ORIGINAL ARTICLE

Randomized, Prospective Study of the Impact of a Sleep Health Program on Firefighter Injury and Disability

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Study Objectives: Firefighters' schedules include extended shifts and long work weeks which cause sleep deficiency and circadian rhythm disruption. Many firefighters also suffer from undiagnosed sleep disorders, exacerbating fatigue. We tested the hypothesis that a workplace-based Sleep Health Program (SHP) incorporating sleep health education and sleep disorders screening would improve firefighter health and safety compared to standard practice.
Design: Prospective station-level randomized, field-based intervention.
Setting: US fire department.
Participants: 1189 firefighters.
Interventions: Sleep health education, questionnaire-based sleep disorders screening, and sleep clinic referrals for respondents who screened positive for a sleep disorder.
Measurements and Results: Firefighters were randomized by station. Using departmental records, in an intention-to-treat analysis, firefighters assigned to intervention stations which participated in education sessions and had the opportunity to complete sleep disorders screening reported 46% fewer disability days than those assigned to control stations (1.4 ± 5.9 vs. 2.6 ± 8.5 days/firefighter, respectively; $p = .003$). There were no significant differences in departmental injury or motor vehicle crash rates between the groups. In post hoc analysis accounting for intervention exposure, firefighters who attended education sessions were 24% less likely to file at least one injury report during the study than those who did not attend, regardless of randomization (OR [95% CI] 0.76 [0.60, 0.98]; $\chi^2 = 4.56$; $p = .033$). There were no significant changes pre- versus post-study in self-reported sleep or sleepiness in those who participated in the intervention.
Conclusions: A firefighter workplace-based SHP providing sleep health education and sleep disorders screening opportunity can reduce injuries and work loss due to disability in firefighters.
Keywords: education, firefighters, sleep, injuries, disability.

Statement of Significance
Firefighters are exposed to many risk factors that can affect their sleepiness including long work shifts, arduous work and a high prevalence of undiagnosed sleep disorders. This randomized clinical trial shows that a Sleep Health Program, consisting of a mandatory educational session plus a voluntary sleep disorders screening, diagnosis and treatment program, can substantially reduce absences due to injury and disability and decrease reported injuries. A specific sleep health education and sleep disorders risk screening program should be incorporated into workplace health and wellness initiatives to reduce the physical, mental and economic burden of avoidable sleepiness-related workplace injuries in firefighters.

INTRODUCTION

Firefighters work demanding schedules under highly stressful and challenging conditions. The need to work frequent extended shifts and long work weeks leads to acute and chronic sleep deficiency as well as misalignment of circadian phase.[1] In addition, it is likely that a significant proportion of firefighters suffer from undiagnosed sleep disorders, which may further disturb sleep and exacerbate fatigue.[2] Sleep disorders are common, costly, and treatable, but often remain undiagnosed and untreated.[3] Our national survey of nearly 7000 firefighters, conducted across 66 fire departments, found that 37% of active firefighters were at risk of a primary sleep disorder when assessed using validated questionnaires, particularly obstructive sleep apnea (OSA), most of whom (81%) were undiagnosed.[4]

Since firefighter injuries and disability costs exact a human toll and financial burden on both firefighters and the communities whom they serve, we investigated the efficacy of a Sleep Health Program (SHP) on the risk of injury and use of disability time in firefighters.

Specifically, we used a station-level, randomized experimental design to test the hypotheses that implementation of an SHP will: (1) improve firefighters' health as assessed as fewer days of leave due to sickness/illness or injury/disability; (2) improve firefight safety assessed as (a) fewer on-the-job motor vehicle crashes and (b) fewer reported injuries.

MATERIALS AND METHODS

Fire Department Selection

We initially invited 73 departments to consider participating in our program based on department size and workload, and received expressions of interest from 32 departments. Interested departments were sent additional information and appointments were arranged with senior departmental, union, and wellness program representatives to discuss the program. Final selection was based on department cooperation, the practicalities of initiating the program, and the availability of departmental measures to use in analysis of program impact. We selected Columbus OH Division of Fire, a mid-sized fire department with 1211 active firefighters and 32 stations. The study was approved by the Partners Healthcare Human Research Committee and registered at ClinicalTrials.gov Identifier: NCT01988129. (Note, the ClinicalTrials.gov registration originally incorporated additional work [not directly related to this trial]. For clarity, we have now reverted

to describing only this original study in ClinicalTrials.gov and updated the entry accordingly.)

Cohort Selection and Station-Level Randomization

Stations were paired according to the previous calendar years' workload, number of employees, and general station type. Retrospective workload for the 54-week study period was captured by the number of equipment runs (ladder and engine) and medic runs per station. Following pairing, the number of firefighters and workload were compared between the two groups using paired Student's *t* tests. One station from each pair was then randomly selected to receive the SHP by the investigators. All personnel from the intervention stations were instructed to attend scheduled education sessions. Any firefighter present at the station was permitted to attend. Nominal scheduling operations for the fire department resulted in some spillover between personnel from control and intervention stations. Participation in education sessions was captured via sign-in sheets.

