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Injury among a population based sample of career firefighters in the central USA

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ABSTRACT

Background Rates of occupational injuries among firefighters are high because of the physically demanding and variable tasks required by their job. While descriptive data about injuries exist, few studies have explored individual risk factors and their relationship to occupational injury.

Methods The current study presents data from a population-based sample of 462 career firefighters from 11 randomly-selected fire departments in the Missouri Valley region of the USA (Kansas, Missouri, Iowa, North Dakota, South Dakota, Colorado, Wyoming, Nebraska) who participated in a study evaluating risks for negative cardiovascular outcomes and injury. Relationships were examined between injury and demographic characteristics, body composition, fitness, and health behaviours.

Results Participants were most likely to be injured during physical exercise and those who reported regular on-duty exercise had a fourfold increase in risk for exercise-related injury compared with those who did not exercise on duty (OR=4.06, 95% CI 1.73 to 12.24). However, those who exercised were half as likely to sustain non-exercise injuries (OR=0.53, 95% CI 0.32 to 0.85).

Conclusions Findings highlight the benefit of physical training for firefighters despite the risk of injury during exercise.

Firefighting is a dangerous occupation with injury rates exceeding most occupational groups.[1] The National Fire Protection Association (NFPA) reported 71 875 firefighter line-of-duty injuries in 2010, with 20.8% of injuries resulting in time away from work.[2] Strains, sprains and muscular pain accounted for the largest portion of injuries (51.4%), followed by wounds, cuts, bleeding and bruising (17.5%), and 'other' injuries (12.8%). Poplin *et al*[3] examined a 5-year period of injury reports for Tucson firefighters and found that 32.9% were due to physical exercise, followed by patient transport (16.9%), training drills (11.1%) and fire ground operations (10.2%). Sprains and strains were reported as the most common injury (56.2%) followed by lacerations and contusions (15.5%).

Firefighter injuries have significant economic costs. Walton *et al*[4] studied firefighters from 77 municipalities in Illinois who filed worker's compensation from 1992–1999. They found nearly a third of claims were for overexertion, of which 83% were related to strain or sprain. The average firefighters' worker's compensation claim was $5168. Costs of injuries sustained by firefighters nationally were estimated between $830–980 million annually in 1997 dollars.[5] Given the high prevalence and associated costs of injuries in the fire service, understanding risk and protective factors for injury is an important topic in occupational health research.

To date, studies examining risk factors for firefighter injury largely focus on environmental context and usually limit their focus to injuries occurring on the fire ground. For instance, Fabio *et al*,[6] reported that fires with five or more alarms or those in buildings with more than three stories resulted in a 400% and 250% increased injury risk when compared with fires with fewer alarms or those on a ground floor, respectively. Moore-Merrill *et al*,[7] conducted a retrospective review of 3450 injuries, and found that the leading contributing factors to injury in the line of duty were a lack of situational awareness (37.4% of injuries), lack of wellness fitness (28.6% of injuries) and human error (10.7% of injuries). While information about location and environmental context is useful, little is known about non-occupational risk factors (eg, health behaviours, fitness level, body composition) that may be related to increased injury risk.

We located two studies that examined the relationships between non-occupational risk factors and firefighter injuries. Liao *et al*[8] examined predictors of injury frequency and duration in a 12-year longitudinal firefighter cohort (N=171) and found that age, tenure, gender, marital status, type of injury and wage were significant predictors of injury duration. Those who scored high on the Minnesota Multiphasic Personality Inventory scales associated with conflict, struggle, anger and respect for societal rules were injured more frequently and missed more work. However, all firefighter injuries were combined which limits the ability to look at whether predictors vary by type of injury. Heineman *et al*[9] explored risk factors associated with fire ground injuries in a retrospective case-control study and found that neither age nor experience were significantly related to risk of injury; rather, situational elements (eg, task being performed by firefighter when injured, location of the fire) were the most likely correlates of injury. Additional research that focuses specifically on the most common type of injury (musculoskeletal (MS) injuries) or the most frequent duty type when injured (exercise) will help expand the understanding of the role of non-occupational risk factors.

