Cardiorespiratory fitness and the metabolic syndrome in firefighters

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Aims
To document the levels of cardiorespiratory fitness and the metabolic syndrome, as well as to determine if there is a relationship between these variables, in firefighters.

Methods
Maximal cardiorespiratory fitness was assessed using the Bruce treadmill protocol in 214 male firefighters from Colorado. As part of a comprehensive cardiovascular disease risk evaluation, each firefighter was also screened for the metabolic syndrome using the National Cholesterol Education Program/Adult Treatment Panel III (NCEP/ATP III) guidelines.

Results
At the time of their evaluation, 32 firefighters (15%) met the NCEP/ATP III diagnostic criteria for the metabolic syndrome, and 54 firefighters (25%) failed to achieve a generally accepted minimum cardiorespiratory fitness level of 42.0 ml/kg/min. A significant inverse trend of increasing cardiorespiratory fitness with decreasing metabolic abnormalities was found ($P < 0.001$).

Conclusions
Increased levels of cardiorespiratory fitness are associated with an improved metabolic profile in male firefighters. Comprehensive cardiovascular disease risk factor management and cardiorespiratory fitness improvement are essential for firefighter health and safety.

Key words
Exercise; firefighters; heart disease.

Introduction
Firefighters represent a unique occupational group in that their job puts them in harm’s way on a daily basis in order to protect the safety and well-being of others. Yet, the leading cause of mortality among this occupational group is not injury but sudden cardiac death [1]. From 1995 to 2004, 440 of the 1006 (44%) fatalities in USA career firefighters on duty fell into this category (excluding the 340 firefighter deaths at the World Trade Center in 2001) [1]. In contrast, sudden cardiac death accounts for ~22% of deaths among on-duty police officers, 11% of deaths among emergency medical services workers and 15% of all deaths that occur at work in the USA [2,3]. This clearly represents a major health concern not only for firefighters but also for the general population which relies on their services.

Unfortunately, the reasons for this remain unclear despite advances in the understanding of the aetiology of cardiovascular disease. It has been suggested that the high incidence of sudden cardiac death among firefighters may be the result of elevated susceptibility, as determined by the high prevalence of cardiovascular disease risk factors, in individuals exposed to acute physiological and psychological stress [4–8]. While previous research has focused primarily on individual risk factors such as hypertension, dyslipidemia and obesity, less work has been done to examine the prevalence of the metabolic syndrome, or the clustering of several cardiovascular disease risk factors, in this occupational group. This is despite the fact that the risk factors associated with the syndrome are believed to act synergistically to increase cardiovascular disease morbidity and mortality [9]. An increasing volume of literature also implicates low cardiorespiratory fitness as a major modifiable risk factor for several chronic diseases and premature mortality [10]. The purpose of this study was therefore to document the levels of cardiorespiratory fitness...
fitness and the metabolic syndrome, as well as to determine if there is a relationship between these variables, in career firefighters in the USA.

Methods

The present study used data previously collected from career firefighters who had participated in the Heart Disease Prevention Programme (HDPP) through the Human Performance Clinical/Research Laboratory (HPCRL) at Colorado State University. At the time of participation, each firefighter provided written informed consent to allow his/her data to be used for research purposes. Study approval was granted by the Human Research Committee at Colorado State University.

Numerous fire departments across the state of Colorado have used the HDPP as a means by which to conduct annual and semi-annual health and fitness evaluations for on-duty firefighters. From 10 March 2004 to 12 October 2006, a total of 242 firefighters from five fire departments participated in the HDPP. Departments represented varied in size and geographic location. Participation was mandatory for all on-duty firefighters within these departments. All firefighters were free of diagnosed heart disease at the time of their evaluation and had no contraindications to exercise testing. Three participants were excluded from the study sample due to acute illness or infection at the time of their evaluation. Subjects included in the final analysis were of data from 214 male firefighters.

Each firefighter presented to the HPCRL for a preliminary evaluation and a maximal graded exercise test. Prior to arriving at the HPCRL, subjects completed a medical history questionnaire, emotions questionnaire including the Center for Epidemiological Studies-Depression Scale and the Cook Medley Hostility Scale [12,13], and 4-day nutrition log. Therefore, demographic characteristics, personal and family history of chronic diseases, medication use and alcohol and tobacco use were determined by self-report.

All blood chemistry analyses were completed by a Clinical Laboratory Improvement Amendments certified off-site contract laboratory. The Friedewald equation was used to calculate low density lipoprotein cholesterol for all subjects with a serum triglyceride level <400 mg/dl (<4.5 mmol/l) [14]. Height and weight were measured on a standard physician’s scale and stadiometer. Waist circumference was measured at the level of the umbilicus, and body composition was determined via hydrodensitometry.