Intervention

The intervention consisted of three parts: (1) Mandatory Educational Sessions, (2) Voluntary Sleep Disorders Screening, and (3) Sleep Disorders Diagnosis and Treatment for those who screened at risk for a sleep disorder.

Mandatory Educational Sessions

Firefighters were scheduled to attend a mandatory 30-minute education training presentation centrally at fire department headquarters as operations allowed. These sessions were provided to firefighters over the last 2 weeks of August, as documented by a sign-in attendance sheet. Nearly all sessions (98%) were conducted by one investigator (CSO) and the remaining 2% by another (SWL). The session provided information on firefighter mortality, fatigue-related health hazards, and the physiological importance of sleep. The sleep health education also included strategies to improve sleep hygiene and tips on how to use caffeine and naps effectively to promote alertness. Eye masks and ear plugs were distributed to aid with sleep hygiene. This information was supplemented by distribution of brochures on various sleep health topics from the American Academy of Sleep Medicine and referral to the Harvard Division of Sleep Medicine education site: www.understandingsleep.org.

Voluntary Sleep Disorders Screening

Following the education, firefighters were invited and encouraged to complete a voluntary sleep disorders screening questionnaire. Prior to administration of the questionnaire, volunteers signed a research consent form. Participation was kept confidential; neither the department nor union was informed as to who completed the voluntary sleep disorders screening. This questionnaire used validated, self-report screening tools for OSA (Berlin Questionnaire; sensitivity 0.86, specificity 0.77),[5] moderate to severe insomnia (Athens Insomnia Scale; sensitivity 0.93, specificity 0.85),[6] and restless legs syndrome (Epidemiology, Symptoms, and Treatment Questionnaire; sensitivity 0.82, specificity 0.90).[7] For shift work disorder, we created a screening tool based on the International Classification of Sleep Disorders-2 diagnostic criteria.[8]

Sleep Disorders Diagnosis and Treatment

All of the respondents who screened positive for risk of any sleep disorder were notified by letter and provided with contact information for local American Academy of Sleep Medicine–certified, partnering sleep clinics. Participants were encouraged to use a sleep clinic partnering with the study but were free to seek medical follow-up elsewhere. Telephone calls were also made to all at-risk participants to ensure that they were aware of the results and to facilitate scheduling a sleep clinic appointment. Participants were asked to provide voluntary medical records release consent for tracking diagnoses.

Primary Outcome Measures

Health, safety, and performance outcomes were assessed cumulatively over the study period from departmental records.

Firefighter Health

The number of 24-hour pay periods coded as "sick" time per firefighter and the number of 24-hour pay periods coded as injury/disability per firefighter were assessed from payroll records. Fewer leave days lost to sickness/illness or injury/disability were considered indicative of better health. Only leave days occurring after study initiation were included in these analyses. Contiguous long-term disability days that began before study start were excluded.

Firefighter Safety—Motor Vehicle Crashes

Accidents were counted as any incident that resulted in the filing and review of a department Fleet Accident Report. Fewer accidents were considered indicative of better safety. Only Fleet Accident Reports made after study initiation were included in these analyses.

Firefighter Safety—Injuries

On-the-job injuries that triggered the filing of an official city government injury report as the result of following normal departmental procedures were included in this study. Fewer injury reports were considered indicative of better safety. Only injury reports made after study initiation were included in these analyses.

Firefighter Performance—Response Time

Following detailed review of departmental procedures and records, we determined that "turn-out time" was already very rapid and not considered an accurate measure of firefighters' performance by the department. Clearance time (time from the start until the end of the event), which could last for many hours, was also not considered an appropriate measure of firefighters' performance in relation to sleep and alertness given the multiple factors, many of which are not under the control of the firefighters, that could affect clearance times. Similarly, we intended to collect additional data on cognitive performance but found that it was impractical to do so in this operational environment. We therefore did not address firefighter performance.

Baseline and End-of-Year Surveys

All individuals in the intervention stations were invited to complete a voluntary survey at the start of the study in conjunction with the

education and sleep disorders screening intervention. Firefighters in the control group were not asked to complete the survey in order to ensure that any engagement with the study did not influence their behavior. These surveys provide comparative data pre- versus post-intervention to examine whether the program significantly improved sleep and general health. The baseline education and survey data were collected in the last 2 weeks of August 2009. Year-end surveys were collected from August through October 2010. Database measures encompass data from mid-August 2009 to September 2010. Sleep clinic follow-up records collection was completed in August 2013. We had intended to collect additional survey data to assess changes in firefighters' and families' job satisfaction but, due to unanticipated additional work in gathering the primary outcomes, we were unable to do so.

Data Analysis

Data are reported as mean ± *SD* unless noted otherwise. Comparisons between the control and intervention group for primary outcomes used unpaired Student's *t* tests assuming equal variances. Disability days also used a hierarchical mixed model to allow for possible station-level pairing correlation. In addition, a negative binomial regression was used to evaluate disability days due to overdispersion and high percentage of firefighters reporting zero disability use. Chi-square Fisher's exact tests were used to compare the gender and race between the control and intervention groups. Post hoc odds ratios were calculated to compare risk of reported injuries across those who did or did not attend the educational sessions. For survey outcomes, paired Student's *t* tests were used to compare pre- versus post-intervention outcomes. Statistical analyses were conducted using SAS for Windows (ver. 9.4, SAS Institute Inc., Cary, NC).