There is wide agreement that firefighters need to be physically fit to perform their job tasks. However, many departments raised concerns about the potential for high injury rates occurring during exercise.[10 11] In addition, little is known about predictors or correlates of exercise injuries among

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firefighters, even though there is extensive information in relevant occupational groups (eg, the military).[12–16] Jones and Knapik[12] identified a number of intrinsic (eg, demographic factors, anatomical factors, fitness, behavioural traits and past injury) and extrinsic (eg, training parameters, equipment) factors related to exercise injuries among military members. Low levels of physical training and fitness prior to entering the military resulted in high injury rates during training.[12–16] In contrast, overtraining among military members also had a negative impact on health. In particular, there seems to be a threshold above which training injuries from long distance running increase while aerobic fitness does not.[16] Successful interventions among military personnel for decreasing overuse injuries include reducing long distance running, gradually building up training, and emphasis on endurance training prior to increasing anaerobic and strength training.[16] Findings among military members highlight the importance of focusing on risk factors for exercise injuries in particular among firefighters as a means of focusing intervention and prevention efforts.

Despite the clear need for firefighters to be physically fit to effectively carry out their job tasks, the frequency of exercise-related injuries has raised concern among fire service administrators and risk managers and raised questions about the relative utility of encouraging on-duty exercise.[10 11] Given these concerns, it is important to have a clear, evidence-based understanding of the relationship between non-occupational risk factors, exercise on duty, and injury to direct policy and prevention/intervention efforts. We examined the relationship between reported on-duty exercise, as well as non-occupational risk factors, and exercise and MS injuries.

METHODS

Participants and procedures

Data are from the baseline assessment of the Firefighter Injury and Risk Evaluation (FIRE) Study (Federal Emergency Management Agency grant#; EMW-2007-FP-0257). The project was approved by relevant Institutional Review Boards and Compliance offices and data was collected between 2008 and 2010. Participating career (N=11) and volunteer (N=13) fire departments were randomly selected in the Missouri Valley Region of the USA (Kansas, Missouri, Iowa, Nebraska, North Dakota, South Dakota, Colorado and Wyoming). Of all firefighters solicited (N=736), 97% (N=714) consented to study participation. All firefighters on duty the days of data collection were solicited. For larger departments, more than one shift day was scheduled to solicit participation. Given the differences in occupational environment and risk exposure between career and volunteer departments, only career firefighters were included in this analysis. Participation among career firefighters was 93.3%. In addition, given the low number of females in the sample (n=21) and our resultant inability to address gender differences, females were excluded. Additional detail about department selection has been previously reported.[17]

Measures

Domains selected were based on previous literature in the fire service, military studies, workers compensation personnel and consultation with fire service experts.

Injury questions were adapted from the National Health Interview Survey.[18] Fire service-specific questions were modelled after items from the National Institute of Standards and Technology (2005), review of workers compensation data collection tools, and tailored with the assistance of fire service experts. Injury questions were preceded with this explanation:

> The following questions are about injuries you have incurred in the past *12 months*. An injury is anything for which you have completed an accident report for the department, reported to workers compensation, or received medical care (by a physician or other medical professional).

Participants were asked 'We would like to ask you a few questions about any injuries you might have sustained while you were working as a firefighter. We are only interested in injuries while on duty regardless of the activity you were performing'. They were asked to indicate the number of injuries they sustained during the 12 months prior to the baseline evaluation, how many injuries resulted in them completing a departmental injury report and/or a report to workers compensation if their department participated in the programme. Firefighters were asked to indicate the injury type and location (ie, on their body), the duty being performed, and the activity (eg, lifting people, overhaul) they were doing while engaged in that duty. Injuries that were identified as 'dislocations, sprains and strains' were considered MS injuries. Injuries that were classified as 'Training' for type of duty and 'Physical training' as activity (as opposed to other training evolutions) were considered exercise injuries. Participants completed a separate description for each injury reported. For each firefighter who indicated an injury, the description of their injuries were reviewed and classified. In many instances, firefighters wrote in a short explanation of their injury rather than classifying it. Two members of the research team reviewed any that were not clearly classified.

In our initial questionnaire development, we conducted a 2-week, test-retest reliability analysis of each survey item. Participant responses (N=36) on the primary injury question ('How many injuries did you have in the past 12 months?') were identical in 89% of the cases, and within one injury 94% of the time (possibly due to injuries in the lag period in some cases). κ for this injury item was highly significant ($\kappa=0.773$, $p<0.001$).

