Sleep, Obesity, and Injury Among US Male Career Firefighters

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Objective: The aim of this study was to determine the role of obesity on the association between sleep and on-duty injury among male career firefighters. **Methods:** Data on 1419 male career firefighters for this cross-sectional study came from two firefighter cohorts from 2008 to 2013. On-duty injury within the past 6 to 12 months was the dependent variable and getting enough sleep was the independent variable. A multivariable, mixed effect logistic regression model stratified by body mass index (BMI) categories was created to examine the presence of effect measure modification. **Results:** Only obese firefighters who did not get enough sleep were twice as likely to have an on-duty injury than those who got enough sleep. This association was not significant among normal or overweight firefighters. **Conclusions:** Future studies into on-duty injury and sleep should examine body composition as an effect modifier among career firefighters.

Keywords: firefighter, injury, obesity, physical activity, sleep

The prevalence of body mass index (BMI)-defined overweight and obesity among male firefighters is alarmingly high at 80%, which 25 to 36% are obese.[1–3] In the US general population, the prevalence of overweight and obesity among adults is 70.7%, out of 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 also can 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]

Beyond obesity, investigations into other personal health factors, such as physical activity and exercise, associated with on-duty injury have been conducted across many occupations. 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 more serious non-exercise injuries.[7]

Long work hours, which can lead to decreased sleep quantity, also are associated with greater on-duty injury in firefighters and other occupations.[10,11] Sleep has been less explored than obesity and exercise with on-duty injury among firefighters. 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.[7,9,12] Investigations outside the fire service among US working adults report poor sleep and obesity are significant independent predictors of occupational injury.[13] The interaction between sleep and BMI on on-duty injury has not been examined in the fire service, a physically demanding occupation where poor sleep and obesity are both prevalent.

In 2016, 62,085 on-duty firefighter injuries were reported to the National Fire Protection Association (NFPA) during their annual survey.[14] 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.[6–8,14–16] Firefighters and emergency medical service personnel have higher risk of non-fatal injury than most other occupations.[15] Poston et al[8] estimated 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 $1682.90 per class II and III obese firefighter over the last year.

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. 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 1000 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) and the Fuel 2 Fight (F2F) studies. The longitudinal FIRE cohort study was conducted in the US Midwest from 2008 to 2010. Details of the sampling strategy and recruitment have been published.[2] There were 11 career and 13 volunteer departments ($N = 736$) in the International Association of Fire Chiefs Missouri Valley region states (Kansas, Missouri, Iowa, Nebraska, North Dakota, South Dakota, Colorado, and Wyoming) 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 sex comparisons.

The F2F study was a longitudinal cohort study conducted from 2010 to 2013. Detailed information on sampling strategy and recruitment have been published.[3] Briefly, 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

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Clinical Significance: Health care professionals should discuss weight management and sleep habits with male career firefighters to improve personal health and occupational health and safety, particularly on-duty injury.

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departments not implementing the WFI. Overall, 94.4% ($N = 1035$) 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 also were excluded.

In total there were 1419 eligible male firefighters for this analysis. Institutional Review Boards approved the FIRE and F2F study protocols prior to onset of the 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. Interested firefighters were consented in person using written consents for both studies. 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-reported demographic (age, race/ethnicity, education) and occupational (years in fire service, rank) 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.[17,18] 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. We are asking you a few questions about any injuries you might have sustained while you were working as a firefighter.'' 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

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 (less than 18.5 kg/m^2), normal weight (18.5 to 24.9 kg/m^2), overweight (25.0 to 29.9 kg/m^2), and obese (more than 30 kg/m^2).[19] 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, more than 102 cm).[19] Body fat percentage was measured using foot-to-foot bioelectrical impedance Tanita 300 and was dichotomized using CDC cut points (obese male, more than 25%).[19]

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 with waist circumference),[20] and its ability to distinguish normal, overweight, and obese firefighters.

Physical Activity and Fitness

The Self-Report of Physical Activity (SRPA) questionnaire used in FIRE and F2F measured physical activity pattern during the past 30 days.[21] Firefighters chose their physical activity patterns by selecting a response from a range from 0 (avoids walking or exertion) to 7 (more than 3 h/wk of vigorous activity). SRPA categories were collapsed to provide adequate cell sizes during analyses.

Fitness was measured using estimated VO_{2max} in a non-exercise model with SRPA, BMI, age, and sex.[3] Fitness was dichotomized into meeting NFPA fitness guideline of 12 metabolic equivalents or not.