Blood pressure was assessed according to standard protocol using a mercury sphygmanometer. Measurements were taken in the seated position during the preliminary evaluation or prior to beginning the graded exercise test. A 5-min rest period preceded the measurement.

Cardiorespiratory fitness was assessed via a maximal graded exercise test. All exercise testing sessions were supervised by a cardiologist or internal medicine physician. Firefighters performed a Bruce protocol on a motor-driven treadmill to volitional fatigue or until the test was terminated by the physician [11]. During each test, a 12-lead electrocardiogram was used to monitor the subject’s heart rhythm and rate. Heart rate was recorded every minute and blood pressure was measured by a trained technician every 3 min. Total graded exercise test time was used to predict maximal oxygen consumption ($V_{O_{2,max}}$) using a previously validated formula [11].

Mean descriptive characteristics were assessed and presented as means and standard deviations (SDs) or per cents. The following variables were evaluated for potential confounding: age, body mass index (BMI), smoking status, alcohol consumption, self-reported anxiety level, high density lipoprotein (HDL) and triglyceride levels, hypertension, fasting insulin and glucose concentrations, diabetes mellitus, the metabolic syndrome, chronic infection or inflammation, cardiorespiratory fitness and aspirin, statin, fibrate or niacin use. All analyses were performed using SAS (version 9.1, Cary, NC, USA) statistical software. Two-sided probability ($P$) values <0.05 were considered statistically significant.

The prevalence of the metabolic syndrome among the sample population of firefighters was determined using National Cholesterol Education Program/Adult Treatment Panel III (NCEP/ATP III) guidelines [15]. These state that presence of any three of the following risk factors are sufficient for the clinical identification of the metabolic syndrome: abdominal obesity (waist circumference >102 cm in men or >88 cm in women), hypertriglyceridemia ($\geq$150 mg/dl (>=1.7 mmol/l)), low HDL cholesterol [$<40$ mg/dl ($<1.0$ mmol/l) in men or $<50$ mg/dl ($<1.3$ mmol/l) in women], elevated blood pressure ($\geq 130$ mmHg systolic or $\geq 85$ mmHg diastolic) and hyperglycaemia ($\geq 110$ mg/dl $^{-1}$ (>=6.1 mmol/l)). After controlling for confounders using a generalized linear model, a linear regression analysis was conducted comparing cardiorespiratory fitness (expressed as estimated $V_{O_{2,max}}$) across the number of metabolic abnormalities. Least-squared mean differences with 95% confidence intervals (CIs) were used to assess differences in cardiorespiratory fitness according to the number of metabolic abnormalities (0, 1, 2 or $\geq$3 metabolic syndrome components). The multivariable model stability was assessed using collinearity diagnostics. The Shapiro–Wilk test was used to assess normality of the residuals, and no transformations were necessary.
Results

The final analysis consisted of 214 career male firefighters from Colorado. The clinical characteristics of firefighters with and without the metabolic syndrome are presented in Table 1. Overall, the mean age of the study population was 39 (SD = 9) years. A majority of firefighters were Caucasian (95%). Using standardized BMI classifications, 25% of the firefighters tested were of normal weight (BMI < 25.0), 56% were overweight (BMI 25.0–29.9) and 19% were obese (BMI ≥ 30.0) [16]. Descriptive frequencies for smoking and alcohol consumption are also included in Table 1.

Table 2 shows the prevalence of individual metabolic syndrome components as well as the number of metabolic abnormalities, as defined by NCEP/ATP III clinical guidelines. At the time of testing, 32 firefighters (15%) met the diagnostic criteria for the metabolic syndrome. The prevalence of the metabolic syndrome by age group is depicted in Figure 1. Fourteen per cent of 20–29 year olds, 9% of 30–39 year olds, 21% of 40–49 year olds and 18% of 50–59 year olds met the diagnostic criteria for the metabolic syndrome. High blood pressure was the most prevalent abnormality among the study population (55%). At the time of their evaluation, 10% of firefighters had a resting blood pressure of ≥ 140/90 mmHg and 14% were currently taking antihypertensive medication.

Discussion

We found the prevalence of metabolic syndrome in the group of firefighters studied to be 15%. Furthermore, we found an inverse relationship between cardiorespiratory fitness and the number of metabolic abnormalities. Several strengths in the study design should be noted. First, cardiorespiratory fitness and each of the components of the metabolic syndrome were objectively measured.
assessed by trained technicians according to standardized protocols, thus reducing the potential for misclassification or observation bias. Specifically, cardiorespiratory fitness was estimated by way of a maximal graded exercise test rather than a sub-maximal test or self-reported physical activity data. The Bruce treadmill protocol has been frequently used for this purpose by other groups to examine the aerobic capacity of firefighters [17,18]. The availability of detailed information on medical history, smoking and medication use also allowed potential confounders to be tested and adjusted for statistically. The self-reported smoking rate was found to be low (4%) in the study group, but similar to that reported by others [8]. This can be attributed to common departmental mandates prohibiting cigarette use by career firefighters in Colorado.