Our study was powered assuming 500 firefighters per group, 90% power, and a two-sided alpha of 0.05. For our primary departmental database outcomes (injury and motor vehicle crash rates), we had the power to detect a 25% reduction in crash rates or injury rates. For sleep duration, we had the power to detect a 10% difference in weekly sleep hours.

RESULTS

Based on retrospective departmental data for 2008 prior to study start, the control and intervention stations showed no significant difference in the number of firefighters (mean ± *SD*; 41.5 ± 15.9 vs. 38.4 ± 10.5 firefighters/station for control and intervention stations, respectively; $p = .15$), the number of equipment (ladder and engine) runs (3193.1 ± 1602.9 vs. 3361.1 ± 1610.2 equipment runs/station for control and intervention stations, respectively; $p = .25$), or medic runs (3254.8 ± 1369.0 vs. 3478.9 ± 1341.0 medic runs/station for control and intervention stations, respectively; $p = .15$). Similarly, during the months comprising the 54-week study period, there were no significant differences in the number of equipment (ladder and engine) runs (mean ± *SD*; 3288.8 ± 1557.2 vs. 3889.5 ± 1583.5 equipment runs/station for control and intervention stations, respectively; $p = .49$) or medic runs (3506.6 ± 1437.9 vs. 3726.3 ± 1426.0 medic runs/station for control and intervention stations, respectively; $p = .18$; all paired Student's *t* test).

The final cohort of 1189 firefighters represents 98% (1189/1211) of the active firefighters in the participating fire department at the time that the study was implemented. Of the 601 firefighters assigned to stations in the intervention group, 542 (90.2%) participated in one of 52 sleep education sessions provided to firefighters over a 2-week interval, as documented by sign-in attendance sheets (Figure 1). The cohort consisted predominately of white males with a mean age of 43.6 years (Table 1). The intervention group was slightly younger (42.7 vs. 44.4 years; $p < .0001$) on average as compared to the control group. There were no differences in gender (Fisher's exact $p = .208$) or race (Fisher's exact $p = .367$).

Departmental Database Measures

In terms of exposure to possible injury, firefighters stationed at intervention stations had one or two more 24-hour work shifts on average over the year as compared to firefighters in control stations (101.1 ± 15.2 vs. 99.7 ± 17.3, respectively; $p = .120$). Intervention firefighters had 4% more run/call deployments over the year on average than the non-intervention group (552.3 ± 286.2 vs. 531.9 ± 269.8, respectively; $p = .208$).

At the start of the study (baseline; mid-August–September 2009), there were no significant differences in the 24-hour pay periods coded as injury disability per firefighter between the firefighters assigned to the control and intervention stations (control 0.03 ± 0.4 vs. intervention 0.04 ± 0.5; $p = .820$). Over the entire 12-month study period, however, these departmental payroll records showed that non-intervention station firefighters averaged nearly double the number of 24-hour pay periods coded as injury and disability per firefighter than the intervention group (2.6 ± 8.5 vs. 1.4 ± 5.9 days/firefighter; $F(1,1157) = 8.79$; $p = .003$; Figure 2). On average there was a small significant difference in age, however, adding age as a covariate did not alter the outcomes. Seasonal variations in disability were not different between intervention and control stations (Figure 3A) and the benefits of the intervention were sustained over the study period (Figure 3B). The distribution of disability days across firefighters (Figure 3C) illustrates that a small number of firefighters in one group were not biasing the results. The intervention stations had 532/601 (89%) of their firefighters without any recorded disability days and the control stations had 497/588 (85%). After excluding those firefighters without disability days, the result remained significant; mean 16.96 ± 15.14 versus 11.91 ± 13.60 days/firefighter; $p = .031$, Student's *t* test. The medians were 12 and 6, respectively. Furthermore, a general linear model regression to account for overdispersion, assuming a negative binomial distribution, showed a significant difference between groups (Wald $\chi^2 = 4.61$; $p = .032$). There was no significant difference in the average number of sick days per firefighter reported between the two groups (3.2 ± 4.5 vs. 3.1 ± 4.3 days/firefighter; $p = .660$).

City government injury reports filed during the study period showed a marginally higher average number of injuries per firefighter in the control group (0.40 ± 0.63 vs. 0.37 ± 0.63 injury reports/firefighter; $p = .31$). In post hoc analysis accounting for exposure to the intervention, however, firefighters who attended education sessions (160/400) were 24% less likely to file at least one official injury report during the study duration than those firefighters who did not attend (216/413) regardless of randomization (OR [95% CI] 0.76 [0.60, 0.98]; $\chi^2 = 4.56$; $p = .033$).

