Firefighters and on-duty deaths from coronary heart disease: a case control study.

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ABSTRACT

Background: Coronary heart disease (CHD) is responsible for 45% of on-duty deaths among United States firefighters. We sought to identify occupational and personal risk factors associated with on-duty CHD death.

Methods: We performed a case-control study, selecting 52 male firefighters whose CHD deaths were investigated by the National Institute for Occupational Safety and Health. We selected two control populations: 51 male firefighters who died of on-duty trauma; and 310 male firefighters examined in 1996/1997, whose vital status and continued professional activity were re-documented in 1998.

Results: The circadian pattern of CHD deaths was associated with emergency response calls: 77% of CHD deaths and 61% of emergency dispatches occurred between noon and midnight. Compared to non-emergency duties, fire suppression (OR=64.1, 95% CI 7.4-556); training (OR=7.6, 95% CI 1.8-31.3) and alarm response (OR=5.6, 95% CI 1.1-28.8) carried significantly higher relative risks of CHD death. Compared to the active firefighters, the CHD victims had a significantly higher prevalence of cardiovascular risk factors in multivariate regression models: age ≥ 45 years (OR 6.5, 95% CI 2.6-15.9), current smoking (OR 7.0, 95% CI 2.8-17.4), hypertension (OR 4.7, 95% CI 2.0-11.1), and a prior diagnosis of arterial-occlusive disease (OR 15.6, 95% CI 3.5-68.6).

Conclusions: Our findings strongly support that most on-duty CHD fatalities are work-precipitated and occur in firefighters with underlying CHD. Improved fitness promotion, medical screening and medical management could prevent many of these premature deaths.

BACKGROUND

Excluding September 11, 2001, firefighting claims about 100 lives annually in the United States (U.S.) [1-3]. Thus, U.S. firefighters have one of the nation's highest occupational fatality rates [4]. Coronary heart disease (CHD) has consistently been the leading cause of "on-duty deaths" or fatalities resulting from injury or illness occurring during fire department duties. CHD accounted for about 45% of these deaths from 1977-2002 [1-3]. This compares with 22% of on-duty deaths due to CHD among police and detectives, 15% among occupational fatalities overall [2], and 11% among other emergency medical service (EMS) workers [5].

Experts have often held that smoke exposure, physical exertion and psychological stressors increase cardiovascular risk among firefighters [6]. The Industrial Disease Standards Panel in Toronto, Canada [7], and "heart presumption" legislation in 38 U.S. states [8] have recognized this assumption compensating firefighters who develop CHD. However, definitive scientific evidence of increased cardiovascular mortality rates among firefighters remains elusive [9-12]. In addition, it remains unclear whether on-duty CHD deaths are work-related and which occupational and personal risk factors increase the risks of on-duty CHD death.

Numerous occupational factors could precipitate CHD events in firefighters. First, firefighting includes long sedentary stretches followed by irregular heavy exertion [9]. Firefighters react immediately to alarms with significant increases in pulse rate [13, 14]. During fire suppression, they work at near maximal heart rates [13] while wearing about 50 pounds of protective equipment, sometimes for prolonged periods [15, 16]. Heat stress and fluid losses can result in decreases in cardiac output despite sustained tachycardia [17]. Second, self-contained breathing apparatus use has reduced, but not eliminated chemical exposures including carbon monoxide, particulates and other toxicants [18]. Third, firefighters experience intermittent noise exposure [19, 20], which may increase blood pressure. Fourth, firefighters often perform shift work, which may increase the risk of CHD [21, 22].

Personal factors may also increase firefighters' susceptibility to CHD. Few fire departments require veterans to maintain the physical standards required of new hires [23]. Therefore, many incumbent firefighters lack the minimum exercise tolerance thought necessary to safely perform the most demanding tasks [23-25]. In addition, firefighters have high prevalences of overweight, obesity and hypercholesterolemia [26-31]. Furthermore, although the National Fire Protection Association (NFPA) recommends fire department medical examinations and specific fitness for duty criteria [16], most firefighters do not receive these examinations.

While the literature on firefighters' exposures, risk factors and cardiovascular response to stressors is extensive, mortality studies are largely limited to two types. The NFPA, Federal Emergency Management Association (FEMA) and the National Occupational Safety and Health Administration (NIOSH) have conducted descriptive, case series and case reports of on-duty fatalities [1-3, 32], without control populations or other means of comparative analysis. Therefore, these studies cannot statistically associate specific occupational and personal risk factors with increased CHD risks. The medical community has primarily utilized cohort mortality data [11, 12, 33-41], which have failed to find a consistently increased risk of lifetime CHD mortality among firefighters. Because these cohort mortality studies combine on-duty deaths with off-duty deaths and deaths occurring after retirement, they cannot adequately address whether on-duty CHD events are work-related.

Firefighting is more likely to precipitate an acute cardiac event in a susceptible person rather than cause the underlying atherosclerosis. Therefore, we undertook an internal, case-control study by pooling publicly available NIOSH reports of individual on-duty CHD firefighting fatalities to elucidate job-related precipitants as well as underlying medical risk factors. Steenland [10] has recommended this approach for occupational cardiovascular studies to control for confounding from the predominant, nonoccupational risk factors for heart disease.

MATERIALS AND METHODS

We performed a case-control study, selecting as cases 52 male firefighters whose CHD deaths were investigated by the NIOSH. We defined on-duty deaths as "fatalities resulting from injury or illness occurring while a firefighter was working and/or performing any fire department duty [3]." For this study, we considered on-duty fatalities investigated and reported by NIOSH [32] as on-duty deaths. We selected two control populations: 51 male firefighters who died of on-duty trauma; and 310 male firefighters examined in 1996/1997, whose vital status and continued professional activity were re-documented in 1998.

NIOSH Firefighter Fatality Investigation Reports

NIOSH investigators conduct multifactorial fatality investigations, and completed reports are available on the NIOSH website [32]. We reviewed all fatality reports posted from 1996 through December 2002. The NIOSH series does not include firefighter fatalities from September 11, 2001. Because the overwhelming majority of the reports regarded men, women make up less than 1% of firefighters nationally [42], and there are distinct differences in cardiovascular risk between men and women, we excluded fatalities in women from the data analyses.

