# Predictors of On-Duty Coronary Events in Male Firefighters in the United States

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**Coronary heart disease (CHD) accounts for 39% of "on-duty" deaths in firefighters in the United States. No studies have examined the factors that distinguish fatal from nonfatal work-associated CHD events. Male firefighters experiencing on-duty CHD events were retrospectively investigated to identify cardiovascular risk factors predictive of case fatality; 87 fatalities (death within 24 hours of the event) were compared with 113 survivors who retired with disability pensions for heart disease after on-duty nonfatal events. Cardiovascular risk factors were then examined for associations with case fatality. Predictors of CHD death in multivariate analyses were a previous diagnosis of CHD (or peripheral/cerebrovascular disease) (odds ratio [OR] 4.09, 95% confidence intervals [CI] 1.58 to 10.58), current smoking (OR 3.68, 95% CI 1.61 to 8.45), and hypertension (OR 4.15, 95% CI 1.83 to 9.44). Age ≤45 years, diabetes mellitus, and serum cholesterol level were not significant predictors of case fatality. In conclusion, previous CHD, current smoking, and hypertension are strong predictors of fatality in male firefighters experiencing on-duty CHD events. Accordingly, prevention efforts should include early detection and control of hypertension, smoking cessation/prohibition, and the restriction of most firefighters with significant CHD from strenuous duties.**  **(Am J Cardiol 2008;101:585–589)**

Few physicians are aware that coronary heart disease (CHD) is responsible for 39% of on-duty deaths in firefighters.[1] Recent evidence supports that these CHD events are often precipitated by strenuous duties.[1–3] Biologic-plausible explanations include the effects of heavy protective equipment, irregular physical exertion, gaseous and particulate smoke exposures, and psychological stressors on patients with underlying CHD.[1,2,4–9] In this study, on-duty CHD events in male firefighters were retrospectively investigated to identify cardiovascular predictors of case fatality.

## Methods

A retrospective design was used to examine 2 groups of male firefighters. Specifically, we compared those who died within 24 hours of an on-duty CHD event with colleagues who survived similar occupational CHD incidents and later received disability pensions. Because of the low proportion of female firefighters and, therefore, the minimal number of available CHD events in women, the study was restricted to men.

The fatal CHD events were drawn from the Fire Fighter Fatality Investigation and Prevention Program of the National Institute for Occupational Safety and Health, which conducts detailed analyses of selected on-duty firefighting deaths.[10] Figure 1 illustrates the selection and exclusion criteria for the fatalities; 2 independent reviewers examined each narrative account posted on the Institute's website[10] between January 1996 and July 2006 and selected those due to CHD. Age, professional status (volunteer or career), cause of death, occupational circumstances, and underlying cardiovascular risk factors were extracted. A third reviewer resolved any classifications that were not concordant between the first 2 reviewers.

The nonfatal events were disability retirements associated with a specific, on-duty nonfatal CHD event. They were selected from a previous study of heart disease pensions in Massachusetts firefighters from 1997 through 2004[3] (Figure 1). Briefly, nursing staff from the Public Employee Retirement Administration Commission of Massachusetts used a standardized form to extract data from the files of each subject. The completed extraction forms, void of any personal identifiers, were further clarified by an occupational medicine physician before entry into a database. The

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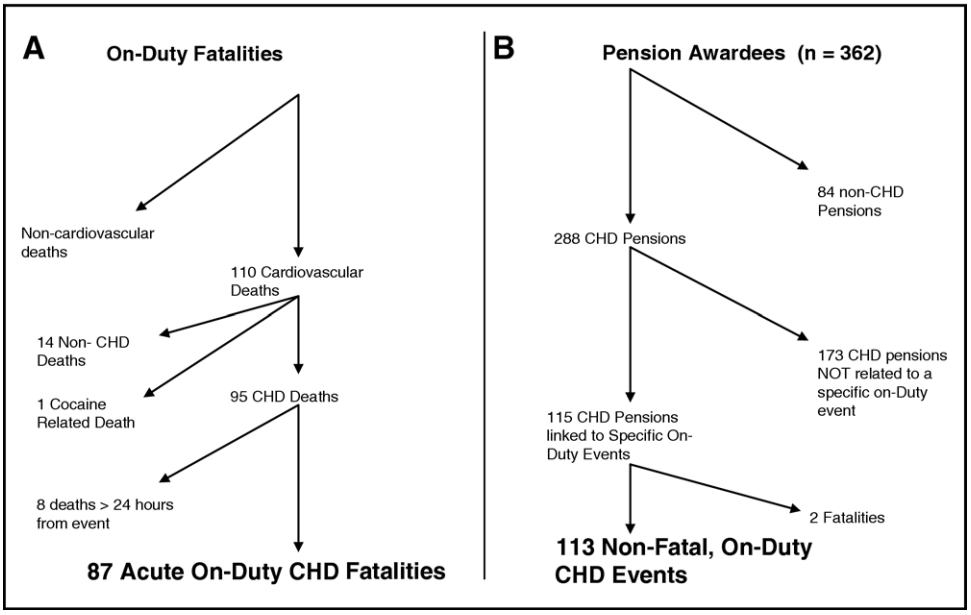