Body composition was determined by body mass index (BMI), body fat percentage (BF%) and waist circumference (WC). Height was measured using a portable stadiometer. Weight and BF% were assessed with foot-to-foot bioelectrical impendence (Tanita 300; Tanita Corporation of America, Inc.; Arlington Heights, Illinois, USA). The Tanita 300 demonstrated strong concurrent validity when compared with dual energy x-ray absorptiometry ($r=0.94$; $p<0.001$), the 'gold standard' of body fat assessment.[19] WC was measured with a non-stretchable tape measure based on recommendations from the US obesity guidelines.[20 21] BMI was calculated as kg/m^2. Cut-offs for obesity classification using BMI, BF % and WC were based on current standards.[20 21]

Estimated maximal oxygen consumption (VO_{2max}) was determined with a non-exercise model that combined participants' age, gender, BMI and physical activity assessed with the Self-Report of Physical Activity Questionnaire.[22] This non-exercise model has been compared with measured VO_{2max} and found to be as accurate as submaximal aerobic testing.[22–25]

Torso strength was assessed with the Jackson Strength Evaluation System, as recommended by the NFPA 1500 Standard on Fire Department Occupational Safety and Health Programme.[26] The body weight corrected maximum strength ratio (ie, average of two maximum strength pulls/participants' body weight) was used for analysis.

Flexibility was assessed using the adjustable sit and reach test, also recommended by the NFPA 1500 standard.[26] Averages of the maximum stretch were calculated for analysis.

Tobacco use questions were modelled after those from the Department of Defence Survey of Health Related Behaviours

Among Personnel[27] and the National Household Survey on Drug Abuse.[28] Firefighters who had not smoked 100 cigarettes in their lives were considered non-smokers. Those who smoked 100+ cigarettes in their lives but none in the past 30 days were considered former smokers. Those who had smoked 100 cigarettes in their lifetime and smoked in the past 30 days were classified as current smokers. Those who indicated they had used smokeless tobacco in the past 30 days were classified as current smokeless tobacco users.

Problematic alcohol use was measured with the CAGE questionnaire.[29] Response options were yes/no to the following questions: (1) Have you ever felt you should cut down on your drinking?; (2) Have people annoyed you by criticising your drinking?; (3) Have you ever felt guilty about your drinking?; and (4) Have you ever had a drink first thing in the morning to steady your nerves or get rid of a hangover? Affirmative responses were totalled for an overall score range of 0–4. Scores >2 are considered indicative of potential problematic alcohol use.

On-duty sleepiness was evaluated with the Epworth Sleepiness Scale, which asked how likely firefighters were to doze off in a number of situations. Response options were 0–3.[30] Standard cut-offs for excessive daytime sleepiness (Epworth Sleepiness Scale >11) was used.[30]

Depression was assessed with the Center for Epidemiological Studies Short Depression Scale (CES-D 10). Total scores were calculated and those scoring >10 were considered in the range of concern for clinical depression.[31] The CESD has been found to be highly reliable among the general population (Spearman-Brown, split halves r=0.85) and in patient samples (r=0.90).[31]

Exercise on Duty was assessed with the question 'Most weeks, I exercise at the fire station or while at work:' Response options were dichotomised to either Never/Some Days or Most Days/ Every Day.

Approach to analysis

All statistical analyses were performed with SPSS V.19 (SPSS, Chicago, Illinois, USA) and SAS V.9.3 (SAS, Cary, North Carolina, USA). As noted previously, women were excluded due to their lack of representation in our sample (and the national fire service[32]) and our resulting inability to make statistical inferences based on gender differences. The first reported injury was used for firefighters reporting more than one injury. Logistic regression was used to examine associations between all injury, MS injury, and exercise injury and demographic characteristics (those noted in table 1), body composition, fitness and health behaviours. For MS injuries, comparisons were made between those with and without a MS injury in the 12 months prior to baseline data collection. Exercise injuries comparisons were between those who did and did not experience an exercise injury in the 12 months prior to baseline data. Given the concern by fire service management about exercise injury, descriptive data on days missed was tabulated. χ^2 analysis was used to determine if there was a difference between exercise and non-exercise injuries with respect to missing shifts from work, which was coded dichotomously as missed any shifts versus missed no shifts. No demographic variables were significantly related to injury, so they were not included as covariates in subsequent models examining associations between body composition, fitness, health behaviours and injury. Given the sampling strategy used in the larger study, the group-level factor 'department' was entered into each model as a random effect to determine if parameter estimates were significantly impacted by its inclusion. In no case did the models adjusted for department result in substantively different parameter estimates, thus unadjusted models are presented.