We extracted age, sex, professional status, and the state where the firefighter served from all fatality reports. We also recorded: the time (of the accident for trauma deaths or the onset of symptoms for CHD deaths); the last job activity of the decedent; whether the decedent engaged in strenuous professional duties within 12 hours of the accident or the onset of symptoms; whether smoke exposure was likely at the incident; the cause of death and autopsy findings if reported. For CHD deaths, most NIOSH reports provided additional information: including the presence of CHD risk factors; the type of shift the firefighter was working; the number of hours on duty for professional firefighters prior to the onset of symptoms; and the carboxyhemoglobin saturation.

Two physicians (SNK, ESS) independently reviewed all CHD risk factor information and resolved any discrepancies between their determinations by further consensus review.

Study populations:

On-Duty Coronary Heart Disease (CHD) Death Cases:

We identified 58 cardiovascular deaths for further investigation. We excluded six cases because autopsies indicated that CHD was not the primary cause of death.

On-Duty Traumatic Fatality Controls:

Because general agreement exists that fatalities resulting from on-duty trauma are work-related, we used trauma deaths investigated by NIOSH as a reference group for job-related factors. The 51 trauma fatalities we selected for this study resulted from: 21 fire department vehicle crashes (41%); 11 structure collapses (22%); five electrocutions (10%); four explosions (8%); three falls (6%); three private vehicle crashes en route to an incident (6%); three firefighters struck by other vehicles (6%) and one collision with an object (2%).

Active Firefighter Cardiovascular Controls:

We chose male firefighters from a Massachusetts cohort as controls for cardiovascular risk factor prevalence. We first examined the group in 1996/1997 when a statewide medical surveillance program was initiated. For the study, we selected all 310 male firefighters who underwent baseline medical examinations, and whose vital status and continued professional activity were re-documented at the 1998 periodic examination. We used the baseline examination results to minimize the potential effects of serial examinations on health behaviors and medical treatment. The Massachusetts firefighters' primary professional duties are as municipal firefighters. They spend a much smaller percentage of their time as independent contractors working with the state's regional hazardous materials teams. Compliance with the examination program is excellent for two reasons. First, it is mandatory for participation on the regional teams, the Commonwealth withholds salary from firefighters who miss the annual medical examination and continued incompletion results in termination from the regional team. Second, the Commonwealth legally forbids the surveillance program from reporting any results to the municipal fire departments who are the firefighters' primary employers. The Institutional Review Boards of the Harvard School of Public Health, the Cambridge Health Alliance, and Northeast Specialty Hospital approved review of the firefighters' medical records for research.

Determination of CHD Risk Factors

On-Duty CHD Death Cases

Hypertension was present if a resting blood pressure was ≥140/90 mm Hg, the firefighter had a diagnosis of hypertension, and/or the firefighter was receiving anti-hypertensive therapy. We also considered firefighters as hypertensive if the autopsy or another examination demonstrated left ventricular hypertrophy (LVH), a finding highly associated with hypertension [43]. We defined cases reported to have smoking as a risk factor as current smokers, unless they had quit smoking more than 12 months prior to their death [43]. We considered cases having serum cholesterol ≥ 5.18 mmol/L (200 mg/dl), a diagnosis of hypercholesterolemia and/or prescribed lipid-lowering therapy as hypercholesterolemic. Diabetes mellitus was present if the firefighter had received this diagnosis, was receiving insulin or hypoglycemic medication and/or a random blood glucose exceeded 8.3 mmol/L (150 mg/dl) [43].

We conservatively coded as absent risk factors undeterminable from the reports with two exceptions. First, regarding hypercholesterolemia, when no evidence of cholesterol testing was available, we assigned the value as missing. Second, in several reports, NIOSH investigators stated that the victim had several cardiovascular risk factors, but did not identify them. For these subjects, we assigned missing values in the initial unadjusted analyses to the risk factors not mentioned. Later, in multivariable-adjusted analyses, we re-coded these data as the absence of the risk factor to make the most conservative assumption.

We considered a previous abnormal exercise or radionuclide stress test, a history of coronary artery bypass grafting, angioplasty, myocardial infarction, angina, carotid stenosis or peripheral vascular disease as pre-existing evidence of arterial occlusive disease.

Active Firefighter Cardiovascular Controls

We considered hypertension as present if resting blood pressure was ≥140/90 mm Hg, or the firefighter was receiving anti-hypertensive medication. Smokers reported current cigarette smoking at the baseline examination. We defined hypercholesterolemia, diabetes mellitus and prevalent arterial occlusive disease as above for the cases.

Estimation of the Relative Proportions of Firefighters' Time Spent in Different Duties

We used information from fiscal year 2002 from the Cambridge (Massachusetts) Fire Department serving a community of about 100,000 inhabitants. The department provided: the total number of incidents and runs; the distribution of emergency calls and dispatches by hour of the day; a breakdown of incident types between fire and non-fire emergency responses; as well as mean incident and mean response times; and the estimated number of hours spent each week in training and fire prevention activities, respectively.

Statistical Analyses

We performed statistical analyses with SPSS® [44], and used independent T-tests to compare differences in mean values. We used the "Crosstabs" procedure to generate chi-square values and calculate odds ratios and Fisher's exact test as appropriate. Subsequently, we performed binary logistic regression to generate multivariable-adjusted odds ratios. We set the level of statistical significance at 0.05 (two-tailed) for all tests.

RESULTS

A preponderance of evidence demonstrated that the 52 firefighters included as CHD cases died as a result of ischemic heart disease, including autopsies in 36 cases (69%), and pre-morbid evidence of arterial occlusive disease in six additional cases (12%). Risk factors and symptomatology supported CHD as the most likely cause of death in the remaining 10 (19%) fatalities. Non-autopsy verified cases were more likely to be over 50 years old (p=0.001), but otherwise, their prevalence of risk factors was similar to the autopsy verified cases. Regarding professional status, 35 (67%) were professional firefighters with the remainder serving as volunteer firefighters. However, we found no significant differences in the prevalence of CHD risk factors between career and volunteer CHD decedents, and the majority of both groups had not undergone a fire department medical examination in the two years preceding their death (Table 1). Therefore, we combined the volunteer and the professional CHD cases for the case-control analyses.