Figure 1. Selection of study populations. *(A)* On-duty fatalities reported between January 1996 and July 2006 from the Fire Fighter Fatality Investigation and Prevention Program of the National Institute for Occupational Safety and Health. *(B)* Disability pensions for heart disease between 1997 and 2004 in Massachusetts.

Table 1
Characteristics of on-duty coronary heart disease events in men

| Variable | Nonfatal Events (n = 113) | Fatal Events (n = 87) | p Value |
|---|---|---|---|
| Age, mean ± SD (yrs) | 54.4 ± 6.6 | 50.4 ± 7.6 | <0.001 |
| Age range (yrs) | 33–66 | 29–69 | n/a |
| Career firefighters | 113 (100%) | 54 (62%) | <0.001 |
| Mean BMI ± SD (kg/m$^2$) | 30.3 ± 5.7 (n = 86) | 31.3 ± 6.2 (n = 31) | 0.447 |
| Type of duty at time of event | | | 0.001 |
| Fire suppression | 36/90 (40%) | 27 (31%) | |
| Alarm response | 16/90 (18%) | 6 (7%) | |
| Alarm return | 1/90 (1%) | 10 (12%) | |
| Physical training | 3/90 (3%) | 14 (16%) | |
| Nonfire emergency | 10/90 (11%) | 8 (9%) | |
| Nonemergency duty | 24/90 (27%) | 22 (25%) | |
| Strenuous duty at time of event* | 56/90 (62%) | 57 (66%) | 0.648 |

* Strenuous duty included fire suppression, alarm response, alarm return, or physical training.

Human Subjects Committee of the Harvard School of Public Health exempted our investigation of these retirements from review.

The presence of major cardiovascular risk factors were defined according to previous investigations.[2,3,11] Hypertension was defined as blood pressure at rest ≥140/90 mm Hg, previous diagnosis of hypertension, antihypertensive therapy, or left ventricular hypertrophy. Current smoking was defined as smoking within the 12-month period before death, diagnosis, or examination. Hypercholesterolemia was a serum cholesterol ≥200 mg/dl, low-density lipoprotein cholesterol ≥160 mg/dl, previous diagnosis of hypercholesterolemia, or lipid-lowering therapy. Diabetes mellitus was defined as random blood glucose >150 mg/dl, a previous diagnosis, insulin, or hypoglycemic medication. Body mass index (BMI) was calculated from each firefighter's height and weight in kg/m$^2$, and obesity was defined as BMI ≥30 kg/m$^2$. Pre-existing and incident CHD were defined by any of the following: an abnormal exercise or radionuclide stress test; a history of coronary artery bypass grafting; angioplasty; myocardial infarction; angina; autopsy or angiography findings of significant coronary atherosclerosis; or sudden cardiac death (in the absence of other likely explanations). Previous diagnoses of carotid stenosis or peripheral vascular disease were also considered indicative of pre-existing CHD. With the exception of obesity, if no information to affirm the presence of a specific risk factor was found, that risk factor was classified as absent.