Table 1 Demographics of firefighters at baseline by injury status

	Not injured N=346	All injured N=115	MS injury N=87	Exercise injury N=30
Ethnicity (% White)	90.0	92.0	90.6	86.0
Age, years (SD)	38.1 (10.2)	38.8 (9.2)	38.9 (8.5)	36.7 (9.5)
% Married	73.5	70.5	72.6	75.0
Education				
High School/Some college	74.7	72.6	72.9	62.1
College grad/graduate degree	25.3	27.4	27.1	37.9
Rank (%)				
Firefighter	32.9	33.9	33.3	44.8
Firefighter/paramedic	15.9	21.4	21.4	10.3
Driver operator	20.2	17.0	16.7	10.3
Company officer (Lt, Capt)	22.8	22.3	22.6	27.6
Chief (asst, deputy, other)	7.5	4.5	4.8	6.9
Other	0.6	0.9	1.2	0.0
Years in fire service, years (SD)	13.9 (9.2)	14.4 (8.6)	14.3 (8.5)	13.7 (8.8)

MS, musculoskeletal.

RESULTS

Demographic characteristics of participants are presented in table 1.

Of the 478 male career firefighters who consented to study participation, 462 completed the injury questions on the baseline survey and were included in this report. Among this group, 20.1% reported having one injury, 3.0% reported having two injuries and 1.7% reported having three or more injuries in the previous 12 months. Most injured firefighters (66.1%) completed departmental reports, but only 37.4% reported to workers compensation. MS injuries, such as dislocations, sprains and strains, were the most common type, accounting for 76.3% of injuries, followed by superficial injuries or open wounds (13.0%; see table 2).

Type of duty

Injuries primarily occurred during training (exercise or other training revolutions; 33.3%) or on the fire ground or during

Table 2 Type of injuries incurred by firefighters, baseline

Type of injury	% of firefighters	% of injuries
Dislocation, strain, sprain	18.8	76.3
Superficial injury, open wound	3.2	13.0
Concussion, internal injury	1.3	5.2
Fire/chemical burn, scald, frostbite	1.3	5.2
Fractures	0.4	1.7
Eye injury	0.4	1.7
Amputation	0.0	0.0
Acute poisoning, infection	0.0	0.0
Respiratory injury	0.0	0.0
Thermal stress/heat exhaustion	0.0	0.0
Heart attack, stroke	0.0	0.0
Other	0.2	0.9

rescue operations combined (27.9%). The remaining injuries happened on scene at non-fire calls (17.1%), during other duties (eg, inspection; 13.5%) and while responding to or returning from a call (8.1%), respectively. The majority of injuries were associated with training and most training injuries (81.1%) occurred during exercise (table 3).

The most common fire ground injuries occurred while advancing or directing hose (50.0%), during overhaul operations (16.7%) and forcible entry (10.0%). Most non-fire emergency injuries resulted from lifting people (77.8%). Among other on-duty, non-emergency injuries, almost half (43.8%) happened during inspecting activities such as truck checks.

Risk factors of all injury

Table 4 presents correlates of all injury, MS injury and exercise injury. None of the demographic variables listed in table 1 were associated with risk of all injury nor were body composition or fitness measures. Smoking status was significantly related to all injury, with former smokers more likely to have experienced an injury compared with never smokers (OR=1.84, 95% CI1.31 to 2.99). Depressive symptoms were also significantly related to injury, with those scoring in the range of concern for symptoms being more likely to have been injured (OR=2.33, 95% CI 1.33 to 4.08).

Risk factors of MS injury

Similar to the analysis of any injury, no demographic, body composition or fitness measures were significantly related to MS injury. Only scores on the depression scale were significantly related to MS injury, with those scoring in the range of concern being significantly more likely to be injured (OR=1.99, 95% CI 1.08 to 3.66).

Risk factors of exercise injury

No demographic characteristics noted in table 1 were significantly associated with exercise injuries. Estimated VO_{2max} demonstrated a significant association with exercise injury; each unit increase in estimated VO_{2max} was related to a 6% per unit increase in exercise injury (OR=1.06, 95% CI 1.01 to 1.12). Strength was also related to exercise injury with an increase in exercise injury for each unit increase in the strength ratio (OR=4.03, 95% CI 1.48 to 10.97). Slightly more than half (54.1%) of firefighters reported exercising at work on most or all days they were on duty. Those who exercised were 4.6 times more likely to have an exercise injury (OR=4.60, 95% CI 1.73 to 12.24). However, those reporting on-duty exercise were approximately half as likely to sustain a non-exercise injury (OR=0.53, 95% CI0.32 to 0.85). Only 39.3% of those reporting exercise injuries reported any lost duty days while more than half (52.4%) of firefighters with non-exercise injuries missed work, although the difference was not statistically significant (χ^2=1.4, p=0.23).