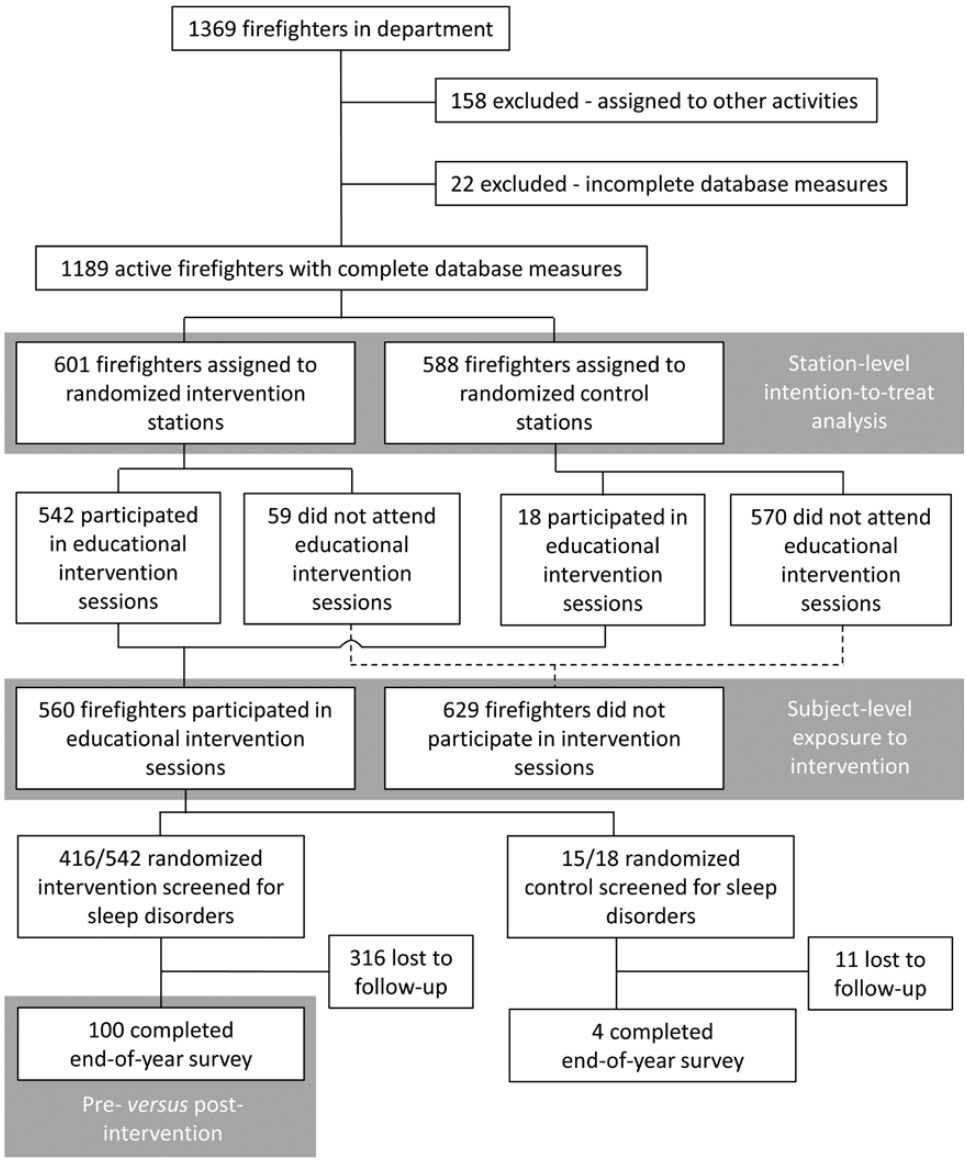

Figure 1—Participant disposition diagram.

Departmental records of fleet vehicle accidents showed that there were a total of 125 incidents reported during the entire study and there was no significant difference in the rate of incidents between the intervention and control groups (0.11 ± 0.35 incidents/firefighter vs. 0.10 ± 0.31 incidents/firefighter, respectively; $p = .87$).

Baseline and End-of-Year Surveys

In within-subject paired *t* test analyses of firefighters from intervention stations who participated in the program, completed both the pre- and post-study survey, and had at least 1 week of work scheduled in the 4 weeks prior to the survey, we did not find any significant differences in self-reported sleep duration or attentional failures while on the telephone, while driving, or while stopped in traffic between the pre- and post-study assessments (Table 2). Similarly, self-reported general health did not change significantly between the pre- and post-study survey (Table 2).

Sleep Disorders Screening, Diagnosis, and Treatment

In addition to sleep health education, the SHP included the opportunity for firefighters to be screened for sleep disorders. Most firefighters who attended the education sessions chose to complete the voluntary sleep disorders screening questionnaire (431/560; 77%) which may represent a measure of the feasibility and acceptability of the occupational SHP. 179/431 (42%) screened positive for one or more sleep disorders and were referred for clinical follow-up (Table 3). Of the 179 referred, 40 (22%) of these firefighters went on to seek medical evaluation at the partnering sleep disorders clinic and 37/40 (93%) were diagnosed with at least one sleep disorder. Records from firefighters who sought treatment at clinics not partnering with the study were not available. 104/431 firefighters who completed the sleep disorders screening also completed a follow-up end-of-year survey. Thirty-seven of these end-of-year respondents had screened positive for one or more sleep disorders 12 months earlier. Sixteen of the 179 positive screen respondents

Table 1—Demographic Information on the Firefighter Department and Study Cohorts.