CHD events were categorized by the specific duty performed during the onset of symptoms or immediately before sudden death. Fire suppression included fighting a fire or at the fire scene after fire suppression. Alarm response included responses to emergency incidents including false alarms. Alarm return included all events occurring during

Table 2
Bivariate odds ratios (OR) for fatal outcome in on-duty coronary heart disease (CHD) events

| Variable | Nonfatal Events (n = 113) | Fatal Events (n = 87) | OR for Fatal Events (95% CI)* |
|---|---|---|---|
| Age ≥45 yrs | 107 (95%) | 68 (78%) | 0.20 (0.08–0.53) |
| Current smoking | 27 (24%) | 35 (40%) | 2.14 (1.17–3.94) |
| Hypertension | 55 (49%) | 68 (78%) | 3.77 (2.01–7.07) |
| Diabetes mellitus | 24 (21%) | 12 (14%) | 0.59 (0.28–1.27) |
| Total cholesterol ≥200 mg/dl | 66 (58%) | 54 (62%) | 1.16 (0.66–2.06) |
| Previous diagnosis of CHD, carotid stenosis, or peripheral arterial disease | 20 (18%) | 27 (31%) | 2.09 (1.08–4.06) |
| BMI ≥30 | 35/86 (41%) | 19/31 (61%) | 2.31 (1.00–5.35) |

* Odds ratios with 95% confidence intervals (CI) in parentheses.

the return from incidents and several hours after an emergency call. Physical training included any job-related physical fitness activities, physical abilities testing, and/or any type of simulated emergency or drill. Nonfire emergencies were emergency medical, rescue, and other nonfire responses. Nonemergency duties included administrative and fire station tasks, fire prevention, inspection, maintenance, meetings, parades, and classroom activities. Based upon the statistical risk of on-duty CHD events associated with each professional activity,[1–3] fire suppression, alarm response, alarm return, and physical training were defined as strenuous duties and nonfire emergencies and nonemergency duties as nonstrenuous.

Data were analyzed using Statistical Analysis System (SAS Institute, Cary, North Carolina). Independent *t* tests were conducted to compare differences in mean values, and chi-square analyses were used to compare proportions and calculate simple odds ratios (OR) and 95% confidence intervals. Multivariate adjusted OR were calculated using binary logistic regression and controlling for covariates. A 0.05 level of statistical significance (2-tailed) was used for all tests.

## Results

Of the 87 fatalities, 38% were volunteers. There were no significant differences in the volunteer and career fatalities in the prevalence of cardiovascular risk factors (smoking, hypertension, hypercholesterolemia, diabetes, and previous diagnosis of CHD) or in the proportion of engagement in strenuous duty at the time of the fatal event. The only significant difference in the volunteer and career fatalities was that 34% of the volunteer fatalities were <45 years compared with 15% of the career firefighters ($p = 0.035$).

Table 1 lists the characteristics of firefighters experiencing nonfatal events and compares them with on-duty fatalities. The groups were similar in most respects, but on average the fatalities were younger, primarily because volunteers were younger. There were no differences in the association of type of event with strenuous duty. In those with available height and weight, 90% and 89% of the fatalities and survivors, respectively, had BMI in the overweight or obese ranges (BMI ≥25 kg/m$^2$).

Table 2 lists unadjusted OR for fatal outcome in on-duty CHD events. Current smoking, previous CHD, and hypertension were significant predictors of fatal events. Obesity was associated with a similar magnitude of increased risk of death, which was borderline significant ($p = 0.049$) and limited by missing data for about 2/3 of the fatalities.

Table 3
Multivariate odds ratios (OR) for fatal outcome in on-duty coronary heart disease (CHD) events

| Variable | Multivariate OR* for Fatal Event (95% CI)† | p Value |
|---|---|---|
| Current smoking | 3.68 (1.61–8.45) | 0.002 |
| Hypertension | 4.15 (1.83–9.44) | <0.001 |
| Total cholesterol ≥200 mg/dl | 1.16 (0.53–2.54) | 0.72 |
| Previous diagnosis of CHD, carotid stenosis, or peripheral arterial disease | 4.09 (1.58–10.58) | 0.004 |

* Multivariate OR adjusted for all other risk factors in the table, as well as professional status, age ≥ and <45 years, diabetes mellitus, and strenuous duty.

† Odds ratios with 95% confidence intervals (CI) in parentheses.

Table 3 lists the multivariate OR for fatal outcome in on-duty CHD events adjusted for potential confounders. In this model, previous CHD, current smoking, and hypertension were strong independent predictors of fatality.

In those with previous CHD, the time from the initial diagnosis to the final on-duty event was similar for fatalities and survivors. The mean times were 66 ± 67 and 56 ± 40 months ($p = 0.54$), and median times were 40 and 43 months, respectively. In the fatalities with previous CHD, however, 74% had evidence of myocardial damage preceding the final on-duty event compared with 35% of the survivors ($p = 0.007$).

