko, M, Sönmez, S and Apostolopoulos, Y. Work patterns, sleeping hours and excess weight in commercial drivers. *Occupational Medicine.* 2015;65:725-731.

18. Solovieva, S, Lallukka, T, Virtanen, M and Viikari-Juntura, E. Psychosocial factors at work, long work hours, and obesity: A systematic review. *Scand J Work Environ Health.* 2013:241-258.

19. Choi, B, Dobson, M, Schnall, P and Garcia-Rivas, J. 24-hour work shifts, sedentary work, and obesity in male firefighters. *Am J Ind Med.* 2016;59:486-500.

20. Sullivan, J P, O'Brien, C S, Barger, L K, et al. Randomized, prospective study of the impact of a sleep health program on firefighter injury and disability. *Sleep.* 2017;40:10.1093/sleep/zsw001.

21. Carey, M G, Al-Zaiti, S S, Dean, G E, Sessanna, L and Finnell, D S. Sleep problems, depression, substance use, social bonding, and quality of life in professional firefighters. *J Occup Environ Med.* 2011;53:928-933.

22. Lombardi, D A, Wirtz, A, Willetts, J L and Folkard, S. Independent effects of sleep duration and body mass index on the risk of a work-related injury: Evidence from the US national health interview survey (2004–2010). *Chronobiol Int.* 2012;29:556-564.

23. Williamson, A, Lombardi, D A, Folkard, S, Stutts, J, Courtney, T K and Connor, J L. The link between fatigue and safety. *Accident Analysis & Prevention.* 2011;43:498-515.

24. Fafrowicz, M, Oginska, H, Mojsa-Kaja, J, Marek, T, Golonka, K and Tucholska, K. Chronic sleep deficit and performance of a sustained attention task—an electrooculography study. *Chronobiol Int.* 2010;27:934-944.

25. Kronholm, E, Sallinen, M, Era, P, Suutama, T, Sulkava, R and Partonen, T. Psychomotor slowness is associated with self-reported sleep duration among the general population. *J Sleep Res.* 2011;20:288-297.

26. Lombardi, D A, Folkard, S, Willetts, J L and Smith, G S. Daily sleep, weekly working hours, and risk of work-related injury: US national health interview survey (2004–2008). *Chronobiol Int.* 2010;27:1013-1030.

27. CDC. National health interview survey (NHIS). Retrieved from http://www.cdc.gov.utsph.idm.oclc.org/nchs/nhis.htm.

28. National Institutes of Standards and Technology (NIST). The economic consequences of firefighter injuries and their prevention. final report. 2005;NIST GCR 05-874.

29. CDC. About adult BMI. 2015. Retrieved from http://www.cdc.gov.utsph.idm.oclc.org/healthyweight/assessing/bmi/adult_bmi/index.html.

30. Jitnarin, N, Poston, W S, Haddock, C K, Jahnke, S A and Day, R S. Accuracy of body mass index-defined obesity status in US firefighters. *Safety and Health at Work.* 2014;5:161-164.

31. StataCorp. *Stata statistical software: Release 15*. College Station, TX: StataCorp LLC. 2017.

32. Pole, J D, Franche, R L, Hogg-Johnson, S, Vidmar, M and Krause, N. Duration of work disability: A comparison of self-report and administrative data. *Am J Ind Med.* 2006;49:394-401.

JOURNAL ARTICLE

Psychosocial Factors, Obesity, and Injury among US Male Career Firefighters

Journal of Occupational and Environmental Medicine

Introduction

The number of on-duty injuries reported to the National Fire Protection Association (NFPA) increased by 7.5% from 2014 to 2015[1]. Most injuries occur on the fireground or during training/ exercise, the leading type of injury was sprains and strains, and most injuries were due to overexertion or slips, trips, or falls[1-6].

Investigations into personal health factors associated with injury, such as obesity, sleep, and physical activity, have been conducted across many occupations, including firefighting. Obesity has been a significant predictor of on-duty injury and injury-related outcomes in firefighters in cross-sectional and prospective studies[3, 5-8]. We found obesity modified the association between on-duty injury and sleep among a large national sample of male career firefighters[9]. Specifically, among obese firefighters who had an injury, the odds of not getting enough sleep compared to enough sleep were twice as likely than among uninjured firefighters.

We also found on-duty injury was associated with self-reported physical activity among obese firefighters only, not in normal or overweight firefighters[9]. In previous investigations in the fire service looking at only one component of physical activity, on-duty exercise has been associated with any type of on-duty injury, but firefighters who engaged in on-duty exercise had half the odds of non-exercise injuries[5]. Our study findings highlight the need to explore obesity as an effect modifier in investigations of on-duty injury predictors.

The association between psychosocial factors, such as depression and job stress, with on-duty injury in the fire service has been less explored than obesity. Depression has been assessed

in epidemiologic studies in the fire service using self-report healthcare provider diagnosis of depressive disorder or using the Center for Epidemiological Studies Depression (CES-D) screening tests for depression. The prevalence of physician diagnosed depressive disorder is approximately 6%, and the mean CES-D-10 scores are low (approximately 1.7) among male career firefighters[10]. Jahnke et al. found those scoring in the range of concern for symptoms for depression using the CES-D-10 had 2.33 times the odds of on-duty injury than those not scoring in the range of concern for depression among Midwest career firefighters[5]. Depression was not a significant predictor of incident on-duty injury[8] or missed work days[6] among the same cohort. However, depression has been assessed as a predictor of injury among other occupations and populations. Tiesman et al. conducted the first prospective analysis of depression as a risk factor for injury among a cohort of 1,493 working men and women in rural Iowa[11]. They found those who had depressive symptoms had a 41% higher risk of injury than those who did not have depressive symptoms.

Depression and job stress have a reciprocal causal relationship and have both been associated with a variety of occupational illnesses and injury[12]. Male career firefighters in the US self-report low levels of job stress, even though they work in high stress jobs, suggesting they manage the stress well[10]. Poston et al. found stress not to be associated with missed work days due to on-duty injury, but stress was not examined in association with on-duty injury occurrence[6]. Job stress was found to be significantly associated with injury among Korean firefighters assessed using an in-depth measure of job stress[13]. Specifically, high job demand, high interpersonal conflicts, and negative workplace environment were components of job stress significantly associated with on-duty injury among different ranks of Korean firefighters.

The psychological burden from repeated exposure to traumatic events and the potential association with on-duty injury signal the need to explore psychosocial predictors of injury. Musculoskeletal injury, the most common type of injury in the fire service[5, 14] is caused by biomechanical factors (physical characteristics of work and mechanical load) and psychosocial factors (work design, management)[12]. Physical and psychosocial risk factors independently predict musculoskeletal injury, but also have interactive effects stronger than their independent effects[12]. Overall, depression and job stress appear to be associated with on-duty injury in the fire service, although results are conflicting from the small number of studies. These associations, along with physical factors like obesity, need to be explored among a larger, more geographically diverse sample of career firefighters. The aim of this study was to identify psychosocial predictors (job stress and depression) of on-duty injury among male career firefighters in the largest national cohort of over 1,000 firefighters, coupled with almost 500 firefighters from multiple fire departments in eight Midwest states.

Methods

Participants and Procedures

Data from baseline assessments of the Firefighter Injury and Risk Evaluation (FIRE) study and the Fuel 2 Fight (F2F) study were used in this cross-sectional study. FIRE, a longitudinal cohort study of Midwest firefighters, was conducted from 2008-2010. The U.S. Fire Department Census Database was used to create a list of fire departments from all eight International Association of Fire Chiefs Missouri Valley region states (Kansas, Missouri, Iowa, Nebraska, North Dakota, South Dakota, Colorado, and Wyoming). Sampling strategy and recruitment details have been published[15]. Approximately 97% (N=714) of all firefighters solicited from the 11 career and 13 volunteer departments (N=736) randomly selected for

participation consented to participate. The low numbers of female firefighters (n=21) in this study warrant their exclusion due to the inability to make gender comparisons, so only data from male career firefighters (n=478) are used.

The longitudinal cohort study F2F was a conducted from 2010-2013. Ten heterogeneous fire departments self-reporting to implement key aspects of the Fire Service Joint Labor Management Wellness-Fitness Initiative (WFI) were selected using a purposive sampling approach[10]. Ten standard departments that had not implemented the WFI were matched by size, call volume, staffing, and catchment area to the 10 WFI departments. A solicitation posted on Chief Billy Goldfeder's "Secret List" (a popular, worldwide listserv for firefighters) was used to generate a list of potential standard departments. The research team along with an Expert Fire Service Panel screened and selected departments. The sampling strategy and recruitment information have been published[10]. Of the firefighters solicited, over 94% (N=1,035) consented to participate. This study will use only male firefighters (n=941) with complete data in the analyses because of the inability to make gender comparison with the low number of female firefighters (n=33) in this career sample.

There were 1,419 eligible firefighters from the FIRE and F2F study. Both study protocols were approved by Institutional Review Boards prior to onset of the studies. The 21 fire departments were visited by investigators for 2-8 days depending on shift structure and department size to maximize participation. Consent was obtained in person using written consents.

Measures

Data collection meetings for on-duty firefighters were scheduled with departments and the same investigative team conducted both studies. Similar sets of questions were answered by

firefighters in both studies using paper questionnaires. Physical measurements (height, weight, waist circumference, and body fat) were done using the same protocols by trained investigators. Occupational (years in fire service, rank, total work hours, fitness using estimated VO_{2max} in a non-exercise model[10]) and self-report demographic (age, race/ethnicity, education) information were collected along with the following measures.

Injury

Questions based and modeled off the National Health Interview Survey (CDC) and firefighter-specific questions from the National Institute of Standards and Technology were used to assess injuries[16, 17]. The injury section began with the following, "*The following questions are about injuries you have incurred in the past 12 months. An injury is anything for which you have or should have received medical care (by a physician or other medical professional) whether you reported the injury or not.*" Firefighters indicated the number of injuries they had in the past 12 months for the FIRE study and in the past 6 months for the F2F study. Responses from both studies were dichotomized as no injuries or one or more injuries.

Depression

The presence of depressive symptoms was measured by the Center for Epidemiologic Studies Short Depression Scale (CESD-10) in both studies[18]. Firefighters responded yes or no to ten statements about how they felt or behaved in the past week, including: "I felt depressed," "My sleep was restless," "I felt sad," and "I could not get going." Selecting four or more symptoms in the past week indicates being in the range of concern for depression. Presence of depressive symptoms were dichotomized yes/no based on the four or more symptom cut point.

Job Stress

Job stress was measured in both studies using the following question from the DOD Worldwide Survey[19], "During the past 12 months, how much stress did you experience at work while carrying out your duties in the fire service?". Firefighters responded by selecting, "a lot," "some," "a little," or "none at all." Job stress was categorized using the same categories as the response options.

Body Composition

Study personnel measured body mass index (BMI), waist circumference, and body fat percentage. A stadiometer was used to measure height and a Tanita 300 to measure weight. Standard CDC cut points for not obese (<30 kg/m^2) and obese (≥30 kg/m^2)[20] were used to categorize BMI. A spring-loaded tape measure was used to measure waist circumference following standard procedures. Measures were dichotomized using standard CDC cut points for high risk for developing obesity related conditions (high risk male, >102cm)[20]. The Tanita 300 measured foot-to-foot bioelectrical impedance and body fat percentage was dichotomized using CDC cut points (unhealthy male, >25%)[20].

The three measures of body composition were evaluated to determine the best measure for inclusion in analyses. BMI was chosen due to its ease for comparability to other studies, the prevalence was similar across the body composition measurements, and it is accuracy in defining obesity in firefighters (false positive 9.2% and false negative 14.6% compared to waist circumference)[21].