Compared to the trauma fatalities, the CHD decedents were significantly older as expected: 51.6 ± 6.9 years old vs. 37.9 ± 13.2 years old (p<0.001). The CHD fatalities were also more likely to be professionals: 67% vs. 41% (p=0.008). We found no significant differences in geographic or temporal distribution (by year) between the CHD and trauma fatalities.

Circadian Patterns

Figure 1 depicts the circadian distribution of CHD and trauma fatalities in firefighters, both of which were similar to the daily distribution of emergency calls. The majority of on-duty CHD fatalities (77%), trauma fatalities (69%) and emergency calls (61%) occurred between noon and midnight. The distribution of CHD deaths was significantly different than a chance distribution of 25% in each quartile of the day (p=0.002). In the general population, CHD deaths peak between 6 am and noon. The difference between the observed pattern among the firefighters and that expected for the community based on over 19,000 cases from 19 studies [45] was also highly significant ($p<0.001$) (Figure 2). This pattern persisted even when only professional firefighters working 24-hour shifts or only volunteer firefighters were considered with 73% and 70%, respectively, occurring between noon and midnight.

Occupational Activities and Exposures

Table 2 compares various occupational circumstances for CHD and trauma fatalities. Fatality investigations reported strenuous physical activity on the job more frequently among the CHD deaths than for trauma deaths: OR 3.2 (1.4-7.2). While fire suppression was the last job activity for over 30% of both CHD and trauma deaths, we found a significant difference between these two groups in the percentage of firefighters engaged in other activities prior to death ($p=0.002$). Among CHD fatalities, we found similar distributions of last job activity engaged in prior to death for both professionals and volunteers ($p=0.60$).

Table 3 describes the estimated relative risks of CHD death in various job duties adjusted for the estimated proportion of time per year spent in each activity. Compared to non-emergency duty, the risk of CHD death was increased in all other activities. We found significantly increased risks during fire suppression (OR=64.1, 95% CI 7.4-556); training (OR=7.6, 95% CI 1.8-31.3) and alarm response (OR=5.6, 95% CI 1.1-28.8).

Cardiovascular Risk Factors

Table 4 compares the cardiovascular risk factor profiles of the CHD fatality cases and the active control firefighters. The mean age of the controls was 39 ± 7 years (range 20-58) compared with 52 ± 7 (range 34-69) for the decedents ($p<0.001$). Fifty of the deaths (96%) occurred in firefighters who were over 40 years old, while 51% of the active firefighters were younger than 40 years old. Initial unadjusted, univariate, odds ratios for all cardiovascular risk factors were significantly elevated. Of the 25 whose autopsies described their left ventricle, 76% had left ventricular hypertrophy.

We also estimated univariate relative risks for each cardiovascular risk factor in two additional models. We restricted the first to firefighters less than 60 years old and without a prior diagnosis of arterial-occlusive disease. In the second, we examined only those firefighters between 40 and 59 years of age. We consistently observed significantly elevated odds ratios for age ≥ 45 years, age over 50 years old, smoking, hypertension, diabetes and prior arterial-occlusive disease. The odds ratios for hypercholesterolemia were elevated, but not statistically significant in these two models, likely due to decreased sample sizes from the exclusion criteria and missing data among the cases.

Table 5 describes the results of two multivariable-adjusted models. These models were restricted to firefighters less than 60 years old due to the relatively small number of professional firefighters beyond this age in most fire departments, and the lack of controls older than 59 years old. Only two controls had any missing risk factor data, and we excluded them from the multivariate analyses. In these models, we found that age ≥ 45 years, smoking, hypertension, and prior arterial-occlusive disease remained strong independent predictors for on-duty death. To control further for the effects of age, we also performed a multivariate analysis that included age as a continuous variable. In this model, we found that the OR for hypertension (3.6, 95% CI (1.5-8.9)) and the OR for prior arterial-occlusive disease (11.5, 95% CI (2.5-53.3)) were somewhat attenuated, while the OR for smoking (7.6, 95% CI (2.9-20.1)) increased slightly. All three, however, remained strong independent predictors for on-duty CHD death.

Finally, we compared the prevalence of cardiovascular risk factors among firefighters dying of CHD during different types of activities. We found no significant differences in risk factor prevalence except that firefighters whose last duty was fire suppression were more likely to be ≤ 50 years old (p=0.032). Figure 3 shows that more dangerous duties were associated with a higher proportion of CHD deaths among relatively younger firefighters.

DISCUSSION

Our study demonstrated three major findings, which taken together strongly support that most on-duty CHD fatalities are work-precipitated and occur in firefighters with underlying CHD. First, the circadian distribution of on-duty CHD deaths among firefighters differed from the pattern of the general population and was associated with the temporal distribution of fire department incident responses. Second, more strenuous occupational activities carried the highest relative risks of death. Third, we found a significantly higher prevalence of cardiovascular risk factors among firefighters dying of on-duty CHD as compared to control firefighters. Conversely, we found that on-duty CHD deaths are unlikely to occur in firefighters without traditional cardiovascular risk factors.

Importantly, major cardiovascular risk factors are detectable at routine examinations and mostly modifiable. Yet, 75% of the firefighters who died from on-duty CHD in this study had not had a recent fire department medical examination. Therefore, fitness promotion, medical screening and improved medical management could prevent many of these premature deaths, and should be promoted and provided by fire service authorities.

Firefighters often work 24-hour shifts or provide 24-hour coverage through a variety of arrangements. Therefore, if on-duty CHD events had no relation to work, firefighter deaths should have a circadian pattern similar to the general population in whom cardiovascular events peak between 6 am and noon [45-48]. In stark contrast, we found most on-duty CHD fatalities occurred between noon and midnight. In agreement, a 10-year study of all U.S. firefighter deaths by FEMA found similar results, with 67% of cardiac fatalities occurring between noon and midnight [2]. Although the FEMA study did not hypothesize a reason for this afternoon-evening predominance, the most likely explanation is the higher volume of emergency calls during the latter half of the day.