	Cohort	Control	Intervention	Screened
Firefighters, *n*	1189	588	601	431
Age[a], years mean ± *SD* (range)	43.6 ± 7.4 (22–72)	44.4 ± 7.4 (25–72)	42.7 ± 7.3 (22–65)	42.7 ± 7.4 (22–62)
Gender[b], *n* (%)				
Women	16 (1.3)	5 (0.8)	11 (1.8)	9 (2.1)
Men	1173 (98.7)	583 (99.2)	590 (98.2)	422 (97.9)
Race[b], *n* (%)				
White	1081 (90.9)	540 (91.8)	541 (90.0)	398 (92.3)
Black	85 (7.1)	40 (6.8)	45 (7.5)	24 (5.6)
Hispanic	6 (0.5)	2 (0.3)	4 (0.7)	3 (0.7)
Asian	4 (0.3)	3 (0.5)	1 (0.2)	1 (0.2)
Native American	4 (0.3)	1 (0.2)	3 (0.5)	1 (0.2)
Bi-racial	9 (0.8)	2 (0.3)	7 (1.2)	4 (0.9)

These were the categories provided by the fire department.

[a]Control versus intervention unpaired *t* test $p < .0001$.

[b]Control versus intervention Fisher's exact gender $p = .207$ and race $p = .367$.

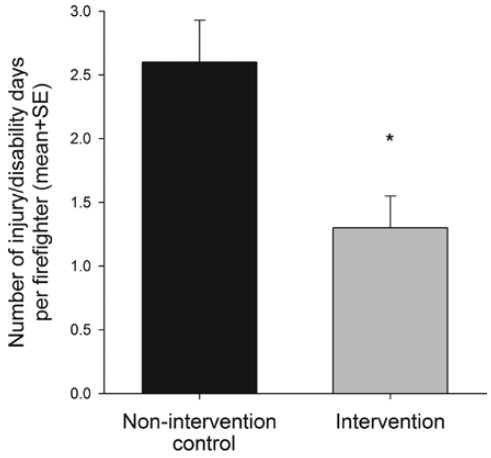

Figure 2—Departmental payroll records revealed that non-intervention firefighters ($n = 588$) averaged double the number of 24-hour pay periods per firefighter coded as injury/disability than the intervention group ($n = 601$) (mean ± *SE*, $*p = .003$).

for whom we have an end-of-year survey indicated they sought clinical evaluation for a sleep disorder, 12 at the partnering clinic and 4 elsewhere.

DISCUSSION

This study is the first randomized prospective trial to demonstrate a reduction in risk of injury and disability through implementation of an SHP. In an intention-to-treat analysis, firefighters assigned to intervention stations which participated in education sessions and had the opportunity to complete sleep disorders screening reported 46% fewer disability days on average than those assigned to control stations. Furthermore, when analyzed with respect to intervention exposure, firefighters who attended education sessions were 24% less likely to file at least one official injury report during the study duration than those firefighters who did not attend. Our findings therefore suggest that a firefighter workplace-based wellness program providing sleep health education and sleep disorders screening opportunity can reduce injuries and subsequent work loss due to disability in firefighters.

The finding that 42% (179/431) of the firefighters in this cohort screened positive for one or more sleep disorders is comparable to that reported in a larger nationwide cohort that included these firefighters, in which 37% of firefighters screened positive for a sleep disorder.[4] The reasons for the high prevalence include standard risk factors, such as age and body mass index,[9,10] but also other factors more highly associated with firefighters, such as hypertension.[11] Of concern, in this cohort, we found that at baseline, only 16.3% (22/135) of those who had screened positive for OSA reported being treated, consistent with the low rate of diagnosis of sleep disorders in the general population. It is well established that untreated sleep disorders carry a high risk of cardiovascular disease and metabolic disorders,[12] as well as a high risk of drowsy driving crashes[13] and therefore programs to identify and treat these disorders are likely to be beneficial to both short-term safety and long-term health, and occupational groups provide a convenient avenue through which diagnosis, treatment, and health can be promoted.