Total Work Hours

Total work hours at the fire department and from employment outside the fire department 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 ''less than 50 hours per week,'' ''50 to 69 hours per week,'' ''70 to 89 hours per week,'' and ''more than or equal to 90 hours per week.''

Statistical Analyses

Statistical analyses were performed with Stata version 15 (StataCorp. College Station, TX).[22] 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% confidence interval (CI), and P-value ($P < 0.05$) were used to evaluate results for significance and model fit was explored.

RESULTS

Firefighter demographics are presented in 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 6 months to 12 months, and 56% of firefighters did not meet the NFPA fitness guideline of 12 metabolic equivalents. Crude injury prevalence stratified by BMI, sleep, and physical activity are presented in Table 2. The age-adjusted prevalence of injury was 247.51 per 1000 firefighters.

In model building, years in the fire service was dropped due to collinearity with age. In this cross-sectional study, male career firefighters who reported not getting enough sleep were 62% (odds ratio [OR]: 1.62; 95% CI: 1.21, 2.16) more likely to have had an on-duty injury in the past 6 to 12 months than those who reported getting enough sleep after adjusting for confounding (Table 3). Firefighters who reported vigorous physical activity more than 3 hours per week were 76% (OR: 1.76; 95% CI: 1.06, 2.92) more

TABLE 1. Characteristics of US Male, Career Firefighters, FIRE (2008 to 2010) and Fuel 2 Fight (2010 to 2013)

	Male Career Firefighters ($n = 1419$) n (%)
Injury	
≥1 injury	343 (25.11)
BMI[a]	
Normal	261 (18.6)
Overweight	710 (50.6)
Obese	433 (30.8)
Physical activity	
≤1 hr Moderate/wk	162 (12.2)
>1 hr Moderate/wk	203 (15.3)
≤1 hr Vigorous/wk	411 (31.0)
1–3 hr Vigorous/wk	284 (21.4)
>3 hr Vigorous/wk	265 (20.0)
Fitness[b]	
Meet NFPA	579 (43.8)
Don't Meet NFPA	743 (56.2)
Rank[c]	
FF/Medic/Driver	977 (72.5)
LT/CPT/Chief	371 (27.5)
Education	
High school or less	129 (9.5)
Some college	907 (67.2)
College/Grad degree	314 (23.3)
Minority	
White non-Hispanic	986 (72.4)
Minority	375 (27.6)
	Mean (SD)
Total work hours	68.2 (18.5)
Age, yr	38.8 (9.2)
Years of service	14.0 (8.6)

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 ($n = 64$).

[a]BMI normal weight (18.5 to 24.9 kg/m^2), overweight (25.0 to 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.

likely to have had an on-duty injury in the past 6 to 12 months than those who reported avoiding exertion.

Results from effect measure modification analyses necessitated presenting stratified results (Table 4). Among obese firefighters, the odds of on-duty injury was double among firefighters not getting enough sleep versus getting enough sleep. The odds of on-duty injury among normal weight firefighters not getting enough sleep was 1.59, and among overweight was 1.39, although neither were significant ($P > 0.05$). Obese firefighters with greater duration and intensity of physical activity had double to triple the odds of on-duty injury versus avoiding exertion. The association between on-duty injury and sleep appears to be modified by body composition, and obese firefighters who reported not getting enough sleep had the highest odds of on-duty injury.

DISCUSSION

Firefighters are an occupational group with one of the highest prevalence rates of obesity.[23] 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 with only a handful of studies 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.[12,24] A meta-analysis found individuals with obstructive sleep apnea (OSA), a sleep disorder, were twice as likely to report an occupational accident compared with workers without an OSA.[25] The Barger et al[26] investigation, included in the meta-analysis, found firefighters who screened positive for a sleep disorder were two times more likely to report a motor vehicle accident, a type of injury, than those who didn't screen positive for a sleep disorder.

The effect of BMI on injury and sleep had not been examined in the fire service, a physically demanding occupation where poor sleep and obesity are prevalent. This study found obese firefighters who did not get enough sleep had twice the odds of injury than obese firefighter who got enough sleep. 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[13] examination of sleep effects and BMI on injury risk among working adults in the United States found poor sleep and obesity were significant independent predictors of injury, but effect modification was not significant. 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, particularly obstructive sleep apnea.[27] The interaction between sleep and BMI on injury is biologically plausible in this occupation. Considering the proposed mechanisms for obesity and sleep on injury, the extra weight altering mechanics placing stress on soft connective tissues,[28] combined with fatigue due to poor sleep,[10,29–32] potentially places obese firefighters at high risk for impaired performance and safety.