Sleep

Sleep was assessed by response to the following two questions in both studies, "*Most nights when I am on duty at the fire station, I get enough sleep*" and "*Most nights when I am not on duty at the fire station and I am at home, I get enough sleep*." Firefighters responded using a

5-point Likert scale from strongly disagree to strongly agree. Responses from these two variables were dichotomized into not enough sleep at the fire station and/or at home, or enough sleep. Firefighters responding strongly disagree or disagree were grouped to "not enough sleep", and firefighters responding strongly agree, agree, and no opinion were grouped to "enough sleep."

Physical Activity

FIRE and F2F measured physical activity pattern during the past 30 days using the Self-Report of Physical Activity (SRPA) questionnaire[22]. Firefighters selected their physical activity patterns from a range from 0 (Avoids walking or exertion) to 7 (>3 hours/week of vigorous activity). SRPA categories were collapsed to provide adequate cell sizes during analyses.

Statistical Analyses

The association between injuries, depression, job stress, and the potential confounders age, rank, total work hours, physical activity, obesity, sleep, and years in fire service was evaluated using logistic regression. Backward elimination and change in estimate of 10% was used to evaluate the potential confounders and model efficiency. Age and rank were forced into the final model.

A group level factor of "department" was entered as a random effect in all multivariable models to account for the sampling approach. A multivariable mixed effect logistic regression model was created with the confounders and stratified by BMI defined obesity to examine the presence of effect measure modification by comparing stratified odds ratios. The stratified odds ratio, 95% CI, and p-value ($p<0.05$) were used to evaluate results for significance and model fit was explored. Stata version 15 was used to perform statistical analyses[23].

Results

In this large cohort of firefighters, 15% scored in the range of concern for depression, 36% reported a little job stress, 39% reported some, and 13% reported a lot of job stress. Approximately 81.4% were overweight or obese and 25% of the sample experienced one or more injuries in the previous six to twelve months. Firefighter demographics stratified by BMI defined obesity are presented in Aim 2a Table 1. Obese firefighters reported less vigorous physical activity, and fewer obese (11.5%) firefighters met the NFPA fitness standard of 12 metabolic equivalents than non-obese firefighters (57.8%). Obese firefighters worked more hours per week, were slightly older, and had the most years of service compared to non-obese firefighters.

In model building, years in the fire service was dropped due to collinearity with age. The odds of scoring in the area of concern for depression among male career firefighters who had an on-duty injury was 1.64 (95% CI: 1.15, 2.35) times more likely than scoring in the area of concern for depression among uninjured firefighters, after adjusting for confounding (Aim 2a Table 2). The odds of reporting a little job stress versus no job stress among male career firefighters who had an on-duty injury was 2.57 (95% CI: 1.43, 4.61) times more likely than among the uninjured. The odds of reporting some job stress versus no job stress among on-duty injured firefighters was 2.52 (95% CI: 1.40, 4.55) times more likely, and the odds or reporting a lot of job stress among on-duty injured firefighters was 4.14 (95% CI: 2.12, 8.06) times more likely than uninjured firefighters.

Stratified results from effect measure modification analyses are presented in Aim 2a Table 3. Among non-obese firefighters, the odds of scoring in the area of concern for depression among firefighters who had an on-duty injury was 2.32 (95% CI: 1.53, 3.53) times more likely

compared to scoring in the area of concern for depression among uninjured firefighters, after adjusting for confounding. Among non-obese firefighters, the odds of reporting a little job stress versus no job stress among male career firefighters who had an on-duty injury was 3.18 (95% CI: 1.52, 6.68) times more likely, the odds of some job stress was 3.08 (95% CI: 1.46, 6.50) times more likely, and the odds of a lot of job stress was 6.09 (95% CI: 2.65, 13.99) times more likely than among uninjured firefighters. On-duty injury was not associated with either depression nor job stress among the obese firefighters. However, among obese firefighter who had an injury, the odds of not getting enough sleep were 1.90 (95% CI: 1.08, 3.32) times as likely than among uninjured firefighters. Among obese firefighters who had an injury, the odds of increasing intensity and duration of physical activity versus avoiding exertion were two to three times as likely than among uninjured firefighters. On-duty injury was not associated with neither sleep nor physical activity among the non-obese.

Discussion

Firefighters work high stress jobs, are exposed to traumatic events, and also have a high prevalence of obesity. Previous investigations have found depression and obesity are independently associated with on-duty injury, but this is the first investigation in the fire service to examine obesity as an effect modifier between depression and job stress and on-duty injury.

Using a large national sample, this study found non-obese firefighters with an on-duty injury were more likely to score in the range of concern for depression than uninjured firefighters, but the association was not significant among the obese. Previous investigations found depression was associated with injury among Midwest firefighters[5], but was not associated with incident on-duty injury or missed work days due to injury[6, 8].

In a large prospective study among a cohort of working men and women in rural Iowa, Tiesman et al. found depression was a risk factor for injury[11]. Although the current study cannot establish depression occurred before the injury, the Tiesman et al. results indicate depression is a risk factor for injury. Further, the proposed mechanism for depression impairing cognitive functioning, hindering the ability of the firefighter to take information, process information, and act up on it, possibly leading to injury is plausible in this fast-paced occupation[24].

In addition to depression, only non-obese firefighters who had an on-duty injury were more likely to report job stress compared to uninjured firefighters. The previous investigation in the fire service by Poston et al. suggested stress was not associated with severe injuries which would require missed days of work[6], but did not indicate if it is associated with injury itself, particularly less severe injuries, which this study established. The results of the current study do align with the results of the Kim et al. study conducted among Korean firefighters[13], and among many other occupations[12], which have found job stress is associated with occupational injury.

Interestingly, on-duty injury was associated with both psychosocial factors among the non-obese, and among the obese on-duty injury was associated with the health behaviors sleep and physical activity. We found on-duty injury was associated with sleep and physical activity among the obese, but did not find any significant associations among the non-obese[9]. The results of both of these studies suggest the risk profile for injury among the obese and non-obese firefighters may be different. In addition, the interaction between physical and psychosocial factors in association with injury are similar to findings from the Leka et al. review on the health impact of occupational psychosocial hazards[12].

The physical and psychological demands of firefighting necessitate firefighters be physically and mentally healthy. Fire departments looking to implement health and wellness

programs should include mental health resources for firefighters, and work to reduce workplace stress at an organizational level to improve the workplace culture and manage depression and job stress. Job stress and depression have a reciprocal causal relationship[12]. Fire departments should prioritize managing and improving job related stress for factors that can be influenced, which can then also make an impact on depression. Health care professionals should screen and treat mental health disorders and discuss weight management and healthy sleep habits with firefighters. Previous research has found health care providers don't provide weight loss advice to most firefighters (69%), and only half of class I-III obese firefighters reported receiving weight loss advice[25].

There are limitations to be acknowledged. Depression, job stress, sleep, physical activity, and injury were self-report, although self-report injury data can be more sensitive to less severe injuries which firefighters feel do not need to be reported to the department[26]. There was a difference of 6 months in the reference time frame for FIRE and F2F cohorts. However, by dichotomizing injury as any injury or none, it is not likely this differentially biased study results, especially given the high prevalence of injury. More specific analyses on injury subtypes could not be conducted because F2F did not collect detailed injury information. While self-report depressive symptoms were measured rather than a medical diagnosis, the CES-D has good psychometric properties and can capture firefighters who have not sought help but have depressive disorder symptoms. Depressive symptoms were measured over the past week, but injuries were measured over the past 6 months to a year. It was assumed depression was present before and after the injury, although it is possible depression developed after the injury[27]. This is a cross-sectional study, so only associations between factors can be investigated.

Although there were limitations, these two national firefighter cohorts constitute the largest dataset in the fire service to date with injuries spanning over 5 years. The same investigative team conducted in person body composition measurements using validated protocols in both studies. Importantly, this was the first study to examine psychosocial factors with injury stratified by obesity in the fire service.

Conclusion

Obesity should be examined as an effect modifier in future examinations of physical and psychosocial predictors of injury amongst career firefighters. The results of previous studies and this study suggest non-obese and obese firefighters have different risk factors for on-duty injury. Findings from this study and others highlight the need to address depression, job stress, obesity, and sleep in the fire service.

Aim 2a Table 1: Characteristics of US Male, Career Firefighters Stratified by Body Mass Index (BMI), FIRE (2008-2010) & Fuel 2 Fight (2010-2013)

	Not Obese[a] n=971 (69.1%) n (%)	Obese n=433 (30.8%) n (%)
Injury		
≥1 Injury	238 (25.2)	103 (25.1)
Physical Activity		
≤1hr Moderate/wk	86 (9.4)	75 (18.8)
>1hr Moderate/wk	108 (11.8)	90 (22.6)
≤1hr Vigorous/wk	281 (30.7)	129 (32.4)
1-3hr Vigorous/wk	217 (23.7)	64 (16.1)
>3hr Vigorous/wk	224 (24.4)	40 (10.1)
Sleep		
Get Enough Sleep	313 (33.6)	145 (35.9)
Not Enough Sleep	618 (66.4)	259 (64.1)
Fitness[b]		
Meet NFPA	533 (57.8)	46 (11.5)
Don't Meet NFPA	389 (42.2)	354 (88.5)
Rank[c]		
FF/Medic/Driver	680 (73.0)	290 (71.4)
LT/CPT/Chief	251 (27.0)	116 (28.6)
Education		
High School or Less	86 (9.2)	42 (10.5)
Some College	619 (65.9)	282 (70.5)
College/Grad Degree	234 (24.9)	76 (19.0)
Minority		
White non-Hispanic	709 (75.3)	267 (65.3)
Minority	232 (24.7)	142 (34.7)
	Mean (SD)	Mean (SD)
Total Work Hours	67.2 (17.6)	70.5 (20.2)
Age (years)	37.8 (9.1)	40.8 (9.0)
Years of Service	13.3 (8.5)	15.8 (8.9)

[a]BMI not obese (18.5-29.9 kg/m^2) and obese (>30 kg/m^2); [b]NFPA Fitness cutoff: 12 METS; [c]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any type of Chief;
Missing: BMI (n=15); Injury (n=53); Physical Activity (n=94); Sleep (n=73); Fitness (n=97); Rank (n=71); Education (n=69); Minority (n=58); Total Work Hours (n=70); Age (n=8); Years of Service (n=64)

Aim 2a Table 2: Mixed Effects Logistic Regression for Injury on Depression and Job Stress, FIRE (2008-2010) & Fuel 2 Fight (2010-2013)

	OR (95% CI)
Depression[a]	
<4 CES-D 10 Score	Ref.
≥4 CES-D 10 Score	**1.64 (1.15, 2.35)[b]**
Job Stress	
None at all	Ref.
A little	**2.57 (1.43, 4.61)**
Some	**2.52 (1.40, 4.55)**
A lot	**4.14 (2.12, 8.06)**
BMI[c]	
Not Obese	Ref.
Obese	1.05 (0.78, 1.42)
Sleep	
Enough Sleep	Ref.
Not Enough Sleep	**1.39 (1.03, 1.88)**
Physical Activity	
≤1hr Moderate	Ref.
>1hr Moderate	1.33 (0.77, 2.33)
≤1hr Vigorous	1.39 (0.84, 2.29)
1-3hr Vigorous	1.67 (0.99, 2.81)
>3hr Vigorous	**1.81 (1.07, 3.07)**
Age (years)	
<30	Ref.
30-39	1.10 (0.74, 1.64)
40-49	1.23 (0.81, 1.89)
50+	1.09 (0.64, 1.86)
Rank[d]	
FF/Medic/Driver	Ref.
LT/CPT/Chief	0.79 (0.57, 1.11)

[a]Score ≥4 range of concern for depression; [b]bold indicates significance $p<0.05$; [c]BMI not obese (18.5-29.9 kg/m^2) and obese (≥30 kg/m^2); [d]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any Type of Chief

