Occupational Medicine 2014;**64:**228–232
doi:10.1093/occmed/kqu057

EDITORIALS

Sudden cardiac death in the fire service

Fire scenes are unpredictable environments characterized by numerous dangers: loud noise, high temperatures, flames, smoke and its toxic components, and potential instability of the affected structures among others. Accordingly, firefighting is widely recognized as a hazardous profession that can result in burns, trauma, smoke inhalation and other myriad injuries. Nonetheless, in the USA, the leading cause of duty-related fatalities among firefighters is cardiovascular disease (CVD). In fact, sudden cardiac death (SCD) has consistently accounted for approximately 45% of all on-duty firefighting deaths in the USA since at least the 1970s [1–3]. To understand why SCD is the predominant cause of on the job death, one must examine the physical demands of firefighting and the resulting psychophysiologic responses.

Structural firefighting requires the performance of activities combining static and aerobic exertion: stair and ladder climbing (with simultaneous heavy materials handling), forcible entry, search and rescue for victims, cutting and chopping to provide ventilation of the building and advancing charged hoselines to attack and suppress the fire [1,3,4]. Additionally, these essential duties are performed while wearing encapsulating protective clothing that weighs ≥25 kg, plus tools, which exacerbate the heat load and metabolic demands of firefighting. Based on several studies, expert consensus has concluded that firefighters require a minimum aerobic capacity of 42 $ml \cdot kg^{-1} \cdot min^{-1}$ (or 12 metabolic equivalents (METs)) to safely perform all of their essential tasks [1,3].

The psychophysiological responses to these extreme environmental conditions and physical demands are complex. Following an initial fire alarm, a 'fight-or-flight' reaction ensues with prominent sympathetic arousal [1,3–5]. This sympathetic response leads to increases in heart rate and blood pressure and continues during transport to the scene and during the emergency response. Subsequently, the heavy strenuous work described above adds to the considerable cardiovascular strain of firefighting. Moreover, adverse environmental conditions and the use of heavy personal protective equipment (PPE) may produce hyperthermia and dehydration, which further increase heart rate and blood pressure leading to increased vascular shear stress, a decrease in plasma volume and resulting changes in electrolytes, increased blood viscosity and a procoagulatory state [4–7].

Depending on the type and specifics of the emergency scene, firefighters experience alterations in physiological function that can range from moderate to severe. Nonetheless, this work does not normally pose a great risk to healthy and fit firefighters [4,5]. However, in susceptible firefighters including individuals with underlying structural or coronary heart disease (CHD), firefighting may result in pathological changes that greatly increase the risk of thrombosis, coronary plaque rupture and/or arrhythmia, which can lead directly to SCD or a non-fatal CVD event [1,3].

Major advances in epidemiology have clarified job-related and lifestyle/health-related risk factors for on-duty SCD in the fire service. Indeed, numerous studies have shown that a variety of stressful situations (physical exertion, strenuous work, strong emotions, air pollution, respiratory infections and certain intoxicants) can trigger acute CVD events, particularly in more sedentary, susceptible individuals with underlying CHD. Several of these factors (physical exertion, strenuous work, emotional stress and environmental pollutants) are regularly encountered by firefighters during fire suppression activities [1,3].

Not surprisingly, several investigations have now proven that firefighting is a trigger for SCD and other CVD events. The largest of these studies examined all 449 acute line-of-duty deaths from CHD that occurred between 1994 and 2004 in the US fire service [2]. Using a sensitivity analysis, which included three different risk (exposure) estimates to account for uncertainties in the relative time spent by firefighters across different fire service duties, strenuous firefighting activities were associated with markedly elevated odds of SCD in all three statistical models. For example, although fire suppression duties (mitigating and extinguishing fires) were found to represent between 1% and 5% of a firefighter's annual working time, fire suppression activity accounted for more than 30% of on-duty SCD related to CHD. Statistically, this translated to relative risks of 10-fold to over 100-fold for SCD during fire suppression compared to non-emergency duties [2]. Elevated risk (2- to 10-fold) of SCD carries over to the subsequent period of recovery after the fire or 'alarm return'. Increased odds of SCD compared to non-emergency duties were also found during physical training activities (including exercise, simulated fires and training drills) and alarm response (3- to 14-fold) where in this latter case the risk is limited mostly to volunteer firefighters. Notably, the provision of emergency medical services (EMS) (the most frequent emergency duty in the US fire service) has not clearly been associated with a statistically increased SCD risk in any of our studies [3].

Using firefighter fatality investigations and cross-sectional data collection from professionally active firefighters, we have also performed a series of careful case-control studies of SCD, which have elucidated lifestyle/health-related risk factors consistently associated with SCD and CVD [3,8–10]. As a result, we now know that on-duty CVD events occur almost exclusively in (i) firefighters with previously diagnosed CVD; (ii) firefighters with some type of underlying structural heart disease, which is often undetected before death; (iii) firefighters with a clustering of traditional CVD risk factors and subclinical CHD; or (iv) firefighters who fit into more than one of the three categories above (i–iii). Most specifically, autopsies of firefighter SCD victims typically show varying degrees of coronary atherosclerosis usually accompanied by left ventricular hypertrophy (LVH)/cardiomegaly. In fact, we are increasingly appreciating the role of cardiac enlargement in fire service SCD. Among younger SCD victims (</=45 years old), we recently documented a mean difference in excess of 120 g in heart weights compared to victims of traumatic fire deaths; and cardiomegaly (heart weight >450 g) conveyed a 5-fold increase in the risk of SCD [9].