Table 3 Type of duty conducted when injured*

Type of duty	% of injuries N=111	% injuries within category
Fire/rescue activities	27.9 (n=31)	
Advancing/directing hose	13.5	50.0 (n=15)
Overhaul	4.5	16.7 (n=5)
Forcible entry	2.7	10.0 (n=3)
Ventilation	1.8	6.7 (n=2)
Using ground ladders	1.8	6.7 (n=2)
Rescue	1.8	6.7 (n=2)
Salvage	1.8	6.7 (n=2)
Working on aerial ladders	0.9	3.3 (n=1)
Picking up	0.9	3.3 (n=1)
Inspecting	0.9	3.3 (n=1)
Other	1.8	6.7 (n=2)
On scene, non-fire	17.1 (n=19)	
Lifting people	12.6	77.8 (n=14)
Other	3.6	22.2 (n=4)
Training	33.3 (n=37)	
Physical training	27.0	81.1 (n=30)
Lifting people	1.8	5.4 (n=2)
Advancing/directing hose	1.8	5.4 (n=2)
Using ground ladders	0.9	2.7 (n=1)
Rescue	1.8	5.4 (n=2)
Picking up	1.8	5.4 (n=2)
Lifting people	1.8	5.4 (n=2)
Responding/returning	8.1 (n=9)	
Other on-duty	13.5 (n=15)	
Inspecting activities	6.3	43.8 (n=7)
Picking up objects	0.9	6.3 (n=1)
Other	7.2	50.0 (n=8)

*Percentages may not add to 100 because personnel could select more than one category.

DISCUSSION

Exercise injuries among firefighters have received a great deal of attention given their frequency.[3 10] Firefighters in this study who reported consistent exercise on duty were significantly more likely to suffer an exercise injury. Those with an exercise injury also were stronger and evidenced higher cardiorespiratory fitness than their peers not experiencing an exercise injury. However, firefighters who consistently exercised on duty also were significantly less likely to suffer a non-exercise injury and a lower proportion missed any shifts due to injury. Our findings are consistent with Muto and Sakurai,[33] who found that workers who exercised regularly had fewer missed work days due to injury or illness when compared with those who did not report exercise, which is likely due to the protective effects of fitness. Findings have implications for fire service leadership who are working towards increasing programmes and resources for fitness and wellness programmes. While some concern has been expressed about the risk of injuries related to exercise, findings highlight the protective effect exercise has against non-exercise injuries.

Injury rates and type of duty being performed while injured in the present study were similar to those found in existing literature.[3 4] Approximately one-third of firefighters' injuries took place during training and slightly more than a quarter occurred on the fire ground. Fifteen per cent of injuries happened during non-fire calls and the most frequent injury in these environments was the result of lifting patients. Nearly 14% of injuries transpired during non-emergency response activities, often during truck checks.

Firefighters in the range of concern for depressive symptoms were twice as likely to have experienced an injury in the past 12 months. Kim,[34] using the National Health Interview Survey, found a 37% increase in injuries among distressed participants when compared with those without distress. However, given the cross-sectional nature of our data, it is not possible to infer a causal direction in the relationship between injury and depression. It is possible that firefighters who were injured were at higher risk for depression because of their injury. Longitudinal research is needed to determine whether depression is predictive of subsequent injury. Similarly, former cigarette smoking was

Table 4 Logistic regressions, all injury, musculoskeletal (MS) injury and exercise injury and non-occupational risk factors