Aim 2a Table 3: Mixed Effects Logistic Regression for Injury on Depression and Job Stress Stratified by Obesity, FIRE (2008-2010) & Fuel 2 Fight (2010-2013)

	BMI Not Obese[a] OR (95% CI)	BMI Obese[a] OR (95% CI)
Depression[b]		
<4 CES-D 10 Score	Ref.	Ref.
≥4 CES-D 10 Score	**2.32 (1.53, 3.53)[c]**	0.71 (0.34, 1.50)
Job Stress		
None at all	Ref.	Ref.
A little	**3.18 (1.52, 6.68)**	1.62 (0.60, 4.39)
Some	**3.08 (1.46, 6.50)**	1.63 (0.60, 4.39)
A lot	**6.09 (2.65, 13.99)**	2.43 (0.74, 7.95)
Sleep		
Enough Sleep	Ref.	Ref.
Not Enough Sleep	1.16 (0.81, 1.67)	**1.90 (1.08, 3.32)**
Physical Activity		
≤1hr Moderate	Ref.	Ref.
>1hr Moderate	0.99 (0.48, 2.04)	**2.51 (1.00, 6.26)**
≤1hr Vigorous	0.93 (0.50, 1.74)	**2.89 (1.22, 6.83)**
1-3hr Vigorous	1.24 (0.66, 2.35)	**2.77 (1.07, 7.15)**
>3hr Vigorous	1.38 (0.73, 2.60)	**3.10 (1.10, 8.75)**
Age (years)		
<30	Ref.	Ref.
30-39	1.01 (0.64, 1.59)	1.27 (0.55, 2.92)
40-49	1.16 (0.71, 1.89)	1.46 (0.61, 3.52)
50+	1.04 (0.53, 2.01)	1.35 (0.51, 3.55)
Rank[d]		
FF/Medic/Driver	Ref.	Ref.
LT/CPT/Chief	0.80 (0.53, 1.19)	0.79 (0.43, 1.45)

[a]BMI not obese (18.5-29.9 kg/m^2) and obese (>30 kg/m^2); [b]Score ≥4 range of concern for depression; [c]bold indicates significance $p<0.05$; [d]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any Type of Chief

References

1. Haynes, H J G and Molis, J L. U.S. firefighter injuries-2014. 2015.

2. Reichard, A A and Jackson, L L. Occupational injuries among emergency responders. *Am J Ind Med.* 2010;53:1-11.

3. Kuehl, K S, Kisbu-Sakarya, Y, Elliot, D L, Moe, EL; Defrancesco, C A.; Mackinnon, D P.; Lockhart, G.; Goldberg, L.; Kuehl, H E. Body mass index as a predictor of firefighter injury and workers' compensation claims. *J Occup Environ Med.* 2012;54:579-582.

4. Poplin, G S, Roe, D J, Peate, W, Harris, R B and Burgess, J L. The association of aerobic fitness with injuries in the fire service. *Am J Epidemiol.* 2014;179:149-155.

5. Jahnke, S A, Poston, W S, Haddock, C K and Jitnarin, N. Injury among a population based sample of career firefighters in the central USA. *Inj Prev.* 2013;19:393-398.

6. Poston, W S, Jitnarin, N, Haddock, C K, Jahnke, S A and Tuley, B C. Obesity and injury-related absenteeism in a population-based firefighter cohort. *Obesity.* 2011;19:2076-2081.

7. Soteriades, E S, Hauser, R, Kawachi, I, Christiani, D C and Kales, S N. Obesity and risk of job disability in male firefighters. *Occup Med (Lond).* 2008;58:245-250.

8. Jahnke, S, Poston, W, Haddock, C and Jitnarin, N. Obesity and incident injury among career firefighters in the central United States. *Obesity.* 2013;21:1505-1508.

9. Kaipust, C M. Total worker health on occupational injury among male and female, career and volunteer firefighters. 2018.

10. Poston, W S, Haddock, C K, Jahnke, S A, Jitnarin, N and Day, R S. An examination of the benefits of health promotion programs for the national fire service. *BMC Public Health.* 2013;13:805.

11. Tiesman, H M, Peek-Asa, C, Whitten, P, Sprince, N L, Stromquist, A and Zwerling, C. Depressive symptoms as a risk factor for unintentional injury: A cohort study in a rural county. *Inj Prev.* 2006;12:172-177.

12. Leka, S, Jain, A. Health impact of psychosocial hazards at work: An overview. 2010. World Health Organization.

13. Kim, Y K, Ahn, Y S, Kim, K, Yoon, J H and Roh, J. Association between job stress and occupational injuries among korean firefighters: A nationwide cross-sectional study. *BMJ Open.* 2016;6:e012002-2016-012002.

14. Haynes, H J G and Molis, J L. NFPA's "U.S. firefighter injuries-2015". 2016.

15. Poston, W S, Haddock, C K, Jahnke, S A, Jitnarin, N, Tuley, B C and Kales, S N. The prevalence of overweight, obesity, and substandard fitness in a population-based firefighter cohort. *J Occup Environ Med.* 2011;53:266-273.

16. CDC. National health interview survey (NHIS). Retrieved from http://www.cdc.gov.utsph.idm.oclc.org/nchs/nhis.htm.

17. National Institutes of Standards and Technology (NIST). The economic consequences of firefighter injuries and their prevention. Final Report. 2005;NIST GCR 05-874.

18. Irwin, M, Artin, K H and Oxman, M N. Screening for depression in the older adult: Criterion validity of the 10-item center for epidemiological studies depression scale (CES-D). *Arch Intern Med.* 1999;159:1701-1704.

19. Cohen, S, Kamarck, T and Mermelstein, R. A global measure of perceived stress. *J Health Soc Behav.* 1983:385-396.

20. CDC. About adult BMI. 2015. Retrieved from http://www.cdc.gov.utsph.idm.oclc.org/healthyweight/assessing/bmi/adult_bmi/index.html.

21. Jitnarin, N, Poston, W S, Haddock, C K, Jahnke, S A and Day, R S. Accuracy of body mass index-defined obesity status in US firefighters. *Safety and Health at Work.* 2014;5:161-164.

22. Jackson, A S, Blair, S N, Mahar, M T, Wier, L T, Ross, R M and Stuteville, J E. Prediction of functional aerobic capacity without exercise testing. *Med Sci Sports Exerc.* 1990;22:863-870.

23. StataCorp. *Stata statistical software: Release 15*. College Station, TX: StataCorp LLC. 2017.

24. McClintock, S M, Husain, M M, Greer, T L and Cullum, C M. Association between depression severity and neurocognitive function in major depressive disorder: A review and synthesis. *Neuropsychology.* 2010;24:9.

25. Wilkinson, M L, Brown, A L, Poston, W S, Haddock, C K, Jahnke, S A and Day, R S. Physician weight recommendations for overweight and obese firefighters, united states, 2011-2012. *Prev Chronic Dis.* 2014;11:E116.

26. Pole, J D, Franche, R L, Hogg-Johnson, S, Vidmar, M and Krause, N. Duration of work disability: A comparison of self-report and administrative data. *Am J Ind Med.* 2006;49:394-401.

27. Gerismaviciute, V. The association between episodes of mental disorders and workplace injuries among employees in public university settings. 2016.

JOURNAL ARTICLE

Depression, Obesity, and Injury in the Volunteer Fire Service

Journal of Occupational and Environmental Medicine

Introduction

Volunteer firefighters are critical to the US public health safety framework. Volunteer firefighters make up 70% of the US Fire Service, and 67% of fire departments in the US are staffed entirely by volunteers[1]. In the largest epidemiologic study to date among volunteer firefighters, we found the prevalence of overweight and obesity was 80%, and 46% of those volunteer firefighters were obese[2]. The 46% prevalence of obesity among volunteer firefighters is higher than the prevalence among careers (31%[2]), and the general US population (37.9%[3]). Obesity is a risk for many poor personal health outcomes, including cardiac death, the number one cause of line-of-duty deaths in the fire service. Obesity is also a risk factor for occupational health and safety outcomes in the fire service, including on-duty injury[4-8].

Our investigation into on-duty injury among volunteer firefighters found obesity, sleep, and total work hours interact in association with on-duty injury[2]. Among obese volunteer firefighters, working/volunteering 40-49 hours per week compared to <40 hours per week among injured firefighters was less likely than among uninjured firefighters. Further, among non-obese volunteer firefighters, the odds of inadequate sleep among injured firefighters was nearly three times as likely than among uninjured firefighters[2]. This research suggests the risk factors for injury among the obese differ than those among the non-obese. Obesity has not been explored as an effect modifier between psychosocial factors and on-duty injury in the fire service.

The association between depression and injury in the fire service has only been explored among career firefighters in a limited amount of studies. Self-report healthcare provider

diagnosis of depressive disorder and the Center for Epidemiological Studies Depression (CES-D) screening tests for depression have been used to assess depression in the fire service. Approximately 6% of male career firefighters have physician diagnosed depressive disorder, and the mean CES-D-10 scores are low (approximately 1.7)[9]. This prevalence of depressive disorder among career firefighters is similar to the 4.8% among males in the general US population[10]. The odds of injury were 2.33 times higher among Midwest male career firefighters scoring in the range of concern for symptoms for depression using the CES-D-10 than those not scoring in the range of concern for depression[5], although depression was not a significant predictor of incident injury[8] or missed work days due to injury[6] among the same cohort. But, Tiesman et al. found working men and women in rural Iowa with depressive symptoms had a 41% higher risk of injury than those without depressive symptoms in the first prospective analysis of depression as a risk factor for injury[11].

According to the National Fire Protection Association (NFPA), most on-duty injuries among volunteer firefighters occur on the fireground, and a lower proportion during non-fire emergencies because many volunteer fire departments do not run Emergency Medical Services (EMS) calls. The average annual number of injuries in the fire service from 2012-2014 was 14,870[12].

Firefighting is a psychologically demanding occupation which may expose firefighters to traumatic events. The unique demands of firefighters signal the need to explore psychosocial predictors of injury in the volunteer fire service. Physical and psychosocial risk factors independently predict musculoskeletal injury, the most common type of injury in the fire service[12], and their interactive effects are stronger than their independent effects)[13]. Current evidence suggests depression is a risk factor for occupational injury, but the small number of

studies mostly conducted among career departments, which may not be representative of the volunteer fire service, have found conflicting results with on-duty injury related outcomes. Depression, along with physical factors like obesity, have never been explored in the volunteer fire service. The aim of this study is to determine the association between depression, obesity, and on-duty injury among 201 male volunteer firefighters from 13 departments across eight Midwest states coupled with 332 male volunteer firefighters from ten departments located in ten states across the USA.

Methods

Participants and Procedures

This cross-sectional study utilized Firefighter Injury and Risk Evaluation (FIRE) study and The First Twenty (TF20) study baseline assessment data. FIRE was a longitudinal cohort study of Midwest volunteer and career firefighters conducted from 2008-2010. Investigators generated a list of fire departments, using the U.S. Fire Department Census Database, from all eight International Association of Fire Chiefs Missouri Valley region states (Kansas, Missouri, Iowa, Nebraska, North Dakota, South Dakota, Colorado, and Wyoming). Previous publications detail the sampling strategy and recruitment[14]. Eleven career and 13 volunteer departments (N=736) were randomly selected for participation in the IAFC Missouri Valley region. Over 97% (N=714) of firefighters consented to participate from solicited fire departments. Female firefighters were excluded from analyses for this study due to low numbers and the inability to explore differences in gender, so only male volunteer firefighters (n=201) were used.