Investigators have hypothesized that the morning excess in cardiovascular events among the general population is due to morning increases in arterial blood pressure, catecholamines, coronary tone, platelet aggregability, blood viscosity and a relative increase in serum cortisol [47]. Synchronized increases in these factors may also occur during the psychophysiologic arousal of an emergency response. Our second major result, implicating specific job activities, supports this hypothesis.

We found that fire suppression accounted for 36% of CHD deaths, which is remarkable because fire suppression may only represent 2% or less of a firefighter's yearly duties. The most likely explanation for a CHD death risk 60 times that of non-emergency duty is the increased cardiovascular demands of fire suppression [13, 15-17].

Consistent with the above findings, we found a significantly elevated CHD risk associated with training activities. An episode of heavy exercise, such as a training drill, can be a strong cardiac triggering factor especially among the physically inactive [49, 50]. The CHD training deaths in our study primarily involved strenuous drills carried out by victims lacking adequate physical fitness. Most fire departments do not require firefighters to exercise regularly. We reported a 33% prevalence of obesity among firefighters [27], which increased to 40% four years later [51]. Womack et al [52] found that both exercise tolerance and lean body mass were below age-predicted averages in another firefighter cohort. Furthermore, Roberts, et al [53] demonstrated elsewhere that even new firefighter recruits were overweight and had low-normal aerobic capacities.

Also in agreement with a triggering hypothesis and earlier research documenting increased heart rates in firefighters responding to alarms [13, 14], we found a roughly five-fold increase in the relative risk of CHD death during alarm response. Heart rate and blood pressure increase in response to alarms consistent with fight or flight physiology and remain elevated in unfit firefighters [54]. In addition, firefighters can be exposed to significant noise from truck sirens during alarm response also increasing blood pressure.

Regarding EMS and other non-fire emergencies, we found a smaller, non-significant increase in the risk of CHD death relative to non-emergency duties. This is noteworthy because EMS work has become the dominant emergency task of firefighters, but accounted for less than 6% of CHD fatalities in our study and 4% of cardiac deaths in the FEMA study [2]. Consistent with a lower CHD risk during EMS duty compared to fire suppression, 11% of on-duty deaths in EMS workers are due to cardiovascular causes [5], which is considerably lower than among firefighters.

We found excess cardiovascular risk factor prevalence among the CHD fatalities in agreement with previous studies regarding: the development of non-fatal CHD in firefighters [29], fire brigade retirements due to arterial disease [55], and CHD prediction in the general population [43,56]. We found robust evidence that age ≥ 45 years, current smoking, hypertension and a prior diagnosis of arterial occlusive disease are all strong independent predictors of on-duty CHD death.

Hypertension and hypercholesterolemia were highly prevalent among the CHD decedents in this study. The vast majority of the CHD fatalities in our study had not received a fire department medical examination within two years of the fatal incident, and many had LVH consistent with long-standing hypertension. We have recently shown that hypertension and dyslipidemias are often inadequately treated in firefighters, and that uncontrolled hypertension is associated with a higher risk of adverse changes in employment status [51, 57, 58]. Therefore, we believe that screening alone is insufficient, and fire department medical programs should include incentives to promote more aggressive risk factor reduction. For all of these reasons, we feel that the current NFPA numerical guideline for acceptable blood pressure (≤ 180/100 mm Hg) should be lowered and include provisions for progressively controlling hypertension [58, 59].

Over 25% of the CHD fatalities had known pre-existing arterial disease probably reflecting inadequate fitness for duty programs in their respective fire departments. For those who received a medical clearance for return to duty, these evaluations, in retrospect, did not appear to comply fully with the existing NFPA guidelines for firefighters with CHD [16]. Our results support a mandatory and conservative evaluation of firefighters with arterial occlusive disease as advocated by the NFPA.

Most of the victims in this study had not experienced previous symptoms of CHD or did not disclose them. Our results, therefore, should revive the question of stress tests for selected persons in physically demanding occupations. An abnormal exercise test can be an important prognostic indicator especially when combined with other risk factor information. A recent prospective study of over 25,000 asymptomatic men demonstrated that abnormal exercise tests are highly predictive of subsequent cardiac death, and the association increases for each additional risk factor present [60]. No clear guidelines exist, however, for stress testing in asymptomatic individuals, even for public safety professionals [16, 61-63]. Further study is needed to determine the most appropriate and effective strategy.

Primary CHD prevention should start with fitness promotion. Comprehensive programs can have beneficial effects on firefighters' risk profiles [64]. Robust scientific evidence strongly links increased physical fitness to decreases in cardiovascular risk and overall mortality in the general population [65]. Because CHD is also the leading cause of lifetime mortality among firefighters, averaging 36% [33-40], the benefits of fitness promotion would likely extend into retirement.

Our study has several potential limitations. First, we analyzed CHD deaths selected by NIOSH, most likely on a non-random basis. We believe this did not affect our findings because the circadian and job activity distributions we found were quite similar to those in the FEMA study including all available U.S. firefighting fatalities from 1990-2000. Thus, our cases were representative in terms of the precipitating circumstances. Although the NIOSH cases included a higher representation of professional firefighters compared to volunteers, we found no significant differences in cardiovascular risk factor prevalence or the frequency of fire service medical examinations between these two groups.