	All injury Comparison with all not injured	MS injury Comparison with all not having MS injury	Exercise injury Comparison with all not having exercise injury
Body composition			
Obesity, BMI defined (%)			
Normal weight	–	–	–
Overweight	1.13 (0.64 to 2.01)	1.15 (0.60 to 2.21)	0.87 (0.34 to 2.22)
Obese	1.01 (0.55 to 1.86)	1.18 (0.60 to 2.33)	0.63 (0.22 to 1.81)
Obesity, waist circumference (%)			
Under 40 inches	–	–	–
Over 40 inches	1.04 (0.66 to 1.65)	1.17 (0.71 to 1.93)	1.13 (0.51 to 2.47)
Obesity, body fat defined (%)			
Not obese	–	–	–
Obese	0.90 (0.59 to 1.38)	0.94 (0.59 to 1.51)	0.63 (0.29 to 1.36)
Fitness			
VO_{2max} (ml/kg/min)	1.00 (0.98 to 1.03)	1.00 (0.97 to 1.03)	1.06 (1.01 to 1.12)
Maximum torso strength			
Maximum pull weight/body weight	1.01 (0.54 to 1.91)	1.08 (0.53 to 2.18)	4.03 (1.48 to 10.97)
Flexibility			
Max reach (cm)	0.97 (0.90 to 1.04)	0.97 (0.89 to 1.05)	1.07 (0.94 to 1.21)
Exercise on duty			
Not regular exercisers	–	–	–
Regular exercisers	0.84 (0.55 to 1.28)	1.03 (0.64 to 1.64)	4.60 (1.73 to 12.24)
Health behaviours			
Smoking (%)			
Never/experimental	–	–	–
Former	1.84 (1.31 to 2.99)	1.58 (0.93 to 2.69)	1.33 (0.58 to 3.06)
Current	1.04 (0.54 to 2.02)	0.81 (0.38 to 1.76)	0.75 (0.21 to 2.63)
Smokeless tobacco use (%)			
Not current user	–	–	–
Current user	1.19 (0.70 to 2.04)	0.74 (0.38 to 1.41)	1.39 (0.57 to 3.35)
Alcohol (%)			
Two or less on CAGE questionnaire	–	–	–
More than two on CAGE questions	1.15 (0.59 to 2.23)	1.38 (0.68 to 2.80)	0.51 (0.12 to 2.20)
Daytime sleepiness (%)			
<11 on Epworth Sleepiness Scale	–	–	–
>11 on Epworth Sleepiness Scale	1.74 (0.97 to 3.10)	1.66 (0.89 to 3.12)	1.43 (0.52 to 3.92)
Depression (%)			
<4 CESD-10	–	–	–
>4 on CESD-10	2.33 (1.33 to 4.08)	1.99 (1.08 to 3.66)	1.78 (0.69 to 4.58)

Note: Because no univariate models evidenced a significant relationship between demographic characteristics and risk of injury, only unadjusted models are presented.
BMI, body mass index.

found to be related to increased risk of all injury which is consistent with research in other occupational groups.[35 36]

Limitations to the current study include the use of self-reported injury data. While collecting injury data this way has been found to be more sensitive than workers compensation claims or medical records,[37] particularly for less severe injuries, self-reports presents a different picture of injury than other assessment methods. For instance, the NFPA[2] reported that nearly half of all injuries happened on the fire ground, but these injury data come from fire departments. Data collection at the department level is likely less sensitive to less severe injuries that do not result in lost duty days or medical care. In addition, it is possible that data collection missed firefighters who were on light duty detail or missing from work due to injury. In addition, generalisability of the study is limited to the Missouri Valley region of the country. Additional research should focus on reproducibility in other geographical areas.

Despite the limitations, our study has a number of strengths including the population-based sample from 11 randomly selected fire departments across the central USA. In addition, the assessment protocol included measured weight, body composition, strength and flexibility and a strong and sensitive measure

Table 5 Relationship between exercise and non-exercise injuries

	Exercise injury OR (95% CI)
Those not regularly exercising on duty	–
Those regularly exercising on duty	4.60 (1.73 to 12.24)
	Non-exercise injury OR (95% CI)
Those not regularly exercising on duty	–
Those regularly exercising on duty	0.53 (0.32 to 0.85)

of injury. Findings of the current study confirm and expand the literature on firefighter injury with a large, population-based sample using well-validated outcome measures to examine non-occupational risk factors associated with injury. Despite the disproportionately high rates of injury during exercise, findings also highlight the protective effect of fitness in defending against non-exercise injuries. Based on these findings, injury prevention efforts should focus on increasing fitness and appropriate training among firefighters as a means of decreasing on-duty injury.

What is already known on this topic?

- It is well recognized that firefighting is a dangerous profession with high rates of injury. In particular, exercise on duty has been identified as an activity that results in a high number of injuries.

What this study adds?

- By examining the relationship between on duty exercise, exercise injuries and non-exercise injuries, we are better able to understand the impact of on-duty exercise to injury rates.

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Contributors All authors meet the conditions for authorship including: (1) substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; (2) drafting the article or revising it critically for important intellectual content; and (3) final approval of the version to be published.

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