The TF20 study, a cluster-randomized controlled trial, was conducted from 2014-2017. The email listserv Chief Billy Goldfeder's "Secret List" and the list serve of the National Volunteer Fire Council (NVFC) was used to solicit interest for recruitment. Interested fire

departments across the nation underwent a telephone screening interview. Departments were selected based on size, call volume, region, and interest in the study. Five departments in the wait-list control arm and five in the treatment arm were selected to participate. There was at least one department in each of the four major US Census Bureau Regions, spread across ten different US states (Missouri, New Jersey, New Mexico, North Carolina, Ohio, Oregon, Texas, Utah, Virginia, and Washington). Only data on male firefighters (n=332) were used in this analysis due to the low number of females.

There were 533 volunteer firefighters eligible for analyses from these two studies. Institutional Review Boards approved FIRE and TF20 study protocols prior to onset of the studies. Written consent was obtained in person from interested firefighters for both studies.

Measures

The investigative team and the department chiefs coordinated to schedule data collection meetings for firefighters in both studies. Each department was visited for 1-8 days by investigators depending on the size and structure of the department. Investigators provided a description of the study in person prior to consent. Similar demographic and risk factor questions were included in both studies. The same trained investigators conducted the physical measurements (height, weight, waist circumference, and body fat) using identical protocols in both studies. Self-report occupational (rank, years in fire service, total work and volunteer hours) and demographic (age, race/ethnicity, education, physical activity) information was collected in addition to the following measures.

Injury

Injuries were assessed using questions based on the National Health Interview Survey (CDC) and modeled off firefighter specific questions from the National Institute of Standards

and Technology[15, 16]. The injury section began, "*The following questions are about injuries you have incurred in the past 12 months. An injury is anything for which you have or should have received medical care (by a physician or other medical professional) whether you reported the injury or not.*" Firefighters indicated the number of injuries they had in the past 12 months for the FIRE study and in the past 6 months for the TF20 study. Responses were dichotomized as no injuries or any injury.

Depression

The Center for Epidemiologic Studies Short Depression Scale (CESD-10) was used to measure the presence of depressive symptoms in both studies[17]. Firefighters indicated how they felt or behaved in the past week by responding to ten statements, including: "I felt depressed," "My sleep was restless," "I felt sad," and "I could not get going." Firefighters selecting four or more symptoms in the past week were in the range of concern for depression. Presence of depressive symptoms were dichotomized yes/no based on the four or more symptom cut point.

Body Composition

Standard CDC cut points were used to categorize not obese (<30 kg/m^2) and obese (≥30 kg/m^2) firefighters)[18] from measured weight using a Tanita 300 and height using a stadiometer. Standard CDC cut points for high risk for developing obesity related conditions (high risk male >102cm) were used to dichotomized waist circumference)[18] from measured waist circumferences using a spring-loaded tape measure following standard procedures. Body fat percentage was dichotomized using CDC cut points (unhealthy male >25%) and measured using foot-to-foot bioelectrical impedance from the Tanita 300)[18].

Trained personnel conducted all three body composition measurements. BMI was chosen in this analysis due to its ease for comparability to other studies and its accuracy in defining

obesity in this population (false positive 9.2% and false negative 14.6% compared to waist circumference)[19].

Sleep

In FIRE, firefighters responded using a Likert scale from strongly disagree to strongly agree to the following question, "*Most nights, I get enough sleep*." Firefighters responding strongly disagree or disagree were grouped to "inadequate sleep," and firefighters responding strongly agree, agree, and no opinion were grouped to "adequate sleep."

In TF20, firefighters wrote in responses to the following questions, "*How many hours do you typically need during the night to feel rested the following day?*" and "*Over the past week, how many hours on average did you typically sleep per day?*" Firefighters were categorized into inadequate and adequate sleep by subtracting firefighters' average hours of sleep over the past week from the average hours of sleep they typically need to feel rested the following day. Firefighters with inadequate sleep had reported sleep hours less than their hours needed, while firefighters with adequate sleep reported average sleep equal to or exceeding needed sleep hours. Responses from FIRE and TF20 variables were combined and dichotomized into one sleep variable, inadequate sleep or adequate sleep.

Statistical Analyses

Logistic regression was used to evaluate the association between injuries, depression and the potential confounders age, rank, total work hours, physical activity, obesity, sleep, and years in fire service. Potential confounders were evaluated using backward elimination approach and the change in estimate of 10% applied to determine model efficiency. Age, obesity, and rank were forced into the final model.

A multivariable mixed effect logistic regression model was created with a group level factor of "department" entered as a random effect in all multivariable models. The multivariable mixed effect logistic regression model included confounders and was stratified by BMI defined obesity to examine effect measure modification. The stratified odds ratio, 95% CI, and p-value ($p<0.05$) were used to evaluate results for significance and model fit was explored. Statistical analyses were done with Stata version 15[20].

Results

Approximately 11% of volunteer firefighters experienced an on-duty injury in the past six months to a year, 20.6% scored in the range of concern for depression, and 80% were overweight or obese, of which 46% were obese. Volunteer firefighter demographics stratified by BMI defined obesity are presented in Aim 2b Table 1. Obese volunteer firefighters did less physical activity (679 minutes) than non-obese (841 minutes), reported less inadequate sleep, worked a few hours more per week, and had a few years less experience than non-obese volunteer firefighters.

Years in the fire service was dropped from the regression models due to collinearity with age. In the full multivariable mixed logistic regression model, no predictors were associated with injury ($p>0.05$) (Aim 2b Table 2). BMI defined obesity stratified results are presented in Aim 2b Table 3. Among non-obese volunteer firefighters, the odds of scoring in the area of concern for depression among volunteer firefighters who had an on-duty injury was 3.52 times more likely compared to scoring in the area of concern for depression among uninjured volunteer firefighters. On-duty injury was not associated with depression among the obese firefighters.

Discussion

Depression and obesity are independently associated with injury in firefighters, but this is the first investigation in the volunteer fire service to examine obesity as an effect modifier between depression and on-duty injury.

The odds of scoring in the range for depression among non-obese volunteer firefighters in this study who had an on-duty injury was more likely than among uninjured firefighters, and this association was not significant among the obese. Previous investigations into depression and injury among career firefighters found mixed results[5, 6, 8], but using a large national sample of volunteer firefighters this study found there was an association. The results of this study may also differ from the results of previous examinations in the fire service because the analyses were stratified by obesity, rather than adjusted for with obesity as a confounder. Our results do coincide with Tiesman et al. who also found depression was a risk factor for injury in a large prospective cohort of working men and women in rural Iowa[11]. The proposed mechanism[21] for depression to impact injury describes depression as impairing cognitive functioning, which hinders the firefighter's ability to take, process and act on information. This mechanism could be plausible in an occupation like firefighting requiring physical and mental fitness to perform primary duties.

Depression was associated with on-duty injury only among the non-obese, and no other factors were associated with on-duty injury among the non-obese or obese volunteer firefighters. We found total work hours were associated with injury only among the obese, and inadequate sleep was associated with injury only among the non-obese[2]. Using the same population and adding depression, total work hours was no longer an important risk factor to be included and sleep was no longer associated with injury. These results, along with the results from Kaipust,

propose obese and non-obese may have different risk profiles for injury, and depression appears to be an important factor in association with on-duty injury. These results demonstrate there is an interaction between physical and psychosocial predictors of injury, similar to those found in other occupations. [13].

Firefighting is a physically and psychologically demanding occupation. Health care professionals should discuss weight management and screen and treat mental health disorders to improve firefighter health and safety. Mental health resources should be provided by fire departments looking to implement health and wellness programs. Because job stress has a reciprocal causal association with depression[13], and both were found to be associated with injury among career firefighters[2], fire departments should work at an organizational level to reduce workplace stress and manage depression. Job stress could not be evaluated among volunteer firefighters in this study because it was not evaluated in TF20. Future examinations into on-duty injury in the fire service should examine job stress, in addition to depression.

The limitations of this study should be acknowledged. Depression, sleep, and injury were self-report, although self-report injury data is more sensitive to less severe injuries[22]. The self-reporting reference time frame for injury differed by 6 months for FIRE and TF20. However, this was unlikely to differentially bias results given the high prevalence of injury and the dichotomization of on-duty injury into none or any. Unfortunately, more specific analyses into injury types could not occur because TF20 did not collect detailed information on injuries. Because sleep was measured differently for FIRE and TF20, the combining of these variables may have biased study results, although it's likely it was non-differential. Although depressive symptoms were self-report, the CES-D can capture firefighters who have not sought treatment and has good psychometric properties[17]. Only associations with injury can be explored in this

study due to the cross-sectional design. It is possible depression developed as a result of the injury[23]. Depressive symptoms were measured over the past week while injuries were assessed over the past 6 months to a year.

This study combined two cohorts to examine the association between depression and injury among the largest sample of volunteer firefighters from across the US in an epidemiologic study, a population of firefighters relatively unexplored due to the difficulty accessing large numbers of volunteer firefighters. BMI defined obesity is an appropriate measurement in firefighters given the accuracy of this measurement in this population[19] and the results of this study using different body composition measurements were similar.

This study was the first epidemiologic study to examine depression in association with injury among the volunteer fire service, and to examine obesity as an effect modifier between depression and injury in the volunteer fire service.

Conclusion

Future examinations of injury among volunteer firefighters should examine body composition as an effect modifier between physical and psychosocial factors. Findings from this study and the existing literature highlight the need to address depression and obesity in the volunteer fire service.

Aim 2b Table 1: Characteristics of US Male, Volunteer Firefighters Stratified by Obesity, FIRE (2008-2010) & TF20 (2014-2017)

	Not Obese[a] n=276 (54.0%) n (%)	Obese[a] n=235 (46.0%) n (%)
Injury		
≥1 Injury	27 (10.0)	26 (11.6)
Sleep		
Adequate Sleep	144 (52.2)	141 (60.0)
Inadequate Sleep	132 (47.8)	94 (40.0)
Rank[b]		
FF/Medic/Driver	197 (73.5)	156 (70.6)
LT/CPT/Chief	71 (26.5)	65 (29.4)
Education		
High School or Less	70 (25.5)	61 (26.2)
Some College	133 (48.4)	124 (53.2)
College/Grad Degree	72 (26.2)	48 (20.6)
Minority		
White non-Hispanic	247 (90.2)	211 (91.0)
Minority	27 (9.9)	21 (9.1)
	Mean (SD)	Mean (SD)
Physical Activity Minutes[c]	841.2 (1292.8)	678.8 (1049.3)
Total Work Hours	45.9 (22.4)	49.2 (18.9)
Age (years)	37.3 (12.9)	40.2 (11.1)
Years of Service	10.4 (9.6)	13.2 (10.5)

[a]BMI not obese (18.5-29.9 kg/m^2) and obese (≥30 kg/m^2); [b]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any Type of Chief; [c]Total minutes of moderate and vigorous physical activity per week

Missing: BMI (n=22); Injury (n=20); Sleep (n=4); Rank (n=30); Education (n=9); Minority (n=11); Physical Activity (n=46); Total Work Hours (n=13); Age (n=8); Years of Service (n=11)

Aim 2b Table 2: Mixed Effects Logistic Regression for Injury on Depression, FIRE (2008-2010) & TF20 (2014-2017)

	OR (95% CI)
Depression[a]	
<4 CES-D 10 Score	Ref.
≥4 CES-D 10 Score	1.76 (0.86, 3.66)
Sleep	
Adequate Sleep	Ref.
Inadequate Sleep	1.25 (0.64, 2.42)
BMI[b]	
Non-Obese	Ref.
Obese	1.32 (0.70, 2.51)
Age (years)	
<30	Ref.
30-39	0.40 (0.16, 1.03)
40-49	1.33 (0.61, 2.93)
50+	0.76 (0.27, 2.14)
Rank[c]	
FF/Medic/Driver	Ref.
LT/CPT/Chief	1.04 (0.51, 2.14)

[a]Score ≥4 range of concern for depression; [b]BMI not obese (18.5-29.9 kg/m^2) and obese (≥30 kg/m^2); [c]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any type of Chief

Aim 2b Table 3: Mixed Effects Logistic Regression for Injury on Depression Stratified by Obesity, FIRE (2008-2010) & TF20 (2014-2017)

	Not Obese[a] OR (95% CI)	Obese[a] OR (95% CI)
Depression[b]		
<4 CES-D 10 Score	Ref.	Ref.
≥4 CES-D 10 Score	**3.52 (1.43, 8.66)**[c]	0.52 (0.12, 2.22)
Sleep		
Adequate Sleep	Ref.	Ref.
Inadequate Sleep	2.11 (0.82, 5.44)	1.09 (0.39, 3.04)
Age (years)		
18-29	Ref.	Ref.
30-39	0.65 (0.20, 2.14)	0.15 (0.03, 0.87)
40-49	1.50 (0.49, 4.60)	1.26 (0.37, 4.25)
50+	0.69 (0.15, 3.17)	0.60 (0.13, 2.75)
Rank[d]		
FF/Medic/Driver	Ref.	Ref.
LT/CPT/Chief	1.77 (0.64, 4.92)	0.72 (0.24, 2.18)

[a]BMI not obese (18.5-29.9 kg/m^2) and obese (≥30 kg/m^2); [b]Score ≥4 range of concern for depression; [c]bold indicates significance $p<0.05$; [d]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any Type of Chief

References

1. Haynes, H J G and Stein, G P. U.S. fire department profile-2015. 2017.

2. Kaipust, C M. Total worker health on occupational injury among male and female, career and volunteer firefighters. 2018.