The second potential limitation regarded the estimation of relative risks for specific job-activities using incident and response data from a single fire department for a single fiscal year. While we were aware of this limitation in designing the study, we were unable to find any national data quantifying the proportion of time firefighters spend in various professional duties. In addition, it was impossible to collect such data from each fire department for each fatality. Because we hypothesized that strenuous emergency activities carry the highest risks of CHD death, we sought an urban fire department to ensure a sufficient level of emergency incidents. Cambridge, Massachusetts has a population of approximately 100,000 persons. Because only 14% of U.S. firefighters protect cities with populations greater than 100,000 [42], we feel that our choice was reasonable and conservative. To the extent that using an urban professional department to estimate the frequency of job activities and emergency responses resulted in overestimates of the extent of fire suppression and other emergency activities for rural and volunteer firefighters, this would have biased our results towards the null hypothesis. In terms of reliability, the fiscal year 2002 incident data we used were quite similar to fiscal years 1999-2001. Our study has several additional limitations regarding the assessment of cardiovascular risk factors. The less robust than expected relationship of hypercholesterolemia to CHD mortality in our study may be explained by unavailable data for many of the deaths, and the high prevalence of elevated cholesterol among the controls. Also, we did not have numerical cholesterol data for the CHD death cases. Therefore, we could not evaluate more predictive levels of hypercholesterolemia such as ≥ 6.22 mmol/L (240 mg/dl) [66]. Among Scottish firefighters retiring prematurely due to arterial disease, Ide [55] found significantly higher cholesterol and triglyceride levels compared to firefighters who completed maximum service. In addition, Glueck et al found total cholesterol > 240 mg/dl to be a highly significant predictor of incident CHD among firefighters [29]. The high prevalence of elevated total cholesterol among firefighters [26, 27, 29, 30] and its known relationship to CHD strongly support recommendations to include lipid profiles in firefighter medical examinations [16, 67].

Second, while we strongly associated diabetes mellitus with CHD death in unadjusted models, the relationship of diabetes to on-duty CHD death lost significance in the multivariate models.

Probably, this was due to the expression of CHD risk through the other independent risk factors highly prevalent among the diabetic fatalities (50% pre-morbid CHD, 75% hypertension and 89% over 50 years old). Additionally, because many of the decedents were not receiving regular medical examinations, we may have underestimated their prevalence of diabetes. The unadjusted associations support blood glucose measurement in firefighters and careful cardiovascular evaluations of diabetic firefighters.

Third, the comparability of the study groups and the methods of data ascertainment are always potential concerns in case-control studies. We could not use the trauma fatalities we used to compare circadian and job activity to compare cardiovascular risk factors because their NIOSH reports lacked information on personal risk factors. Although we could not completely match the occupational circumstances of the NIOSH CHD cases and the Massachusetts controls used for cardiovascular risk factor prevalence, we believe our choice was reasonable. Our cardiovascular control group consisted of professional firefighters who were examined in 1996/1997 and remained occupationally active in firefighting over the next two years. The deaths occurred during a comparable period. Although the decedents also included volunteer firefighters, we found no differences in risk factor prevalence between volunteer and professional CHD cases. Because we used the baseline data from the control Massachusetts firefighters, we minimized the effects of serial examinations on health status. In terms of data ascertainment, information constraints led to an incomplete determination of risk factors among the CHD deaths, and most missing risk factors were coded conservatively as absent (negative). The incomplete determination for the cases, but near universal determination of risk factors in the controls most likely biased our results towards the null hypothesis.

Our Massachusetts controls also had several other desirable characteristics. The state does not use physical criteria for selecting hazardous materials team members, and therefore, team participation is not associated with a significant healthy worker effect. Using Framingham predictions, the average 10-year, predicted CHD risk in these firefighters was essentially identical to that of an average person of the same age from the community [68]. Third, we have not documented evidence of any adverse health consequences of hazardous materials duty compared to other firefighters [69, 70].

CONCLUSIONS

The present study provides a firmer basis for developing improved guidelines for determining which CHD events in firefighters are work-related. Our findings support previous suggestions by Guidotti [11] that events during or within a day after fighting a fire are likely to be work-precipitated. In addition, the onset of symptoms during other work events likely to result in cardiovascular arousal also suggests work-relatedness.

There is a strong consensus that fire fighting is a physically demanding occupation requiring good cardiovascular fitness [1, 23, 25, 64]. Our study demonstrated that more strenuous occupational activities carried the highest relative risks of CHD death. Furthermore, we found a significantly higher prevalence of recognized and largely modifiable risk factors among firefighters succumbing to on-duty CHD death.

Despite recommendations that all firefighters receive periodic, occupational medical examinations [6, 16, 67], the fire service is failing to provide adequate medical programs to many U.S. firefighters. Major obstacles include the upfront costs of wellness and medical programs, as well as, the concerns of firefighters and unions that fitness for duty programs may remove some firefighters from active duty. More than a typical employer, the fire service affects firefighters' risk profiles beyond their immediate work activities in areas such as physical training, smoking policies, on-site nutrition and work schedules. Firefighters risk their lives to protect society. Given the preventable nature of CHD, the leading cause of on-duty deaths, fire departments, unions, workers compensation and pension authorities have an obligation to work together to implement adequate medical programs for all firefighters.

List of abbreviations

CI, confidence interval; CHD, coronary heart disease; EMS, emergency medical services; FEMA, Federal Emergency Management Agency; LVH, left ventricular hypertrophy; NFPA, National Fire Protection Association; NIOSH, National Institute of Occupational Safety and Health; OR, odds ratio; U.S., United States.

Competing interests

SNK was a reimbursed speaker at a National Fire Protection Association meeting in 1998 and is a member of the organization.

Authors' Contributions

SNK conceived the study, obtained funding, performed chart reviews of firefighters' CHD deaths cardiovascular risk factors, supervised all aspects of the project and had primary responsibilities for data analysis and manuscript preparation and revision. ESS assisted with study design, performed chart reviews of CHD deaths cardiovascular risk factors, supervised database management, performed multivariate analyses and assisted with manuscript preparation and revision. SGC performed the initial chart reviews, database management and assisted with data analyses. DCC assisted with obtaining funding, study design, manuscript preparation and revision.

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Table 1: Characteristics of the CHD[†] deaths: career versus volunteer firefighters.

	Volunteer Firefighters (n=17) % (n)	Career Firefighters (n=35) % (n)	P-value
Fire Department Medical Exam within 24 months of Incident	**12 (2)**	**32 (11)**	**0.18***
Age ≥ 45 years old	**76 (13)**	**86 (30)**	**0.45***
Age > 50 years old	**53 (9)**	**51 (18)**	**0.92**
Current Smoking	**46 (6/13)**	**50 (15/30)**	**0.82**
Hypertension	**86 (12/14)**	**72 (23/32)**	**0.46***
Diabetes Mellitus	**23 (3/13)**	**21 (6/29)**	**1.00***
Cholesterol ≥ 5.18 mmol/L (200 mg/dl)	**83 (10/12)**	**91 (20/22)**	**0.60***
Prior Diagnosis of CHD or other evidence of arterial-occlusive disease	**31 (5/16)**	**23 (8)**	**0.73***
Autopsy Verified CHD	**53 (9)**	**77 (27)**	**0.076**
LVH[‡] at Autopsy, if Left Ventricle described	**88 (7/8)**	**71 (12/17)**	**0.62***

* Fisher's Exact Test. [†]Coronary heart disease; [‡]Left ventricular hypertrophy.