In terms of risk factors for fatigue, in addition to sleepiness associated with untreated sleep disorders, firefighters in this cohort were routinely scheduled to work 24-hour shifts in a recurring sequence of 24 hours on duty, followed by 48-hours off duty. While 24- or even 48-hour duty shifts are common among US fire departments,[14] such extended duration shifts have been shown to increase the risk of sleepiness, burnout, injuries, and errors when compared to shorter shifts (≤16 hours) in resident physicians[15–19] and first responders such as emergency medical technicians.[20]

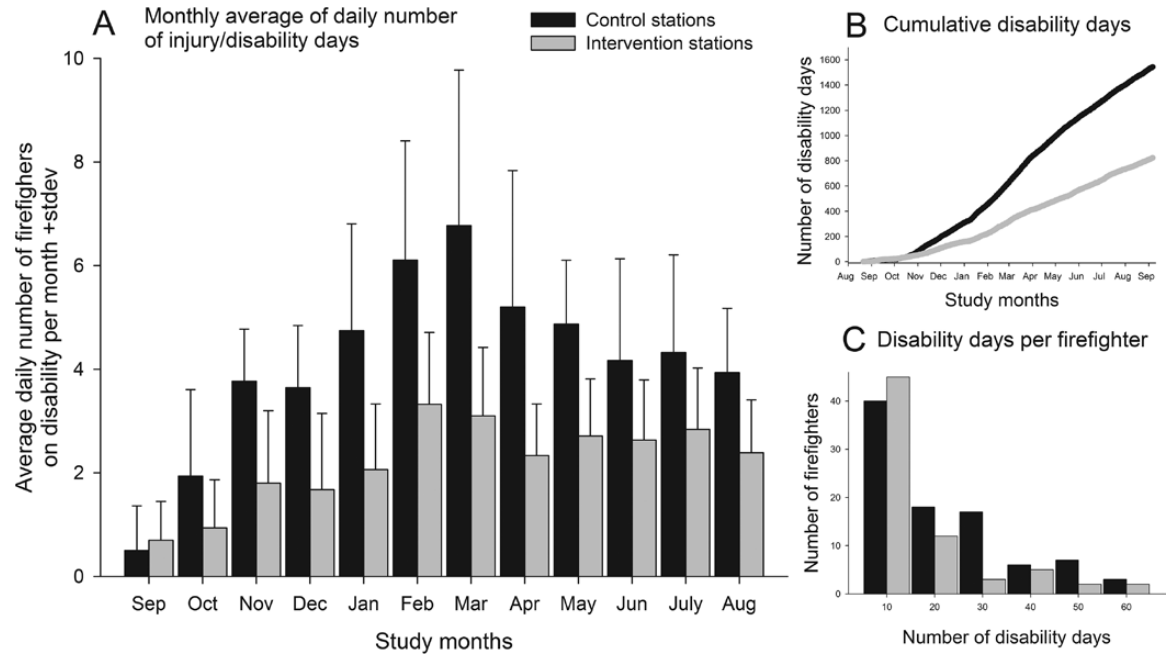

Figure 3—Panel A shows the average daily number of firefighters on disability per month of the study to illustrate that seasonal variations were not different between intervention and control stations. Panel B shows the cumulative number of total disability days between the intervention and control stations. Panel C shows the distribution of disability days across firefighters for the intervention and control stations.

Notwithstanding the high risk of fatigue under such circumstances, we found that implementation of an education and sleep disorders screening program significantly reduced the percentage of firefighters who filed an injury report, such that 12% fewer firefighters who participated in the education intervention reported an injury than those who did not in the subsequent 12 months. Consistent with the proposed health and safety benefits of our program, it also succeeded in reducing reported injuries by 10% per annum, reducing the percentage of firefighters injured by 17% and was accompanied by a 46% decrease in the utilization of paid disability time among firefighters, a substantial impact.

In addition to the considerable human toll of injuries, there are also financial costs. Firefighter injuries in the United States cost an estimated $4.70 to $11.73 billion annually[21] (cost estimates are expressed in 2013 dollars, adjusted from original sources for inflation using the Bureau of Labor Statistics Consumer Price Index Inflation Calculator [www.bls.gov/data/inflation_calculator.htm]), which adds substantially to the $43.81 billion in direct expenditures paid each year for fire protection.[22] In this department of approximately 1200 active firefighters alone, the reduction in disability day usage observed in the sleep health intervention cohort would translate into annual direct payroll savings of $2.1 million (cost estimates associated with missed disability days were calculated using a national hourly rate times the missed number of hours plus the cost of replacing absentee firefighters at time and a half[23]) based on the 2012 firefighter national median pay of $21.75 per hour,[24] and not including the additional and likely substantial direct medical costs or indirect costs associated with the disability.

We found no other published study that evaluated the impact of a health-related intervention on firefighter injuries using a randomized, prospective, parallel group clinical trial design (ClinicalTrials.gov Identifier: NCT01988129), and none that evaluated a sleep health–related intervention. Our results compare favorably, however, with those from the retrospective Promoting Healthy Lifestyles: Alternative Models' Effects (PHLAME) study on behavioral change models focusing on nutrition, physical activity, and cardiorespiratory fitness in firefighters.[25] In this retrospective analysis, a sustained reduction in both workers' compensation claims and medical costs was observed in PHLAME-participating departments, compared with matched departments that did not participate.[26] Similarly, a prospective, but not randomized, study of the implementation of a Physician-Organized Wellness Regime reported a 40% reduction in recordable injuries during the first year.[27] Not all workplace-based intervention programs are successful in reducing injuries, however. Poston et al. recently reported on data collected from 10 purposively sampled fire departments that implemented health promotion measures consistent with the Wellness Fitness Initiative developed by the International Association of Fire Firefighters (IAFF) and the International Association of Fire Chiefs (IAFC) and compared them with 10 fire departments that did not implement such programs. While firefighters in the intervention departments were healthier in a number of dimensions as compared with those in the standard departments, Poston et al. reported that firefighters in departments that implemented the IAFF/IAFC–compliant wellness programs were 63% more likely to have an injury of sufficient severity to report to workers' compensation.[28]

While fatigue risk management programs are commonly implemented in other occupational settings, there is limited empirical evidence on their impact. A fatigue management program for nurses, including sleep health education and encouragement of napping during breaks or meal times, resulted in significant

Table 2—Summary of All Outcomes.