3. National Center for Health Statistics. Health, united states, 2016: With chartbook on long-term trends in health. 2017.

4. Kuehl, K S, Kisbu-Sakarya, Y, Elliot, D L, Moe, EL; Defrancesco, C A.; Mackinnon, D P.; Lockhart, G.; Goldberg, L.; Kuehl, H E. Body mass index as a predictor of firefighter injury and workers' compensation claims. *J Occup Environ Med.* 2012;54:579-582.

5. Jahnke, S A, Poston, W S, Haddock, C K and Jitnarin, N. Injury among a population based sample of career firefighters in the central USA. *Inj Prev.* 2013;19:393-398.

6. Poston, W S, Jitnarin, N, Haddock, C K, Jahnke, S A and Tuley, B C. Obesity and injury-related absenteeism in a population-based firefighter cohort. *Obesity.* 2011;19:2076-2081.

7. Soteriades, E S, Hauser, R, Kawachi, I, Christiani, D C and Kales, S N. Obesity and risk of job disability in male firefighters. *Occup Med (Lond).* 2008;58:245-250.

8. Jahnke, S, Poston, W, Haddock, C and Jitnarin, N. Obesity and incident injury among career firefighters in the central United States. *Obesity.* 2013;21:1505-1508.

9. Poston, W S, Haddock, C K, Jahnke, S A, Jitnarin, N and Day, R S. An examination of the benefits of health promotion programs for the national fire service. *BMC Public Health.* 2013;13:805.

10. National Institute of Mental Health. Major depression. 2017.

11. Tiesman, H M, Peek-Asa, C, Whitten, P, Sprince, N L, Stromquist, A and Zwerling, C. Depressive symptoms as a risk factor for unintentional injury: A cohort study in a rural county. *Inj Prev.* 2006;12:172-177.

12. Haynes, H. U.S. volunteer firefighter injuries 2012-2014. 2016.

13. Leka, S, Jain, A. Health impact of psychosocial hazards at work: An overview. 2010. World Health Organization.

14. Poston, W S, Haddock, C K, Jahnke, S A, Jitnarin, N, Tuley, B C and Kales, S N. The prevalence of overweight, obesity, and substandard fitness in a population-based firefighter cohort. *J Occup Environ Med.* 2011;53:266-273.

15. CDC. National health interview survey (NHIS). Retrieved from http://www.cdc.gov.utsph.idm.oclc.org/nchs/nhis.htm.

16. National Institutes of Standards and Technology (NIST). The economic consequences of firefighter injuries and their prevention. Final Report. 2005;NIST GCR 05-874.

17. Irwin, M, Artin, K H and Oxman, M N. Screening for depression in the older adult: Criterion validity of the 10-item center for epidemiological studies depression scale (CES-D). *Arch Intern Med.* 1999;159:1701-1704.

18. CDC. About adult BMI. 2015. Retrieved from http://www.cdc.gov.utsph.idm.oclc.org/healthyweight/assessing/bmi/adult_bmi/index.html.

19. Jitnarin, N, Poston, W S, Haddock, C K, Jahnke, S A and Day, R S. Accuracy of body mass index-defined obesity status in US firefighters. *Safety and Health at Work.* 2014;5:161-164.

20. StataCorp. *Stata statistical software: Release 15*. College Station, TX: StataCorp LLC. 2017.

21. McClintock, S M, Husain, M M, Greer, T L and Cullum, C M. Association between depression severity and neurocognitive function in major depressive disorder: A review and synthesis. *Neuropsychology.* 2010;24:9.

22. Pole, J D, Franche, R L, Hogg-Johnson, S, Vidmar, M and Krause, N. Duration of work disability: A comparison of self-report and administrative data. *Am J Ind Med.* 2006;49:394-401.

23. Gerismaviciute, V. The association between episodes of mental disorders and workplace injuries among employees in public university settings. 2016.

JOURNAL ARTICLE

Job Stress, Depression, and Injury among Female Career Firefighters

Journal of Occupational and Environmental Medicine

Introduction

The percentage of females in the US fire service is estimated to be 3.7%-6.0%[1, 2]. This prevalence is extremely low compared to similar occupations such as the military and police force, which have about 17% females[1, 2]. A small amount of research on female firefighters has been conducted and published in the fire service compared to male firefighters. The lack of published research on female firefighters is due to the small number of women in the fire service resulting in small numbers captured in previous studies, usually resulting in their exclusion from reports[3]. Women have been included in research studies, they just represent such a small percentage of the total firefighters in studies making their results not generalizable.

On-duty injury data among female firefighters is extremely limited in the literature. Jahnke et al. in 2012 reported on 18 career and 13 volunteer female firefighters from the midwest[4]. Almost 28% of these female career firefighters reported an on-duty injury in the past 12 months. This prevalence is similar to that found by Kaipust et al, where 25% of 1,400+ male career firefighters reported an on-duty injury in the previous six to twelve months[5]. While the prevalence of on-duty injury by gender seems similar, on-duty injury needs to be described among a larger sample of female firefighters to accurately estimate the prevalence.

The prevalence of job stress and depression have been described among a small sample of female firefighters. Murphy et al. used a cross-sectional design to describe gender differences of job stressors and symptoms of stress in firefighters among 670 males and 41 females with 10

years or less experience firefighting[6]. They found female firefighters reported significantly higher scores regarding job skill concerns, job discrimination, and depression than males.

Jahnke et al. found about one-quarter of the Midwest female career firefighters (22.2%) reported scores in the range of concern for depression[2]. Further, 28% of female career firefighters reported feeling nervous and stressed fairly often or very often, and 22% reported feeling angered because things were outside of their control fairly often or very often. However, overall female career firefighters also reported strong perceived coping skills.

The association between job stress and depression has been explored among male career firefighters. Kaipust found 15% of male career firefighters scored in the range of concern for depression, 13% reported a lot of job stress, 39% reported some, and 36% reported a little[5]. Male firefighters with on-duty injury had higher odds of job stress and were more likely to score in the range of concern for depression versus uninjured firefighters. In models stratified by obesity status, only non-obese male career firefighters with on-duty injury had elevated odds of reporting job stress and scoring in the range of concern for depression compared to uninjured firefighters. There are no data on the relationship of these variables among female firefighters.

The previous research done among female firefighters has been primarily descriptive. The scant evidence among small samples suggests female firefighters experience more injuries and have a higher prevalence of depression than males. It is unknown how psychosocial factors are associated with occupational injury among female firefighters, but evidence among males demonstrates the need to explore the association. The aim of this study was to identify psychosocial predictors (job stress, job satisfaction, depression, and anxiety) of on-duty injury among female firefighters using the Health of Women Firefighters (2013-2014).

Methods

Participants and Procedures

Data for this cross-sectional study are from the Health of Women Firefighters cross-sectional survey conducted in 2013 and 2014. A snowball sampling technique was used to identify potential female participants. Primary recruitment was achieved by contacting female participants from the research team's previous studies, through membership of iWomen (a national organization of females in the fire service), email recruitment from the Center for Fire, Rescue & EMS Health Research's email listserv, utilizing the email listserv Chief Billy Goldfeder's "Secret List," and requesting females who participated to solicit their fellow female colleagues for participation. Sampling procedures have been described in detail in Jahnke et al.[3].

Study protocols were approved by Institutional Review Boards (IRB) prior to onset of the study. Interested female firefighters were directed to a web-based survey developed by the investigators. Screening questions at the start of the survey ensured only career female firefighters were eligible to participate. A total of 1,817 female career firefighters responded to injury questions and 1,897 female firefighters responded to job stress questions. The initial page of the web-based survey served as the informed consent describing the study, the confidentiality of responses and providing contact information for the investigators and the IRB.

Measures

The study collected demographic (age, number of children under 18, history of health professional diagnosis of an anxiety disorder), health (height, weight), and occupational (job satisfaction, rank, years of service, having a job outside of fire service) information along with the following measures.

Injury

On-duty injury was assessed using questions from the National Health Interview Survey (CDC) and firefighter-specific questions from the National Institute of Standards and Technology[7, 8]. Firefighters were prompted with the following at the start of the injury section, "*The following questions are about injuries you have incurred in the past 12 months. An injury is anything for which you have or should have received medical care (by a physician or other medical professional) whether you reported the injury or not.*" Female firefighters indicated the number of on-duty injuries they had in the past 12 months and responses were dichotomized as no injuries or one or more injuries.

Job Stress

Job stress was assessed using the DOD Worldwide Survey[9] question, "*During the past 12 months, how much stress did you experience at work while carrying out your duties in the fire service?*". Firefighters selected, "*a lot*," "*some*," "*a little*," or "*none at all*."

Depression

Self-report history of depression diagnosis was assessed by the following question, "*Has a doctor or other healthcare provider EVER told you that you have a depressive disorder (including depression, major depression, dysthymia, or minor depression)?*"[10, 11]. Depression diagnosis was dichotomized based on history of health professional diagnosis of depression or not.

Statistical Analyses

Statistical analyses were performed using Stata version 15[12]. Chi-square analyses were used to determine the crude association between injury and each of the exposures: job stress, depression, anxiety, and job satisfaction. The exposures along with the potential confounders obesity, age, rank, years in fire service, having a second job, education, and having children

under age 18, were evaluated in a multivariable logistic regression model. The correlations between exposures were examined to determine if they could be included in a single model. Potential confounders, and model efficiency were evaluated using a backward elimination and 10% change in estimate approach. Age and rank were forced into the final model as confounders. Obesity was evaluated as an effect modifier due to its association with injury among male career and volunteer firefighters[5]. A multivariable logistic regression model was created with the confounders. The odds ratio, 95% CI, and p-value ($p<0.05$) were used to evaluate results for significance and model fit was explored.

Results

Overall, the average age of female firefighters was 40 years old and 14 years was the average years of experience in the fire service. The prevalence of obesity was about 14%. Approximately 45% of the women indicated an injury in the past 12 months and 21% indicated they had received a diagnosis of depression from a health care provider. About 28% of the total sample indicated a little job stress, 41% indicated some job stress, and 26% indicated a lot of job stress. Overall, female firefighters had a high prevalence of job satisfaction.