Table 2: Comparison of job-related factors preceding the on-duty fatality: CHD[†] deaths versus trauma deaths.

	CHD Deaths (n=52) % (n)	Trauma Deaths (n=51) % (n)	P-value OR[@] (95% CI[$])
Strenuous Physical Activity on the job in the preceding 12 hours	**67 (35)**	**39 (20)**	**0.004** **3.2 (1.4-7.2)**
Possible Smoke Exposure at Incident	**42 (22)**	**31 (16)**	**0.25** **1.6 (0.7-3.6)**
Last Job Activity:			
Fire Suppression	**36 (19)**	**31 (16)**	
Training	**17 (9)**	**8 (4)**	**0.002[1]**
Fire House	**14 (7)**	**0**	
EMS[¶] or Other Non-Fire Emergency	**12 (6)**	**6 (3)**	
Alarm Response	**10 (5)**	**33 (17)**	
Returning from Alarm	**10 (5)**	**6 (3)**	
Desk Duty (Light Duty)	**2 (1)**	**0**	
Inspection or Investigation	**0**	**6 (3)**	
Maintenance	**0**	**8 (4)**	
Non-emergency Transit	**0**	**2 (1)**	
Carboxyhemoglobin Post Incident:			
<3 %	**76 (13/17)**		
3-4.9 %	**18 (3/17)**	———	———
5-10 %	**6 (1/17)**		
Hours on Duty Prior to Symptoms (Professionals Only):			
0-3.9	**24 (7/29)**		
4-7.9	**28 (8/29)**	———	———
8-11.9	**17 (5/29)**		
12-15.9	**10 (3/29)**		
16-19.9	**7 (2/29)**		
20-23.9	**0**		
>24	**14 (4/29)**		
Workshift Type (Professionals Only):			
24 hour	**34 (11/32)**		
Rotating, night or evening	**23 (8/32)**		
Overtime	**22 (7/32)**		
On Call	**9 (3/32)**	———	———
Regular, Daytime	**6 (2/32)**		
48 hour	**3 (1/32)**		

[1]p-value for last job activity relates to the X^2 test of the difference in the distribution of the proportions of firefighters in each group engaged in each of the duties described. [†]See Table 1; [@]Odds ratio; [$]Confidence interval; [¶]Emergency medical services.

Table 3. Relative risk of CHD† for various job duties adjusted for the estimated proportion of time per year spent in each professional duty.

Type of Duty	Actual CHD Deaths (N=52) %(n)	Expected* CHD Deaths (N=52) %(n)	Estimated Odds Ratio for each Activity relative to Non-Emergency Activities †† OR@ (95% CI$)	p Value **
Fire Suppression	**36 (19)**	**2 (1)**	**64.1 (7.4-556)**	**<0.001**
Training	**17 (9)**	**8 (4)**	**7.6 (1.8-31.3)**	**0.006**
Alarm Response	**10 (5)**	**6 (3)**	**5.6 (1.1-28.8)**	**0.042**
Alarm Return	**10 (5)**	**10 (5)**	**3.4 (0.8-14.7)**	**0.12**
EMS¶ or Other Non-Fire Emergency	**12 (6)**	**23 (12)**	**1.7 (0.5-5.9)**	**0.52**
Fire House and Other Non-emergency activities	**15 (8)**	**52 (27)**	**1.0**	**_**

* Expected counts adjusted by yearly Estimated Incident and Response Times, Yearly Frequencies, and assume all activities are of equal risk. ** Fisher's Exact Test. †† Odds Ratios for Observed Counts versus Expected Counts for Each Activity relative to Non-emergency activity Observed and Expected. †See Table 1; ¶ @ $ See Table 2.

Table 4: Characteristics of the study groups: CHD† deaths and active firefighter controls.

	CHD Deaths (n=52) % (n)	Active Firefighters (n=310) % (n)	OR@ (95% CI$)
Age ≥ 45 years old	**83 (43)**	**21 (64)**	**18.4 (8.5-39.6)**
Age > 50 years old	**52 (27)**	**4 (14)**	**22.8 (10.6 – 49.0)**
Current Smoking	**49 (21/43)**	**10 (31)**	**8.6 (4.2 – 17.4)**
Hypertension	**76 (35/46)**	**21 (65)**	**12.0 (5.8 – 24.9)**
Diabetes Mellitus	**21 (9/42)**	**3 (8)**	**10.2 (3.7 – 28.3)***
Cholesterol ≥ 5.18 mmol/L (200 mg/dl)	**88 (30/34)**	**63 (196)**	**4.4 (1.5 – 12.7)**
Prior Diagnosis of CHD or other evidence of arterial-occlusive disease	**26 (13/51)**	**1 (3)**	**35.0 (9.5 -128.4)***

* Fisher's Exact Test. †See Table 1; @ $ See Table 2.

Table 5: Multivariable-adjusted odds ratios for the association of risk factors and on-duty CHD[†] death.

	OR[@] (95% CI[$]) *	
	Model 1 **Age < 60[§]**	**Model 2** **Age <60 and no prior CHD diagnosis[‡‡]**
Age ≥ 45 years old	**6.5 (2.6 – 15.9)**	**6.2 (2.4 – 16.0)**
Current Smoking	**7.0 (2.8 - 17.4)**	**8.7 (3.3 - 22.5)**
Hypertension	**4.7 (2.0 - 11.1)**	**6.2 (2.4 – 15.7)**
Diabetes Mellitus	**2.0 (0.5 – 8.6)**	**2.4 (0.5 – 13.1)**
Prior Diagnosis of CHD or other evidence of arterial-occlusive disease	**15.6 (3.5 – 68.6)**	**-**

* Odds ratios are adjusted for all other risk factors in the table. For example, the OR for current smoking is adjusted for age ≥ 45 years old, hypertension, diabetes and prior CHD. [§] Model 1 included all CHD death cases (n=46) and active control firefighters (n=308) less than 60 years old. [‡‡] Model 2 was restricted to firefighters less than 60 years of age without a prior diagnosis of CHD or other evidence of vaso-occlusive disease. Cases (n=33) and controls (n=305). [†]See Table 1; [@ $] See Table 2.