Primary department level measures				
Between subjects	**Intervention**	**Control**	***p*[b]**	***p*[d]**
n	601	588		
Health "sick" days	3.1 (4.3)	3.2 (4.5)	0.659	0.683
Health "injury/disability" days	1.4 (5.9)	2.6 (8.5)	0.003	0.003
Safety motor vehicle crashes	0.11 (0.35)	0.10 (0.31)	0.886	0.863
Safety injuries	0.37 (0.63)	0.40 (0.63)	0.312	0.434
Performance—response time	x	x	x	x
Secondary survey measures				
Within subjects—intervention only	**Study start**	**Post-study**	***p*[c]**	***n***
Mean total sleep time (h/week)[a]	44.84 (7.05)	45.98 (6.48)	0.218	62
Alertness—sleep during meetings (incidents/month)[a]	0.41 (1.39)	0.30 (0.78)	0.648	27
Alertness—sleep on phone (incidents/month)[a]	0.06 (0.38)	0.05 (0.26)	0.708	88
Alertness—sleep while driving (incidents/month)[a]	0.22 (0.63)	0.14 (0.65)	0.310	81
Alertness—sleep while stopped in traffic (incidents/month)[a]	0.21 (0.72)	0.09 (0.36)	0.159	82
Health—general health	3.73 (0.82)	3.68 (0.81)	0.458	97
Family—job satisfaction	x	x	x	x

All values are mean (*SD*).
[a]Per firefighter. [b]Paired *t* test.
[c]Paired *t* test.
[d]Mixed model adjusted for station pairs.

improvement in self-reported sleep duration, sleep quality, and error prevention.[29] Most recently, a large-scale occupational program in truckers showed that truck drivers with untreated OSA had a five times higher rate of preventable crashes than those truck drivers who were not diagnosed with OSA,[30] suggesting that a sleep disorders screening and treatment program[31] could have a high impact on driver and public safety.

There were several limitations to our study. Although randomized, a double-blind design was not possible in this field study; however, as the outcomes were derived from standard departmental records rather than study participants, we believe it unlikely that knowledge of group assignment influenced the incidence of long-term disability between the groups. While there were no significant differences in outcomes at study initiation, a longer period of baseline data collection prior to study initiation may have alleviated concerns about any inherent differences between groups in this regard. Second, as expected due to the practice of trading shifts and routine temporary re-assignments based on operational needs, some mixing occurred between firefighters assigned to the randomized intervention and control stations. As a result, 59 firefighters assigned to intervention stations did not attend an education session and 19 firefighters assigned to control stations did attend an education session. We do not believe such mixing impacted our conclusions, as (1) the 78 affected firefighters represent only a small fraction (6.4%) of the cohort and (2) we subsequently accounted for such temporary station reassignments by basing our analyses on those firefighters who attended an education session versus those who did not, as shown in Figure 1. An additional limitation is the low response rate to the end-of-year survey which reduced our power to detect changes in self-reported sleep and behavior in those who participated in the program. Given that none of these outcomes were significant, however, any bias due to the low numbers may have resulted in underestimating the impact of the program. It would have been desirable, in retrospect, to collect more detailed data on the potential mechanism by which the program impacted the injury rate, for example through changes in sleep behavior tracked by sleep logs or actigraphy. We were also unable to measure the impact of the program on firefighters' and families' job satisfaction, or firefighter performance, due to reallocation of resources or finding that our approach was impractical in an operational setting. Further work is therefore needed to examine the broader impact of such a program beyond disability days and injuries. Finally, we have limited knowledge of sleep disorder diagnosis, treatment, and compliance after an individual firefighter was advised of screening positive for a sleep disorder. Many, but not all, firefighters provided permission to access medical records at the accredited sleep clinic partnering with our study, and some firefighters chose to follow-up at clinics not connected with our study. Further research is also required to replicate and expand these results in other fire departments to assess the generalizability of the findings, including efforts to determine the relative contribution and mechanism of action of each component of the program to observed safety improvements and how to increase adherence to sleep disorders treatment among firefighters after screening positive for risk of a sleep disorder. One possible way to increase adherence would be to include sleep disorders screening in mandatory

Table 3—Sleep Disorders Screening Outcomes and Self-reported Demographics.