Not surprisingly, compared to control firefighters, younger and older SCD fatalities and CVD retirements demonstrate statistically excess burdens of classic CVD risk factors—smoking, hypertension and obesity [3,8–10]. Our studies have also shown that about 21–30% of SCD firefighting fatalities occur in persons who have a previously known diagnosis of CHD, significant structural heart disease or a clinical CHD equivalent (e.g. peripheral artery disease, ischaemic stroke, etc.). Age is also a strong predictor of SCD and CVD retirement in the fire service, with risks increasing in a consistent dose-response fashion; with a larger upward spike in risk beyond the age of 60 years old [2,10]. Duty-related risks of SCD among firefighters ≥60 years old range from about 4- to 18-fold (depending on the duty performed) greater than colleagues 40–49 years old [2]. Thus, one would reasonably expect that the changes in firefighter retirement age from 55 to 60 years of age discussed in the companion editorial may result in some increase in on-duty SCD in the UK fire service [11].

Based on the established epidemiologic data, several measures to reduce SCD in the fire service logically follow.

(1) Completely ban smoking and tobacco products in fire services.

(2) Balance anti-discrimination and employment law considerations with common sense obesity standards for candidate and incumbent firefighters based on the elevated risks of injury, disability and, particularly, cardiomegaly and SCD linked to excess adiposity.

(3) Encourage wellness programs that among other measures offer on-duty time for required regular exercise to improve and maintain firefighters' fitness; mitigate weight gain over the career span; and help manage existing risk CVD factors.

(4) Ensure that routine medical evaluations are performed yearly for all firefighters, that CVD risk factors are evaluated and aggressively treated, and when appropriate, perform additional screening or testing (such as exercise stress testing, coronary artery calcium scans or echocardiography) to detect atherosclerosis or cardiac enlargement.

(5) Restrict most firefighters with established CHD or other structural heart disease from participating in strenuous emergency duties on the basis of the overwhelming evidence supporting markedly higher relative risks (up to 15-fold even after covariate adjustments) of SCD among such firefighters [3,8,9]. EMS duties may be appropriate for some of these firefighters.

(6) Adopt mandatory retirement from active firefighting (fire suppression and other strenuous duties) at 60 years of age based on statistical evidence, including among volunteer firefighters.

Despite advances in scientific understanding of the psychophysiological responses to firefighting and the factors that increase the risk of SCD, further research is needed. Future investigations should focus on the pathological-anatomic causes of SCD. More systematic examination of autopsy data is needed to better understand the relative and often synergistic roles of structural heart disease (LVH/cardiomegaly) and atherosclerotic CHD, and finding measures that mitigate the risk of SCD due to arrhythmia. Research is also needed to determine the most effective techniques for detecting CHD and pathological structural changes in heart morphology, establishing clinical algorithms for determining who should be screened using such techniques and identifying actionable thresholds of disease for continued monitoring and treatment versus duty restrictions. Finally, research efforts need to be continued to develop effective lifestyle interventions to improve diet and fitness while reducing obesity.

Funding

US Federal Emergency Management Agency (FEMA, Washington DC, USA) Assistance to Firefighters Grant (AFG) program's awards EMW-2009-FP-00835 (PI: Dr. S.N.K.) and EMW-2011-FP-00663 (PI: Dr. S.N.K.). US Federal Emergency Management Agency (FEMA, Washington DC, USA) Assistance to Firefighters Grant (AFG) program's awards EMW-2010-FP-01992 (PI: Dr. D.L.S.).

Conflicts of interest

S.N.K. has served as an expert witness in legal cases involving firefighters and was also contracted to revise the Heart Disease Manual of the International Association of Fire Fighters. D.L.S. has served as an expert witness in legal cases involving firefighters and has conducted investigations for the National Institute of Occupational Safety and Health Fire Fighter Fatality Investigation and Prevention Program.

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doi:10.1093/occmed/kqu068

Fire service pensions review

Life expectancy is increasing but so is the prevalence of obesity and non-communicable disease. Drawing a pension for longer is not economically viable; pressure on pension schemes leads to higher retirement age and longer work life. Uniformed services are not immune to the laws of economics, and the recent changes in terms and conditions for firefighters included a rise in pension age from 55 to 60 years. When this decision was made, there was no formal consideration of the impact of health on working as a firefighter in older age or whether firefighters can remain fit enough to work beyond age 55. As a result, the Firefighter Normal Pension Age Review was commissioned and published in late 2012 [1].

The pension age for firefighters has been considered in the past. It was originally higher, but statute brought it down to age 55 early in the last century. Haisman considered the situation in 1996 [2] and noted that population fitness levels implied that many firefighters would be unfit above the age of 55, and he felt the impact of chronic disease would be significant. However, there has been no calculation of the numbers likely to become unfit before retirement age.

The first step in the Firefighter Normal Pension Age Review was to identify a fitness level needed for firefighting. No single standard has been formally accepted across UK fire and rescue services, although a VO_2max of 42 ml kg^{-1} l^{-1} is currently recommended [3]. Studies show that below a VO_2max of 35 ml kg^{-1} l^{-1}, the risk of sudden cardiac death on extreme exertion increases substantially [4,5], so this is often used as a minimum fitness standard. The pension review used a VO_2max of 42 as their benchmark without endorsing it, leaving it to the FireFit committee to continue their work in developing a robust job-related standard and test protocol.

Population fitness studies suggest that meeting this VO_2max could be increasingly difficult with age, especially