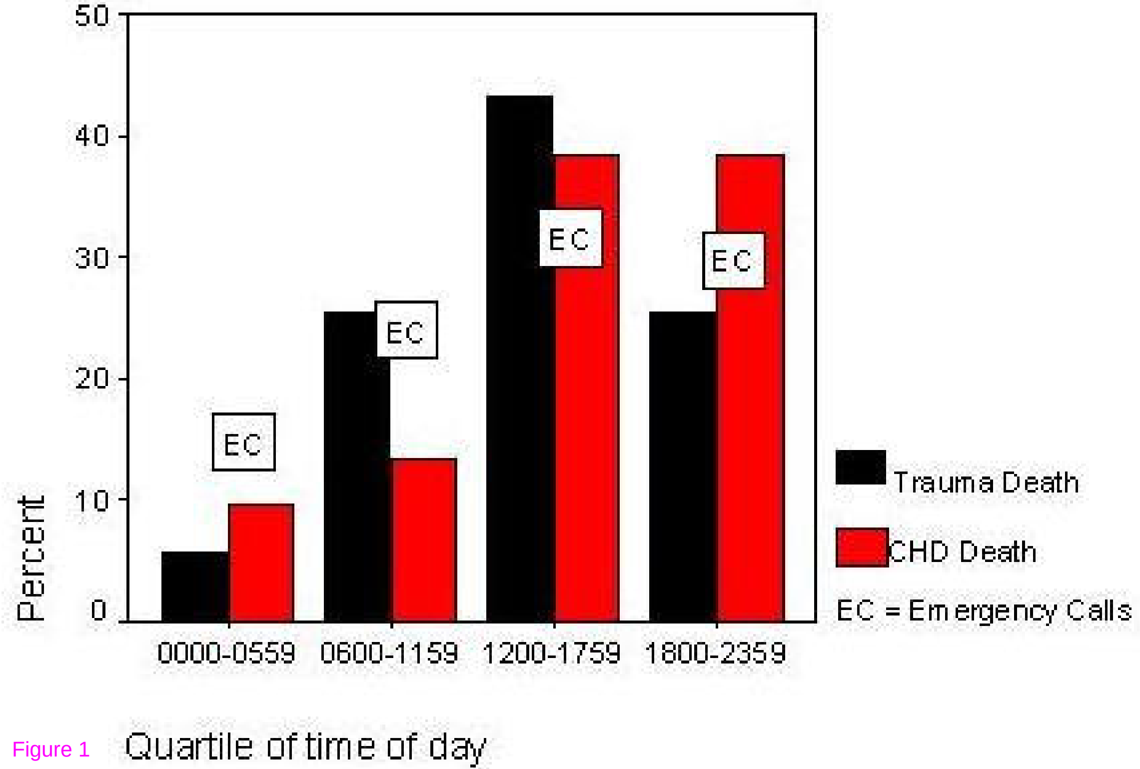
Figure 1: Circadian Distribution of Firefighter Fatalities compared with the Distribution of Emergency Calls.

Figure 2: Circadian Distribution of CHD Deaths for Firefighters and the General Population.

Figure 3: Percent of On-duty CHD Fatalities occurring in Firefighters ≤ 50 years old and Relative Risk of CHD Death as a Function of Different Duties.

Red Boxes: Horizontal line inside each box corresponds to the OR for CHD death for each activity vs. non-emergency activity. Upper horizontal line corresponds to the upper limit of the 95% CI, and the lower horizontal line corresponds to the lower limit of the 95% CI.

Blue Boxes: Horizontal center of each box corresponds to the proportion expressed as a percent of CHD deaths that occurred among firefighters ≤ 50 years old in each activity.


50
40
30
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Percent
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0000-0559
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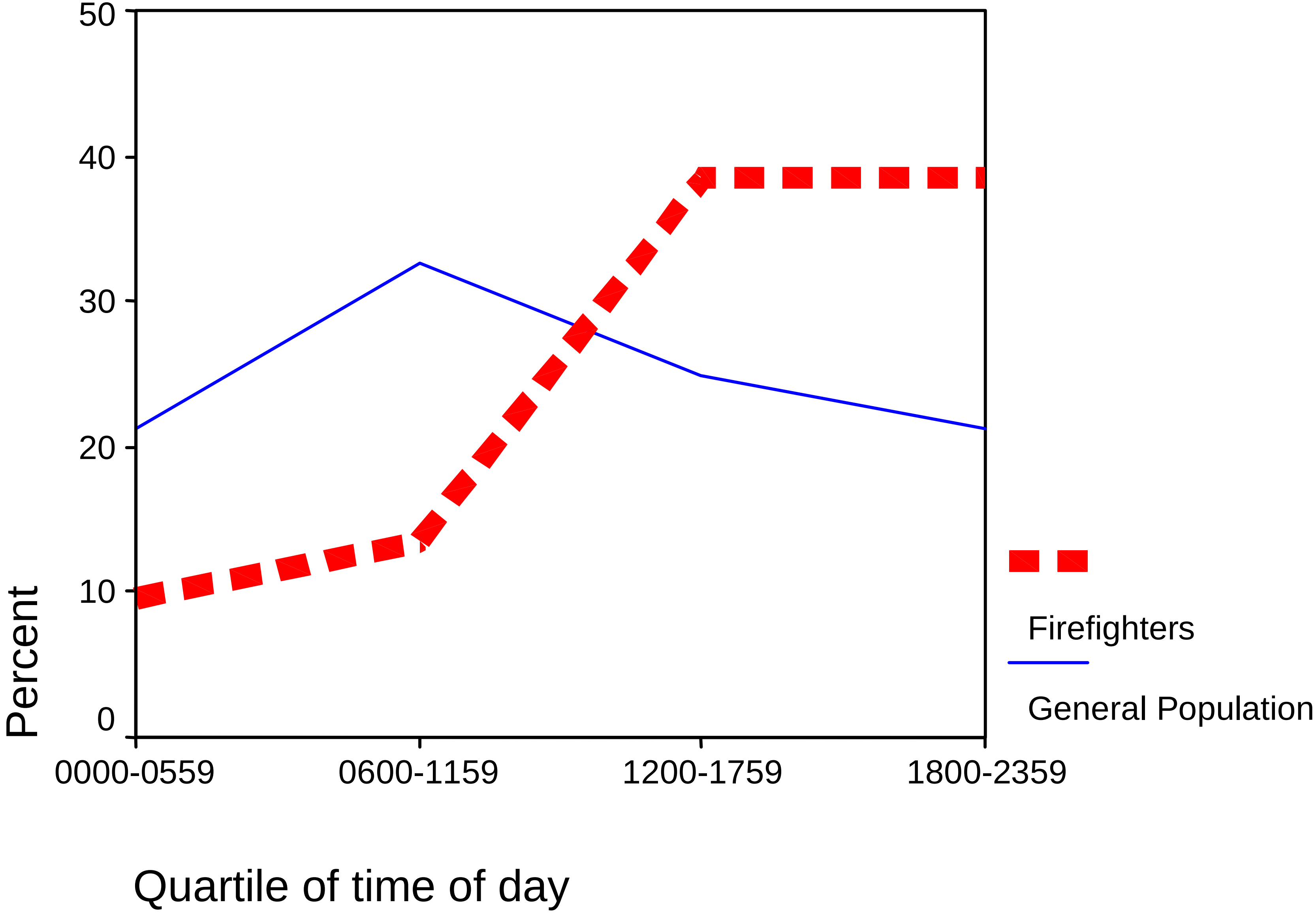
1800-2359
Trauma Death
CHD Death
EC = Emergency Calls
Quartile of time of day