## Discussion

In this study of case-fatality in on-duty firefighting CHD events, a previous diagnosis of CHD, current smoking, and hypertension were highly significant and independent predictors associated with roughly fourfold increases in death. Consequently, efforts to detect and control hypertension, promote smoking cessation, and restrict most firefighters with significant CHD from emergency operations could decrease firefighting fatalities. Our results also indirectly support screening for CHD in asymptomatic firefighters. The findings are likely relevant to other professional settings; occupational stressors such as irregular physical exertion, emergency responses, and dangerous duties are also encountered by police, military, and ambulance workers.[12–14] Likewise, the underlying individual susceptibility factors are likely similar.

A pre-existing CHD diagnosis was a strong independent predictor of fatality, especially when there was evidence of previous myocardial damage. This finding is consistent with our previous studies. Comparing professionally-active firefighters with those experiencing on-duty CHD events, previous CHD diagnosis was associated with roughly 15-fold and 9-fold increases in the risk of on-duty CHD death or disability retirement due to heart disease, respectively, after adjustment for other risk factors.[2,3] Based upon on our review of the cases in this study, some primary care physicians and cardiologists either failed to inquire about occupation or did not consider the unique cardiovascular demands of firefighting when determining whether such workers should return to work. For example, we are aware of several fatalities with known vascular disease that had significant exercise intolerance or were so deconditioned that they were evaluated with chemical stress tests. Nonetheless, based upon a lack of overt ischemia, they were not restricted in terms of work duties.

Blood pressure is often inadequately treated in firefighters.[15,16] Thus, the association of case fatality with hypertension is most likely due to uncontrolled hypertension. For example, in this study, 56% of the autopsies had evidence of left ventricular hypertrophy, which increases the risk of arrhythmia[17] and is a strong predictor of cardiovascular mortality.[18–20]

Surprisingly, age and diabetes mellitus were not predictors of fatal events and, in fact, were positively associated with survival. Previous studies have definitively identified increasing age as a strong risk factor for incident CHD in firefighters.[1–3,21] The present results regarding age and diabetes mellitus are most likely artifacts of the study's most significant limitation—that the fatality and survivor groups were not completely comparable. Ideally, one would compare fatal and nonfatal CHD events emerging prospectively from the same cohort of firefighters with baseline risk factor assessments. Unfortunately, no such data are available and logistically would be difficult to obtain. Thus, the only means available to approach our research question regarding CHD case fatality was to compare 2 groups of firefighters selected in different ways.

The disability retirements were all career firefighters from Massachusetts and may not be representative of firefighters throughout the country and of volunteers. Additionally, using disability retirements to find survivors of on-duty CHD events means that younger firefighters who survived an on-duty CHD event but returned to active duty were not included. Conversely, the National Institute for Occupational Safety and Health was probably more likely to investigate younger deaths because CHD is less expected in such cases. Thus, the design of the study was biased towards older survivors and younger fatalities.

Another limitation is ascertainment bias, which likely explains our results for diabetes mellitus. Firefighters, as a group, tend not to receive regular preventive care or evaluations of cardiovascular risk.[2] However, firefighters who survive a CHD event and are subsequently medically evaluated for disability retirement are required to present pertinent medical information and undergo a series of examinations. Therefore, diabetes mellitus, if present, will be identified. Because most of the firefighters who experienced a fatal event had no recent or only incomplete previous medical evaluations, the prevalence of diabetes mellitus is an underestimate. This latter limitation, although rendering our study uninformative about diabetes mellitus, also biased our investigation in general towards the null hypothesis for all risk factors. For example, elevated serum cholesterol was not associated with fatal events; however, data for the 2 groups were incomplete regarding total cholesterol and also insufficient to allow quantitative analysis for individual lipid panel components, such as low-density lipoprotein and high-density lipoprotein cholesterol. Therefore, our study was conservative, especially because we considered risk factors with unknown status as negative or absent. Considering this, it is remarkable that the results were so strong for pre-existing CHD, smoking, and hypertension.

Finally, our design could not account for other characteristics that could have influenced outcomes, such as the extent of atherosclerosis preceding the events, time from the event to emergency care, and the treatment modalities applied. None of these, however, would likely have affected our findings for underlying cardiovascular risk factors.