Female firefighter demographics stratified by injury prevalence are presented in Aim 3 Table 1. Female firefighters who did not incur an injury in the past 12 months had a slightly higher prevalence of optimism about their future in their department (88% vs 83%), and a slightly higher percentage of the uninjured would recommend being a firefighter to other women (91% vs 87%) than those who had an injury. The female firefighters who had an injury had a higher prevalence of a lot of job stress (31% vs 22%), depression (25% vs 18%) and anxiety (20% vs 13%) than those who did not have an injury.

In model building, years in the fire service was dropped due to collinearity with age. Obesity, having a second job, and having children under age 18 were also dropped during model building as they did not meet the 10% change in estimate criteria. Obesity was not an effect modifier between the psychosocial exposures and on-duty injury. In this cross-sectional study, female firefighters who had an injury over the past 12 months had more than double the odds (OR=2.24, 95% CI: 1.35, 3.74) of having a lot of job stress over the past 12 months verses no job stress compared to the uninjured (Aim 3 Table 2). In addition, the odds of having diagnosed depression was 1.35 (95% CI: 1.06, 1.74) for female firefighters with an injury compared to female firefighters without an injury.

Discussion

This is the first study to examine factors associated with on-duty injury among female career firefighters in a large epidemiologic study. Female firefighters indicated a much higher prevalence of on-duty injury than male career firefighters. Kaipust found 25% of male career firefighters experienced one or more on-duty injuries over the past six months to a year[5] while 45% of female career firefighters experienced an on-duty injury over the past year. The high prevalence of job stress and depression are associated with on-duty injury among this group of female career firefighters.

Female career firefighters had a higher prevalence of job stress than male career firefighters, including more than double the prevalence of a lot of job stress. Kaipust found 36% of male career firefighters reported a little job stress, 39% reported some, and 13% reported a lot of job stress[5]. This study found 28% of female firefighters indicated a little job stress, 41% indicated some job stress, and 26% indicated a lot of job stress. Korean female firefighters also reported more job stress on some subscales compared to males[13]. The odds of a lot of job stress

was 2.37 among female career firefighters with an injury compared to those with no injury. The odds of a little job stress versus no job stress among male career firefighters with an on-duty injury was 2.57 times more likely than among uninjured firefighters, the odds of some job stress was 2.52 times more likely, and the odds of a lot of job stress was 4.14 times more likely than uninjured firefighters[5]. Even though the prevalence of job stress was higher among females, the magnitude of the association between injury and job stress was lower than that in male career firefighters. This suggest there may be other factors, such as gear fit, sleep, and physical activity or fitness, driving the association with on-duty injury among females but not explored in this study.

In the US general population, the prevalence of lifetime depression is higher among females (11.7%) than males (5.7%), and is lower than the reported prevalence of 21% among female firefighters in this study[14]. The prevalence of health care provider diagnosed depression among female firefighters from this sample is similar to the 22% found using the CES-D-10 screening tool among 18 female career firefighters[2].

Kaipust found 15% of male career firefighters scored in the range of concern for depression using a screening tool for depression (CES-D-10) while this study found 21% of female firefighters had received a diagnosis of depression from a health care provider, a more conservative measurement than the CES-D-10[5]. A reciprocal causal relationship between Job stress and depression exists[15], so it is logical female career firefighters had a higher prevalence of depression than male career firefighters given the females reported higher job stress. Female firefighters who had an on-duty injury had greater odds (OR=1.47) of having been diagnosed with depression compared to uninjured female firefighters. Kaipust found male career firefighters who had an on-duty injury were 64% more likely to score in the area of concern for

depression versus not as compared to uninjured firefighters[5]. The odds of depression among injured female career firefighters compared to uninjured were slightly lower than the odds among male career firefighters.

Kaipust further stratified their analyses between injury, depression, and job stress by obesity among male career firefighters and found different associations with on-duty injury among the obese and non-obese[5]. Interestingly, the female results were not stratified or adjusted by obesity as the lower obesity prevalence among female firefighters was not found to be significant in the relationship with on-duty injury as it was in the males. The odds of depression and job stress among female firefighters who had an on-duty injury were lower in magnitude than among male firefighters but were still significant. This finding suggests there may be more important factors in association with on-duty injury among female firefighters not included in this analysis. Hulett et al. found nearly 80% of female firefighters reported ill-fitting equipment, compared to the 21% of male firefighters[1]. Future investigations should explore gear fit among female firefighters and its association with on-duty injury. In addition, future investigations should examine other factors such as sleep, exercise, discrimination and harassment, family stress, and also look into these associations with different types of injury (e.g. fireground, exercise, training).

This study has limitations to discuss. The data from this study was all self-report. However, self-report injury data can be more sensitive as it can collect information on injuries not severe enough to be reported to the department[16]. Depression was self-report history of health care provider diagnosis, which ensures females who reported depression had diagnosed depression, but may miss those who have not been diagnosed because they have not sought help. The studies amongst male firefighters used the CES-D ,which was self-report, but allows the

capture of depression of those who have not sought help. The history of ever being diagnosed with depression does not indicate whether the firefighter experienced depression in the past year when they were injured, and it is also possible depression came after injury. Height and weight were self-reported rather than measured. Self-report height and weight was highly correlated with measured height and weight among male career firefighters, but the correlation is unknown among female career firefighters[17]. Finally, this was a cross-sectional study, so only associations can be explored. However, there is evidence from other studies conducted among many occupational groups that depression and job stress are predictors of injury[15, 18].

Despite the limitations, this is the largest and only study among female career firefighters to explore associations with on-duty injury. This study provides a contribution to the small amount of literature on the health and safety of female firefighters, and underserved population, and identifies important avenues for future research in the area.

Conclusion

Female career firefighters have a higher prevalence of injury, depression, and job stress than male career firefighters. Female career firefighters with an on-duty injury had higher odds of reporting depression and a lot of job stress as compared to uninjured female career firefighters. Behavioral support programs are needed for all firefighters in the fire service, and these data support woman may need special attention. Future research on on-duty injury should examine associations with health behaviors, physical characteristics, workplace issues, and should aim to better understand factors associated with job stress.

Aim 3 Table 1: Characteristics of US Female Career Firefighters Stratified by Injury, Health of Women Firefighters (2013-2014)

	No Injury n=993 (54.7%) n (%)	One or More Injuries n=824 (45.3%) n (%)
Job Satisfaction		
Optimistic Future	852 (88.3)	668 (82.7)
Recommend Firefighting	882 (91.1)	699 (86.6)
Job Stress		
None at all	57 (5.8)	29 (3.5)
A Little	296 (29.9)	201 (24.5)
Some	415 (41.9)	334 (40.6)
A Lot	222 (22.4)	258 (31.4)
Depression		
Yes	176 (17.9)	208 (25.3)
Anxiety		
Yes	132 (13.4)	163 (19.9)
BMI[a]		
Not Obese	841 (85.4)	716 (87.5)
Obese	144 (14.6)	102 (12.5)
Rank[b]		
FF/Medic/Driver	680 (71.0)	561 (69.9)
LT/CPT/Chief	278 (29.0)	242 (30.1)
Second Job		
Yes	363 (37.9)	296 (37.0)
Education		
High School or Less	38 (4.0)	28 (3.5)
Some College	472 (49.0)	400 (49.8)
College/Grad Degree	453 (47.0)	376 (46.8)
Children		
Have children <18	360 (40.6)	314 (41.5)
	Mean (SD)	Mean (SD)
Age	40.0 (9.2)	40.5 (8.8)
Years of Service	13.6 (8.0)	13.6 (7.8)

[a]BMI not obese (18.5-29.9 kg/m^2) and obese (≥30 kg/m^2); [b]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any type of Chief; Missing: Optimistic Future (n=44); Recommend Firefighting (n=42); Job Stress (n=5); Depression (n=10); Anxiety (n=10); BMI (n=14); Rank (n=56); Second Job (n=58); Education (n=50); Children (n=173); Age (n=47); Years of Service (n=70)

Aim 3 Table 2: Logistic Regression for Injury on Job Stress and Depression among US Female Career Firefighters, Health of Women Firefighters (2013-2014)

	OR (95% CI)
Job Stress	
None	Ref.
A Little	1.42 (0.86, 2.37)
Some	1.62 (0.99, 2.65)
A Lot	**2.25 (1.35, 3.74)**[b]
Depression	
No	Ref.
Yes	**1.35 (1.06, 1.74)**
Anxiety	
No	Ref.
Yes	1.28 (0.97, 1.69)
Job Satisfaction	
Optimistic Future	
Agree	Ref.
Disagree	1.23 (0.92, 1.64)
Recommend Firefighting	
Agree	Ref.
Disagree	1.27 (0.92, 1.76)
Age Decade (years)	
<30	Ref.
30-39	1.26 (0.92, 1.71)
40-49	1.20 (0.87, 1.64)
50+	1.20 (0.83, 1.72)
Rank[a]	
FF/Medic/Driver	Ref.
LT/CPT/Chief	0.96 (0.76, 1.21)

[a]FF/Medic/Driver=Firefighter, Paramedic, Driver, or Operator and LT/CPT/Chief=Lieutenant, Captain, Any type of Chief; [b]bold indicates significance p-value<0.05

References

1. Hulett, D M, Bendick, M, Thomas, S Y and Moccio, F. *A National Report Card on Women in Firefighting.* International Association of Women in Fire & Emergency Services Madison, WI; 2008.

2. Jahnke, S A, Poston, W C, Haddock, C K, Jitnarin, N, Hyder, M L and Horvath, C. The health of women in the US fire service. *BMC Womens Health.* 2012;12:1.

3. Jahnke, S A, Poston, W S, Jitnarin, N and Haddock, C K. Maternal and child health among female firefighters in the US. *Matern Child Health J.* 2018:1-10.

4. Jahnke, S A, Poston, W S, Jitnarin, N and Haddock, C K. Health concerns of the US fire service: Perspectives from the firehouse. *American Journal of Health Promotion.* 2012;27:111-118.

5. Kaipust, C M. Total worker health on occupational injury among male and female, career and volunteer firefighters. 2018.

6. Murphy, S A, Beaton, R D, Cain, K and Pike, K. Gender differences in fire fighter job stressors and symptoms of stress. *Women Health.* 1995;22:55-69.

7. CDC. National health interview survey (NHIS). Retrieved from http://www.cdc.gov.utsph.idm.oclc.org/nchs/nhis.htm.

8. National Institutes of Standards and Technology (NIST). The economic consequences of firefighter injuries and their prevention. Final Report. 2005;NIST GCR 05-874.

9. Cohen, S, Kamarck, T and Mermelstein, R. A global measure of perceived stress. *J Health Soc Behav.* 1983:385-396.

10. CDC. 2010 BRFFSS questionnaire. 2009. Retrieved from http://www.cdc.gov.utsph.idm.oclc.org/brfss/questionnaires/pdf-ques/2010brfss.pdf.

11. Haddock, C K, Poston, W S, Jitnarin, N and Jahnke, S A. Excessive daytime sleepiness in firefighters in the central United States. *J Occup Environ Med.* 2013;55:416-423.

12. StataCorp. *Stata statistical software: Release 15*. College Station, TX: StataCorp LLC. 2017.

13. Kim, Y K, Ahn, Y S, Kim, K, Yoon, J H and Roh, J. Association between job stress and occupational injuries among korean firefighters: A nationwide cross-sectional study. *BMJ Open.* 2016;6:e012002-2016-012002.

14. Ford, D E and Erlinger, T P. Depression and C-reactive protein in US adults: Data from the third National Health and Nutrition Examination Survey. *Arch Intern Med.* 2004;164:1010-1014.