No. of respondents	**431**[a]					
Any sleep disorder						
Positive	179 (41.5)		Any sleep disorder		Obstructive sleep apnea	
Negative	251 (58.2)		Positive	Negative	Positive	Negative
Not known	1 (0.2)	*n*	179	251	135	283
Obstructive sleep apnea		Age[b]	43.2 ± 7.7 (26–63)	42.9 ± 7.2 (22–61)	44.1 ± 7.7 (28–63)	42.5 ± 7.2 (22–61)
Positive	135 (31.3)					
Negative	283 (65.7)	Employed[b]	15.9 ± 8.0 (1–37.5)	15.4 ± 7.4 (1–36.7)	16.8 ± 7.9 (1–37.5)	14.9 ± 7.4 (1–36.7)
Not known	13 (3)					
Insomnia		Sex[a]				
Positive	33 (7.7)	Women	4 (2.2)	4 (1.6)	2 (1.5)	6 (2.1)
Negative	391 (90.7)	Men	170 (95.0)	239 (95.2)	129 (95.6)	268 (94.7)
Not known	7 (1.6)	Not known	5 (2.8)	8 (3.2)	4 (3.0)	9 (3.2)
Restless legs syndrome						
Positive	15 (3.5)	BMI[a]				
Negative	400 (92.8)	<25	11 (6.1)	45 (25.1)	4 (3.0)	50 (17.7)
Not known	16 (3.7)	≥25 and <30	67 (37.4)	150 (83.8)	35 (25.9)	177 (62.5)
Shift work disorder		≥20 and <35	76 (42.5)	48 (26.8)	71 (52.6)	49 (17.3)
Positive	40 (9.3)	≥35	24 (13.4)	8 (4.5)	24 (17.8)	7 (2.5)
Negative	337 (78.2)	Not known	1 (0.6)	0 (0.0)	1 (0.7)	0 (0.0)
Not known	54 (12.5)					

BMI = body mass index.
[a]*n* (%).
[b]Years, mean ± *SD* (range).

occupational health physical exams where they already exist. We have also recently shown that an SHP is feasible and effective in increasing firefighter knowledge of sleep health and improving sleep health behaviors, whether delivered by experts, in a "train-the-trainer" format or online.[32]

Fatigue-related accidents and injuries are often underestimated yet contribute substantially to workplace health and safety risk. Sleep and fatigue-related factors are therefore a promising avenue to reduce avoidable workplace injuries. Our study demonstrates that a workplace sleep health education and sleep disorders risk screening can reduce injuries and disability in firefighters and has important public policy implications for the fire service and other occupational groups. A targeted sleep health intervention program thus holds promise for reducing the substantial morbidity and mortality associated with firefighter injury and should be considered as an addition to the Wellness Fitness Initiative standards promulgated by the IAFF/IAFC in order to reduce firefighter injury and associated disability costs.

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JPS and CSB reports no conflicts of interest. LKB has previously received research support from Cephalon, NFL charities, Sysco, and San Francisco Bar Pilots. She has received consulting/lecture fees or served as a board member for Alertness Solution, Ceridian, Davis Joint Unified School Board, San Jose State University Foundation, Puget Sound Pilots, Sygma, and Torvec. SMWR reports that he has served as a consultant through his institution to Vanda Pharmaceuticals, Philips Respironics, EdanSafe, National Transport Commission, Rail, Bus and Train Union, Australian Workers' Union, Tontine Group, Transport Accident Commission, Meda Consumer Healthcare, and New South Wales Department of Education & Communities, and has through his institution received research grants and from Vanda Pharmaceuticals, Philips Respironics, and Rio Tinto and reimbursements for conference travel expenses from Vanda Pharmaceuticals. He serves as a consultant to, and is a Program Leader for, the Cooperative Research Centre for Alertness, Safety and Productivity. His institution has received equipment donations or other support from Optalert, Compumedics, Philips Lighting, and Tyco Healthcare. He is a Director of the Sleep Health Foundation and is a Past President of the Australasian Sleep Association. He has also served as an expert witness and/or consultant to shift work organizations and in legal cases involving sleep loss. In the past 3 years, CAC has received consulting fees from or served as a paid member of scientific advisory boards for Amazon.com, Inc.; A2Z Development Center, Inc.; Bose Corporation; Boston Celtics; Boston Red Sox; Cleveland Browns; Columbia River Bar Pilots; Institute of Digital Media and Child Development; Jazz Pharmaceuticals, Inc.; Merck Sharpe and Dohme; NBA Coaches Association; Purdue Pharma; Quest Diagnostics; RMEI, LLC; Samsung Electronics; Teva Pharmaceutical Industries Ltd; Novartis; Synchrony; and Vanda Pharmaceuticals, Inc. He owns an equity interest in Vanda Pharmaceuticals, Inc. and Zurich Insurance. He has received royalties from McGraw Hill, Penguin Press/Houghton Mifflin Harcourt, and from Philips Respironics, Inc., for the Actiwatch 2 and Actiwatch Spectrum devices; his interests were reviewed and are managed by Brigham & Women's Hospital and Partners HealthCare in accordance with their conflict of interest policies. The

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