Figure 1

Figure 2



50
40
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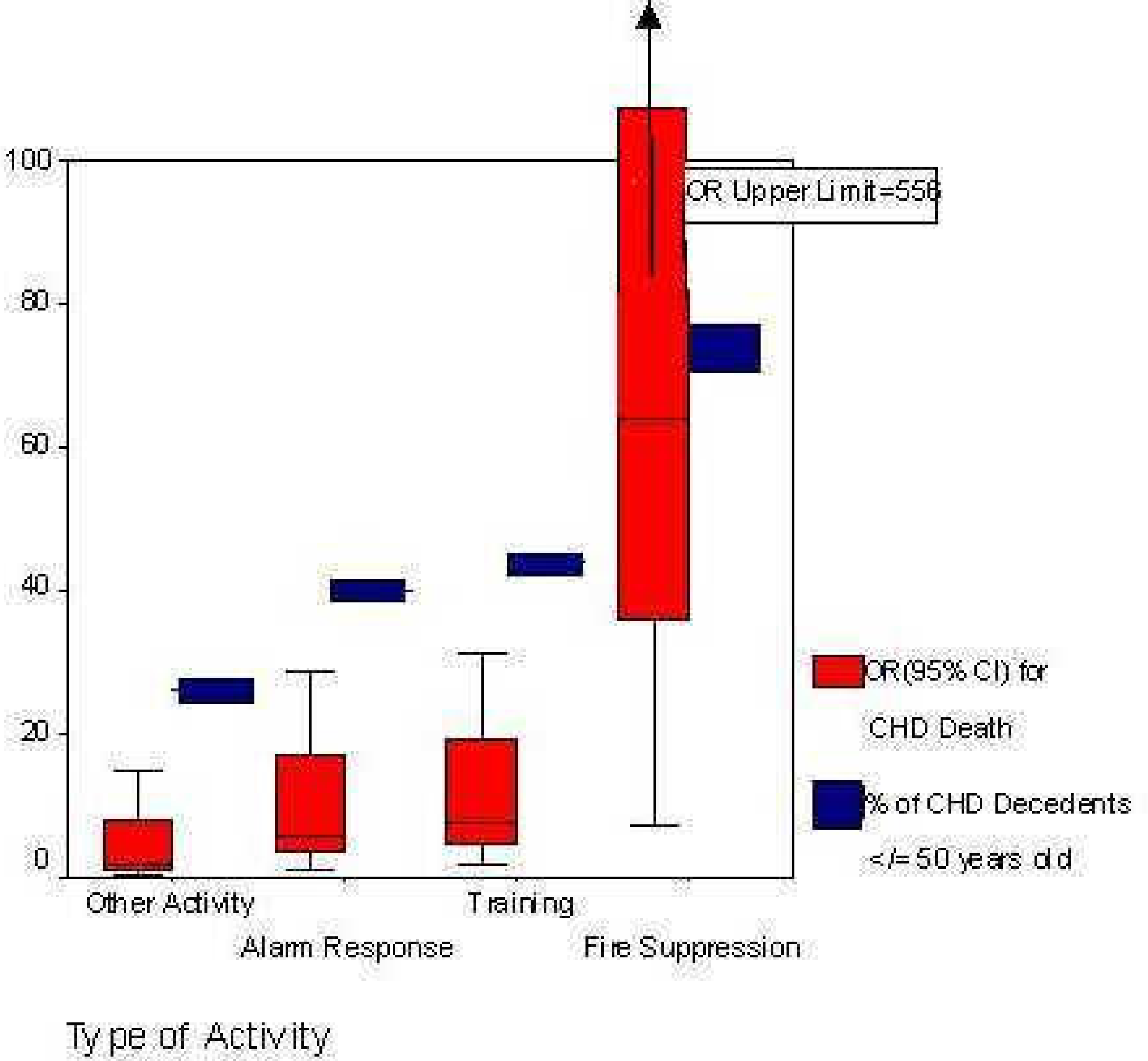
Quartile of time of day
Firefighters
General Population


100
80
60
40
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OR Upper Limit=556
OR(95% CI) for
CHD Death
% of CHD Decedents
</= 50 years old
Other Activity
Alarm Response
Training
Fire Suppression
Type of Activity

Figure 3