In conclusion, we analyzed a selection of nationwide firefighter CHD deaths related to on-duty events and compared them with Massachusetts' firefighters who survived similar occupational CHD incidents to identify predictors of case fatality. Our analysis found that a pre-existing CHD diagnosis, current smoking, and hypertension (presumably uncontrolled) are highly significant predictors of case fatality.

1. Kales SN, Soteriades ES, Christophi CA, Christiani DC. Emergency duties and deaths from heart disease among firefighters in the United States. *N Engl J Med* 2007;356:1207–1215.
2. Kales SN, Soteriades ES, Christoudias SG, Christiani DC. Firefighters and on-duty deaths from coronary heart disease: a case control study. *Environ Health* 2003;2:14.
3. Holder JD, Stalling L, Peeples L, Burress JW, Kales SN. Firefighter heart presumption retirements in Massachusetts: 1997–2004. *J Occup Environ Med* 2006;48:1047–1053.
4. Guidotti TL. Human factors in firefighting: ergonomic, cardiopulmonary, and psychogenic stress-related issues. *Int Arch Occup Environ Health* 1992;64:1–12.
5. Kuorinka I, Korhonen O. Firefighters' reaction to alarm, an ECG and heart rate study. *J Occup Med* 1981;23:762–766.
6. Burgess JL, Nanson CJ, Bolstad-Johnson DM, Gerkin R, Hysong TA, Lantz RC, Sherrill DL, Crutchfield CD, Quan SF, Bernard AM, Witten ML. Adverse respiratory effects following overhaul in firefighters. *J Occup Environ Med* 2001;43:467–473.
7. Smith DL, Manning TS, Petruzzello SJ. Effect of live-fire drills on cardiovascular and psychological responses of recruit firefighters. *Ergonomics* 2001;44:244–254.
8. Rosenstock L, Olsen J. Firefighting and death from cardiovascular causes. *N Engl J Med* 2007;356:1261–1263.
9. Mittleman MA. Air pollution, exercise and cardiovascular risk. *N Engl J Med* 2007;357:1147–1149.
10. The National Institute for Occupational Safety and Health. Fire Fighter Fatality Investigation and Prevention Program. Available at http://www.cdc.gov/niosh/fire/. Accessed on November, 2007.
11. Wilson PW, D'Agostino RB, Levy D, Belanger AM, Silbershatz H, Kannel WB. Prediction of coronary heart disease using risk factor categories. *Circulation* 1998;97:1837–1847.

12. Maguire BJ, Hunting KL, Smith GS, Levick NR. Occupational fatalities in emergency medical services: a hidden crisis. *Ann Emerg Med* 2002;40:625–632.
13. Franke WD, Anderson DF. Relationship between physical activity and risk factors for cardiovascular disease among law enforcement officers. *J Occup Med* 1994;36:1127–1132.
14. Fisher NG, Nicol ED. Cardiological disease in the Armed Forces: a clear and present danger. *J R Nav Med Serv* 2005;91:112–117.
15. Kales SN, Soteriades ES, Christoudias SG, Tucker SA, Nicolaou M, Christiani DC. Firefighters' blood pressure and employment status on hazardous materials teams in Massachusetts: a prospective study. *J Occup Environ Med* 2002;44:669–676.
16. Soteriades ES, Kales SN, Liarokapis D, Christiani DC. Prospective surveillance of hypertension in firefighters. *J Clin Hypertens (Greenwich)* 2003;5:315–321.
17. James MA, Jones JV. Ventricular arrhythmia in untreated newly presenting hypertensive patients compared with matched normal population. *J Hypertens* 1989;7:409–415.
18. Levy D, Garrison RJ, Savage DD, Kannel WB, Castelli WP. Prognostic implications of echocardiographically determined left ventricular mass in the Framingham Study. *N Engl J Med* 1990;322:1561–1566.
19. Haider AW, Larson MG, Benjamin EJ, Levy D. Increased left ventricular mass and hypertrophy are associated with increased risk for sudden death. *J Am Coll Cardiol* 1998;32:1454–1459.
20. Benjamin EJ, Levy D. Why is left ventricular hypertrophy so predictive of morbidity and mortality. *Am J Med Sci* 1999;317:168–175.
21. Glueck CJ, Kelley W, Wang P, Gartside PS, Black D, Tracy T. Risk factors for coronary heart disease among firefighters in Cincinnati. *Am J Ind Med* 1996;30:331–340.