Interestingly, significantly increased odds of greater duration and intensity physical activity versus avoiding exertion among firefighters indicating on-duty injury compared with those uninjured were only more likely among the obese. Jahnke et al[7] used only the

TABLE 2. Injury Prevalence Stratified by BMI,[a] Sleep, and Physical Activity (PA), FIRE (2008 to 2010) and Fuel 2 Fight (2010 to 2013)

	Normal Weight n (%)	Over-Weight n (%)	Obese n (%)	Enough Sleep n (%)	Not Enough Sleep n (%)	≤1 hr Moderate PA n (%)	>1 hr Moderate PA n (%)	≤1 hr Vigorous PA n (%)	1–3 hr Vigorous PA n (%)	>3 hr Vigorous PA n (%)
Injury ≥1	65 (25.6)	173 (25.0)	103 (25.1)	90 (19.6)	249 (28.2)	31 (19.1)	50 (24.9)	97 (23.8)	78 (27.6)	79 (29.8)

[a]BMI normal weight (18.5 to 24.9 kg/m^2), overweight (25.0 to 29.9 kg/m^2), and obese (>30 kg/m^2).

TABLE 3. Mixed Effects Logistic Regression for Injury on Sleep, FIRE (2008 to 2010), and Fuel 2 Fight (2010 to 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	
≤1 hr moderate	Ref.
>1 hr moderate	1.43 (0.84, 2.44)
≤1 hr vigorous	1.30 (0.80, 2.10)
1–3 hr vigorous	1.62 (0.98, 2.67)
>3 hr vigorous	**1.76 (1.06, 2.92)**
Total work hours	
<50 h/wk	Ref.
50–69 h/wk	0.93 (0.59, 1.46)
70–89 h/wk	0.85 (0.53, 1.35)
90+ h/wk	0.95 (0.55, 1.63)
Age, yrs	
<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 to 24.9 kg/m^2), overweight (25.0 to 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.

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. Long work hours were not associated with on-duty injury in this population of firefighters, which differs from previous findings among other populations.[10] This may be due to the uniqueness of the firefighting occupation and shift structures.

Results from this study have implications for health care professionals and fire departments looking to implement health and wellness programs. Brown et al[33] found overall 25% of firefighters reported receiving weight loss advice from a health care professional in the F2F cohort used in this study, and Wilkinson et al[34] found 48% of obese firefighters received no weight loss advice. 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. 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.[35] 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 United States and we are unaware of any major events impacting these study departments during the timeframe of the study. Injuries were dichotomized as 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. For sleep, usual sleep quality may not represent sleep quality at the time of injury. Finally, this is a cross-sectional study, so only associations between factors can be investigated, and it is possible an on-duty injury affected sleep and body composition.

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 with 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.

TABLE 4. Mixed Effects Logistic Regression for Injury on Sleep Stratified by BMI, FIRE (2008 to 2010), and Fuel 2 Fight (2010 to 2013)

	Normal Weight[a] OR (95% CI)	Overweight[a] OR (95% CI)	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			
≤1 hr moderate	Ref.	Ref.	Ref.
>1 hr moderate	1.73 (0.41, 7.23)	0.87 (0.39, 1.94)	**2.44** (1.03, 5.81)
≤1 hr vigorous	1.19 (0.34, 4.16)	0.81 (0.41, 1.60)	**2.49** (1.09, 5.68)
1–3 hr vigorous	1.29 (0.36, 4.57)	1.17 (0.59, 2.34)	**2.59** (1.05, 6.41)
>3 hr vigorous	1.64 (0.45, 5.90)	1.23 (0.62, 2.43)	**3.05** (1.12, 8.31)
Total work hours			
<50 h/wk	Ref.	Ref.	Ref.
50–69 h/wk	0.53 (0.20, 1.39)	1.27 (0.67, 2.43)	1.00 (0.44, 2.30)
70–89 h/wk	0.57 (0.21, 1.56)	1.06 (0.54, 2.08)	0.87 (0.37, 2.05)
90+ h/wk	0.27 (0.07, 1.09)	1.75 (0.83, 3.72)	0.72 (0.27, 1.93)
Age, yr			
<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 to 24.9 kg/m^2), overweight (25.0 to 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.

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