15. Leka, S, Jain, A. Health impact of psychosocial hazards at work: An overview. 2010. World Health Organization.

16. Pole, J D, Franche, R L, Hogg-Johnson, S, Vidmar, M and Krause, N. Duration of work disability: A comparison of self-report and administrative data. *Am J Ind Med.* 2006;49:394-401.

17. Poston, W, Jitnarin, N, Haddock, C, Jahnke, S and Day, R. Accuracy of self-reported weight, height and BMI in US firefighters. *Occupational Medicine.* 2014;64:246-254.

18. Tiesman, H M, Peek-Asa, C, Whitten, P, Sprince, N L, Stromquist, A and Zwerling, C. Depressive symptoms as a risk factor for unintentional injury: A cohort study in a rural county. *Inj Prev.* 2006;12:172-177.

Table 1: National Fire Protection Association Firefighter On-duty Injuries: Location, Cause, and Type, 2015.

	Total Number of Injuries (n=68,085)
Location	
Fire-ground	29,130
Non-fire emergency	14,320
Other activities	13,275
Training	7,560
Responding/returning from call	3,800
	Percentage of Total Injuries
Cause	
Fall/slip/jump	27%
Overexertion/strain	27%
Other	16%
Contact with object	7%
Exposure to fire products	8%
Struck by object	9%
Chemical/radiation exposure	3%
Extreme weather	2%
Type	
Strains/sprains	56%
Wound/cut/bleeding/bruise	15%
Other	14%
Thermal stress	4%
Burns (fire/chemical)	3%
Dislocation/fracture	3%
Smoke/gas inhalation	2%
Other respiratory distress	2%
Heart attack or stroke	1%
Burns & smoke inhalation	1%

NFPA, 2015 (Haynes & Molis, 2016)

CONCLUSION

The association between on-duty injury and sleep, physical activity, depression, and job stress among male career firefighters was modified by obesity. Among male volunteer firefighters, the association between on-duty injury and total work hours, sleep, and depression was modified by obesity. On-duty injury was significantly associated with depression and job stress among female career firefighters, and obesity did not modify this association, likely due to the low prevalence among female firefighters. The results of the study as a whole suggest the risk profile for on-duty injury is different among non-obese and obese, male career and volunteer firefighters. Further the risk profile for female career firefighter on-duty injury is different from that of males.

This study relied on self-report injury, sleep, physical activity, work hours and depression data, and the female data was entirely web-based self-report survey. In addition, because multiple studies were combined, the duration of the reference time frame for on-duty injury differed for male firefighters, subtypes of injury were unable to be explored among male and female firefighters, and the way sleep and total work hours were measured among male volunteer firefighters differed. Finally, this was a cross-sectional study, and it is possible sleep problems, depression, and job stress could have developed after the on-duty injury.

This study combined multiple large national cohort studies to examine injury among male career firefighters and male volunteer firefighters. This was the first study to examine predictors of on-duty injury among male volunteer firefighters and female career firefighters. Further, this was the first study to examine obesity as an effect modifier between on-duty

injury, health behaviors, and psychosocial factors among male career and male volunteer firefighters.

Future research should examine obesity as an effect modifier between on-duty injury and its predictors among male firefighters. Future research among female firefighters should examine the association of on-duty injury with health behaviors, gear fit, physical characteristics workplace issues, and stress. Healthcare professionals should discuss weight management with male firefighters and screen for sleep and mental health disorders. Fire departments looking to implement health and wellness programs should promote health sleep habits and provide optimal sleeping quarters, promote safe and effective physical activity and healthy eating, provide mental health resources, and reduce workplace stress at an organizational level.

APPENDICES

Appendix A: Letters of Support

UTHealth
The University of Texas
Health Science Center at Houston

School of Public Health
Division of Epidemiology, Human Genetics, and Environmental Sciences/
Southwest Center for Occupational and Environmental Health
Michael & Susan Dell Center for Healthy Living
R. Sue Day, MS, PhD

MEMORANDUM

DATE: 10/20/2017

TO: Christopher M. Kaipust, MPH

FROM: R. Sue Day, PhD
Principal Investigator

SIGNATURE: R. Sue Day

RE: PERMISSION FOR USE OF "Fuel 2 Fight" DATA WITHOUT PERSONAL IDENTIFIERS

TITLE: **Total Worker Health on Occupational Injury among Male and Female, Career and Volunteer Firefighters**

This letter is to authorize you to utilize a subset of the de-identified data from the Fuel 2 Fight Study for the purpose of the secondary analysis described in the dissertation proposal of the above title. Specifically, you have permission to

- Analyze the data of Fuel 2 Fight subjects expressly for your dissertation project. Data provided will be age, gender, race, height, weight, BMI, waist circumference, body fat %, physical activity, VO_{2max}, sleep, injury, work hours, rank, years in fire service, stress, job satisfaction, depression, and anxiety.
- Use this data only for the proposed analyses which will be provided without PERSONAL IDENTIFIERS.

I am the Principal Investigator for the study at SPH. Mr. Kaipust was a Graduate Research Assistant working on the project when the grant was active. This data was collected with the approval of an Institutional Review Board (IRB). A copy of the IRB approval notice is on file with the UT Health Science Center (UTHSC) Committee for the Protection of Human Subjects (CPHS) approval number HSC-SPH-10-0240. The project involved two FEMA funded grants and included collaborators at the National Development Research Institutes, Inc. (NDRI). The project was reviewed and approved by the NDRI IRB as well.

Phone 713.500.9317 | Fax 713.500.9329
Email rena.s.day@uth.tmc.edu
1200 Pressler | RAS Building, E1027 | Houston, TX 77030

UTHealth
The University of Texas
Health Science Center at Houston

School of Public Health
Division of Epidemiology, Human Genetics, and Environmental Sciences/
Southwest Center for Occupational and Environmental Health
Michael & Susan Dell Center for Healthy Living
R. Sue Day, MS, PhD

MEMORANDUM

DATE: 10/20/2017

TO: Christopher M. Kaipust, MPH

FROM: R. Sue Day, PhD
Principal Investigator

SIGNATURE: R. Sue Day

RE: PERMISSION FOR USE OF "The First Twenty for Volunteer Firefighters" DATA WITHOUT PERSONAL IDENTIFIERS

TITLE: **Total Worker Health on Occupational Injury among Male and Female, Career and Volunteer Firefighters**

This letter is to authorize you to utilize a subset of the de-identified data from The First Twenty Study for the purpose of the secondary analysis described in the dissertation proposal of the above title. Specifically, you have permission to

- Analyze the data of The First Twenty subjects expressly for your dissertation project. Data provided will be age, gender, race, height, weight, BMI, waist circumference, body fat %, physical activity, sleep, injury, work hours, rank, years in fire service, depression, and anxiety.
- Use this data only for the proposed analyses which will be provided without PERSONAL IDENTIFIERS.

I am the Principal Investigator for the study at SPH. Mr. Kaipust is a Graduate Research Assistant working on the project. This data was collected with the approval of an Institutional Review Board (IRB). A copy of the IRB approval notice is on file with the UT Health Science Center (UTHSC) Committee for the Protection of Human Subjects (CPHS) approval number HSC-SPH-14-0749. The project included collaborators at the National Development Research Institutes, Inc. (NDRI). The project was reviewed and approved by the NDRI IRB as well.

Phone 713.500.9317 | Fax 713.500.9329
Email rena.s.day@uth.tmc.edu
1200 Pressler | RAS Building, E1027 | Houston, TX 77030

NATIONAL DEVELOPMENT AND RESEARCH INSTITUTES, INC.

MEMORANDUM

DATE: 10/16/2017

TO: Christopher M. Kaipust, MPH

FROM: Sara A Jahnke, PhD
Principal Investigator

SIGNATURE: 

RE: PERMISSION FOR USE OF "FIRE" DATA WITHOUT PERSONAL IDENTIFIERS

TITLE: Total Worker Health on Occupational Injury among Male and Female, Career and Volunteer Firefighters

This letter is to authorize you to utilize a subset of the de-identified data from the FIRE Study for the purpose of the secondary analysis described in the dissertation proposal of the above title. Specifically, you have permission to

- Analyze the data of FIRE subjects expressly for your dissertation project. Data provided will be age, gender, race, height, weight, BMI, waist circumference, body fat %, physical activity, VO_{2max}, sleep, injury, work hours, rank, career/volunteer, years in fire service, stress, job satisfaction, depression, and anxiety.
- Use this data only for the proposed analyses which will be provided without PERSONAL IDENTIFIERS.

I am the Principal Investigator for the study at the National Development Research Institutes, Inc. (NDRI). This data was collected with the approval of an Institutional Review Board (IRB). A copy of the IRB approval notice is on file with the NDRI IRB approval number 611.

NDRI 71 West 23rd Street, 8th Floor · New York, NY 10010 · Tel: (212) 845-4400 · Fax: (917) 438-0894 · www.ndri.org
NDRI-Mid America 1920 143rd Street, Suite 120 Leawood, KS 66224 Tel: (913) 681-0300 Fax: (913) 681-0315

NATIONAL DEVELOPMENT AND RESEARCH INSTITUTES, INC.

MEMORANDUM

DATE: 10/16/2017

TO: Christopher M. Kaipust, MPH

FROM: Sara Jahnke, PhD
Principal Investigator

SIGNATURE: 

RE: PERMISSION FOR USE OF "Health of Women Firefighters" DATA WITHOUT PERSONAL IDENTIFIERS

TITLE: Total Worker Health on Occupational Injury among Male and Female, Career and Volunteer Firefighters

This letter is to authorize you to utilize a subset of the de-identified data from the Health of Women Firefighters Study for the purpose of the secondary analysis described in the dissertation proposal of the above title. Specifically, you have permission to

- Analyze the data of Health of Women Firefighters subjects expressly for your dissertation project. Data provided will be age, gender, race, injury, rank, years in fire service, stress, job satisfaction, depression, anxiety, family stress, firefighter self-efficacy, and work discrimination and harassment.
- Use this data only for the proposed analyses which will be provided without PERSONAL IDENTIFIERS.

I am the Principal Investigator for the study at the National Development Research Institutes, Inc. (NDRI). This data was collected with the approval of an Institutional Review Board (IRB). A copy of the IRB approval notice is on file with the NDRI IRB approval number 638.

NDRI 71 West 23rd Street, 8th Floor · New York, NY 10010 · Tel: (212) 845-4400 · Fax: (917) 438-0894 · www.ndri.org
NDRI-Mid America 1920 143rd Street, Suite 120 Leawood, KS 66224 Tel: (913) 681-0300 Fax: (913) 681-0315

REFERENCES

Brown, A. L., Wilkinson, M. L., Poston, W. S., Haddock, C. K., Jahnke, S. A., & Day, R. S. (2014). Adiposity predicts self-reported frequency of poor health days among male firefighters. *Journal of Occupational and Environmental Medicine / American College of Occupational and Environmental Medicine, 56*(6), 667-672. doi:10.1097/JOM.0000000000000163 [doi]

Carey, M. G., Al-Zaiti, S. S., Dean, G. E., Sessanna, L., & Finnell, D. S. (2011). Sleep problems, depression, substance use, social bonding, and quality of life in professional firefighters. *Journal of Occupational and Environmental Medicine, 53*(8), 928-933. doi:10.1097/JOM.0b013e318225898f [doi]

CDC. (2017). NIOSH total worker health. Retrieved from https://www.cdc.gov/niosh/twh/default.html

Choi, B., Dobson, M., Schnall, P., & Garcia-Rivas, J. (2016). 24-hour work shifts, sedentary work, and obesity in male firefighters. *American Journal of Industrial Medicine, 59*(6), 486-500. doi:10.1002/ajim.22572 [doi]

Damrongsak, M., Prapanjaroensin, A., & Brown, K. C. (2017). Predictors of back pain in firefighters. *Workplace Health & Safety, ,* 2165079917709020.

Dembe, A. E., Erickson, J. B., Delbos, R. G., & Banks, S. M. (2005). The impact of overtime and long work hours on occupational injuries and illnesses: New evidence from the united states. *Occupational and Environmental Medicine, 62*(9), 588-597. doi:62/9/588 [pii]

Di Milia, L., & Mummery, K. (2009). The association between job related factors, short sleep and obesity. *Industrial Health, 47*(4), 363-368.

Donovan, R., Nelson, T., Peel, J., Lipsey, T., Voyles, W., & Israel, R. G. (2009). Cardiorespiratory fitness and the metabolic syndrome in firefighters. *Occupational Medicine, 59*(7), 487-492.

Elliot, D., & Kuehl, K. S. (2007). *Effects of sleep deprivation on fire fighters and EMS responders* International Association of Fire Chiefs.

Fabio, A., Ta, M., Strotmeyer, S., Li, W., & Schmidt, E. (2002). Incident-level risk factors for firefighter injuries at structural fires. *Journal of Occupational and Environmental Medicine / American College of Occupational and Environmental Medicine, 44*(11), 1059-1063.

Griffin, S. C., Regan, T. L., Harber, P., Lutz, E. A., Hu, C., Peate, W. F., & Burgess, J. L. (2016). Evaluation of a fitness intervention for new firefighters: Injury reduction and economic benefits. *Injury Prevention : Journal of the International Society for Child and Adolescent Injury Prevention, 22*(3), 181-188. doi:10.1136/injuryprev-2015-041785 [doi]

Haddock, C. K., Poston, W. S., Jitnarin, N., & Jahnke, S. A. (2013). Excessive daytime sleepiness in firefighters in the central united states. *Journal of Occupational and Environmental Medicine / American College of Occupational and Environmental Medicine, 55*(4), 416-423. doi:10.1097/JOM.0b013e31827cbb0b [doi]

Haynes, H. J. G., & Molis, J. L. (2016). *Firefighter injuries in the united states-2015.* ().National Fire Protection Association.

Hulett, D. M., Bendick, M., Thomas, S. Y., & Moccio, F. (2008). *A national report card on women in firefighting* International Association of Women in Fire & Emergency Services Madison, WI.

Jackson, A. S., Blair, S. N., Mahar, M. T., Wier, L. T., Ross, R. M., & Stuteville, J. E. (1990). Prediction of functional aerobic capacity without exercise testing. *Med Sci Sports Exerc, 22*(6), 863-870.

Jackson, A. S., & Ross, R. M. (1997). *Understanding exercise for health and fitness* Kendall/Hunt Pub.

Jackson, A. S., Beard, E. F., Wier, L. T., Ross, R. M., Stuteville, J. E., & Blair, S. N. (1995). Changes in aerobic power of men, ages 25-70 yr. *Medicine and Science in Sports and Exercise*, *27*(1), 113-120.

Jackson, A. S., Wier, L. T., Ayers, G. W., Beard, E. F., Stuteville, J. E., & Blair, S. N. (1996). Changes in aerobic power of women, ages 20-64 yr. *Medicine and Science in Sports and Exercise, 28*(7), 884-891.

Jahnke, S., Poston, W., Haddock, C., & Jitnarin, N. (2013). Obesity and incident injury among career firefighters in the central united states. *Obesity, 21*(8), 1505-1508.

Jahnke, S. A., Poston, W. S., Jitnarin, N., & Haddock, C. K. (2012). Health concerns of the US fire service: Perspectives from the firehouse. *American Journal of Health Promotion, 27*(2), 111-118.

Jahnke, S. A., Poston, W. C., Haddock, C. K., Jitnarin, N., Hyder, M. L., & Horvath, C. (2012). The health of women in the US fire service. *BMC Women's Health, 12*(1), 1.

Jahnke, S. A., Poston, W. S., Haddock, C. K., & Jitnarin, N. (2013). Injury among a population based sample of career firefighters in the central USA. *Injury Prevention : Journal of the International Society for Child and Adolescent Injury Prevention, 19*(6), 393-398. doi:10.1136/injuryprev-2012-040662 [doi]

Jang, T., Kim, H., Lee, H., Myong, J., & Koo, J. (2013). Long work hours and obesity in Korean adult workers. *Journal of Occupational Health, 55*(5), 359-366.

Jurca, R., Jackson, A. S., LaMonte, M. J., Morrow, J. R., Blair, S. N., Wareham, N. J., . . . Jakicic, J. M. (2005). Assessing cardiorespiratory fitness without performing exercise testing. *American Journal of Preventive Medicine, 29*(3), 185-193.

Kim, Y. K., Ahn, Y. S., Kim, K., Yoon, J. H., & Roh, J. (2016). Association between job stress and occupational injuries among korean firefighters: A nationwide cross-sectional study. *BMJ Open, 6*(11), e012002-2016-012002. doi:10.1136/bmjopen-2016-012002 [doi]

Kuehl, K. S., Kisbu-Sakarya, Y., Elliot, D. L., Moe, E. L., Defrancesco, C. A., Mackinnon, D. P., . . . Kuehl, H. E. (2012). Body mass index as a predictor of firefighter injury and workers' compensation claims. *Journal of Occupational and Environmental Medicine / American College of Occupational and Environmental Medicine, 54*(5), 579-582. doi:10.1097/JOM.0b013e318249202d [doi]

Lemke, M., Hege, A., Perko, M., Sönmez, S., & Apostolopoulos, Y. (2015). Work patterns, sleeping hours and excess weight in commercial drivers. *Occupational Medicine, 65*(9), 725-731.

Lombardi, D. A., Folkard, S., Willetts, J. L., & Smith, G. S. (2010). Daily sleep, weekly working hours, and risk of work-related injury: US national health interview survey (2004–2008). *Chronobiology International, 27*(5), 1013-1030.

Lombardi, D. A., Wirtz, A., Willetts, J. L., & Folkard, S. (2012). Independent effects of sleep duration and body mass index on the risk of a work-related injury: Evidence from the US national health interview survey (2004–2010). *Chronobiology International, 29*(5), 556-564.

Luckhaupt, S. E., Cohen, M. A., Li, J., & Calvert, G. M. (2014). Prevalence of obesity among US workers and associations with occupational factors. *American Journal of Preventive Medicine, 46*(3), 237-248.

Lusa, S., Häkkänen, M., Luukkonen, R., & Viikari-Juntura, E. (2002). Perceived physical work capacity, stress, sleep disturbance and occupational accidents among firefighters working during a strike. *Work & Stress, 16*(3), 264-274.

Murphy, S. A., Beaton, R. D., Cain, K., & Pike, K. (1995). Gender differences in fire fighter job stressors and symptoms of stress. *Women & Health, 22*(2), 55-69.

National Fire Protection Association. (2006). NFPA 1582, standards on comprehensive occupational medicine programs for fire departments. (). Quincy, MA: NFPA.

National Institutes of Standards and Technology (NIST). (2005). *The economic consequences of firefighter injuries and their prevention. Final Report.* (No. NIST GCR 05-874). Gaithersberg, MD: US Department of Commerce and National Institute of Standards and Technology.

Poplin, G. S., Harris, R. B., Pollack, K. M., Peate, W. F., & Burgess, J. L. (2012). Beyond the fireground: Injuries in the fire service. *Injury Prevention : Journal of the International Society for Child and Adolescent Injury Prevention, 18*(4), 228-233. doi:10.1136/injuryprev-2011-040149 [doi]

Poplin, G. S., Roe, D. J., Burgess, J. L., Peate, W. F., & Harris, R. B. (2016). Fire fit: Assessing comprehensive fitness and injury risk in the fire service. *International Archives of Occupational and Environmental Health, 89*(2), 251-259. doi:10.1007/s00420-015-1068-4 [doi]

Poplin, G. S., Roe, D. J., Peate, W., Harris, R. B., & Burgess, J. L. (2014). The association of aerobic fitness with injuries in the fire service. *American Journal of Epidemiology, 179*(2), 149-155. doi:10.1093/aje/kwt213 [doi]

Poston, W. S., Haddock, C. K., Jahnke, S. A., Jitnarin, N., & Day, R. S. (2013). An examination of the benefits of health promotion programs for the national fire service. *BMC Public Health, 13*(1), 805.

Poston, W. S., Jitnarin, N., Haddock, C. K., Jahnke, S. A., & Tuley, B. C. (2011). Obesity and Injury-Related absenteeism in a Population-Based firefighter cohort. *Obesity, 19*(10), 2076-2081.

Poston, W. S., Haddock, C. K., Jahnke, S. A., Jitnarin, N., Tuley, B. C., & Kales, S. N. (2011). The prevalence of overweight, obesity, and substandard fitness in a population-based firefighter cohort. *Journal of Occupational and Environmental Medicine, 53*(3), 266-273. doi:10.1097/JOM.0b013e31820af362 [doi]

Reichard, A. A., & Jackson, L. L. (2010). Occupational injuries among emergency responders. *American Journal of Industrial Medicine, 53*(1), 1-11.

Smith, D. L., DeBlois, J. P., Haller, J. M., Lefferts, W. K., & Fehling, P. C. (2015). *Effects of heat stress and dehydration on cardiovascular function*. (). Saratoga, New York: First Responder Health & Safety Laboratory. Skidmore College.

Solovieva, S., Lallukka, T., Virtanen, M., & Viikari-Juntura, E. (2013). Psychosocial factors at work, long work hours, and obesity: A systematic review. *Scandinavian Journal of Work, Environment & Health, ,* 241-258.

Soteriades, E. S., Hauser, R., Kawachi, I., Christiani, D. C., & Kales, S. N. (2008). Obesity and risk of job disability in male firefighters. *Occupational Medicine (Oxford, England), 58*(4), 245-250. doi:10.1093/occmed/kqm153 [doi]

Sullivan, J. P., O'Brien, C. S., Barger, L. K., Rajaratnam, S. M., Czeisler, C. A., & Lockley, S. W. (2017a). Randomized, prospective study of the impact of a sleep health program on firefighter injury and disability. *Sleep, 40*(1)

Sullivan, J. P., O'Brien, C. S., Barger, L. K., Rajaratnam, S. M., Czeisler, C. A., Lockley, S. W., & Harvard Work Hours, Health and Safety Group. (2017b). Randomized, prospective study of the impact of a sleep health program on firefighter injury and disability. *Sleep, 40*(1), 10.1093/sleep/zsw001. doi:10.1093/sleep/zsw001 [doi]

Taris, T. W., Ybema, J. F., Beckers, D. G., Verheijden, M. W., Geurts, S. A., & Kompier, M. A. (2011). Investigating the associations among overtime work, health behaviors, and health: A longitudinal study among full-time employees. *International Journal of Behavioral Medicine, 18*(4), 352-360.

Tiesman, H. M., Peek-Asa, C., Whitten, P., Sprince, N. L., Stromquist, A., & Zwerling, C. (2006). Depressive symptoms as a risk factor for unintentional injury: A cohort study in a rural county. *Injury Prevention : Journal of the International Society for Child and Adolescent Injury Prevention, 12*(3), 172-177. doi:12/3/172 [pii]

Van der Hulst, M. (2003). Long work hours and health. *Scandinavian Journal of Work, Environment & Health,* , 171-188.

Walton, S. M., Conrad, K. M., Furner, S. E., & Samo, D. G. (2003). Cause, type, and workers' compensation costs of injury to fire fighters. *American Journal of Industrial Medicine, 43*(4), 454-458.

Wier, L. T., Jackson, A. S., Ayers, G. W., & Arenare, B. (2006). Nonexercise models for estimating VO2max with waist girth, percent fat, or BMI. *Medicine and Science in Sports and Exercise, 38*(3), 555-561. doi:10.1249/01.mss.0000193561.64152 [doi]