Not surprisingly, this study revealed that the prevalence of the metabolic syndrome is lower among firefighters than the 24% prevalence rate observed among males in the general population of the USA [19]. Several factors could potentially contribute to this difference. First, the mean age of the study population was younger than that of the nationally representative sex-matched sample [19]. It should be noted, however, that the prevalence of the metabolic syndrome among the youngest firefighters in the study (20–29 years old) was nearly double that of the age and sex-matched general population (7%). While this apparent anomaly may be the result of a relatively small sample size of firefighters in this age group (n = 17), it may also represent a group of young individuals at a greater relative risk for future cardiovascular disease events.

In addition to age, the presence of a ‘healthy worker effect’ may also be a contributing factor to the difference in the prevalence of the metabolic syndrome in firefighters compared to the general US population [20,21]. This effect may be exacerbated in firefighters where there is a selection bias for employment due to the demanding nature of the job. Furthermore, firefighters who remain actively employed into their later decades may be healthier than those who stop working or switch to less physically demanding roles such as administration. However, the high levels of physical and psychological stressors faced by firefighters suggest that those individuals with numerous metabolic abnormalities represent a high-risk cohort who warrants aggressive cardiovascular disease risk factor reduction strategies.

Along with the prevalence of the metabolic syndrome, the current study sought to document the level of cardiorespiratory fitness among career firefighters. The mean estimated $\dot{V}_O_2_{max}$ of the study group (46.2 ml/kg/min) was higher than that expected for a similar age and sex-matched population, thus indicating a high overall level of fitness [22]. While no universal ‘fitness-for-duty’ standard currently exists, several studies have demonstrated that the oxygen demands of simulated firefighting tasks range from 23.0 to 42.5 ml/kg/min [23–25]. Therefore, from a job performance standpoint 42.0 ml/kg/min represents a generally accepted minimum level of cardiorespiratory fitness necessary for a firefighter to perform his/her job safely and effectively. In the USA, this level has been accepted by the National Fire Protection Association and published in a report outlining standards on occupational medical programmes for fire departments.
In the current study population, 54 subjects (25%) failed to meet this guideline, suggesting that the problem may not lie in the establishment of a standard itself but rather in the enforcement of that standard. This problem may be compounded by the fact that more than 70% of US fire departments lack structured fitness monitoring or improvement programs [1].

The benefits of regular physical activity on each of the metabolic syndrome components have been well documented [27]. However, relatively few studies have examined the association between cardiorespiratory fitness and the metabolic syndrome as a whole. The results of the present study are consistent with other cross-sectional studies that have demonstrated an inverse association for cardiorespiratory fitness with the prevalence of the metabolic syndrome [28]. While the absolute difference in cardiorespiratory fitness according to the number of metabolic abnormalities is relatively small, with only 4.2 ml/kg/min separating those individuals with zero metabolic abnormalities from those with three or more, the firefighters meeting the diagnostic criteria for the metabolic syndrome had a mean level of cardiorespiratory fitness that was below the suggested minimum of 42.0 ml/kg/min. Additionally, results from the present study suggest that the negative effects of an increased number of metabolic abnormalities on cardiovascular fitness are present even before a clinical diagnosis of the metabolic syndrome is possible, and that proactive risk factor management should be implemented at the first indication of one or more components of the metabolic syndrome. Current clinical guidelines do indicate a role for physical activity in the aetiology and management of the metabolic syndrome [29]. Regular physical activity is a low-cost, safe therapy with minimal adverse side-effects and favourable impact on each of the metabolic syndrome components [27]. Therefore, firefighters with any number of metabolic abnormalities would benefit from an increased emphasis on cardiorespiratory-based exercise training.

This study does have a number of limitations. First, due to the cross-sectional nature of the investigation, temporality cannot be inferred nor can the observed relationship between cardiorespiratory fitness and the metabolic syndrome be directly linked to the high prevalence of sudden cardiac death among firefighters. Additionally, cardiorespiratory fitness was predicted via maximal graded exercise test time rather than measured via indirect calorimetry. Because the present study was also limited to career male firefighters, the results are not generalizable to women or volunteer firefighters nor are they generalizable to less fit populations. Other groups have demonstrated significant differences in demographics and cardiovascular disease risk factor profiles among volunteer firefighters [30]. Reliance on self-reported medical history information and smoking and alcohol consumption may also have introduced reporting bias. Because none of the main outcome variables were reliant on self-reported data, however, it is unlikely that this would have influenced the study results. Finally, while every effort was made to test and control for potential confounders, there remains the potential for residual confounding.

Several practical conclusions can be drawn from the results of the study. First, because increased levels of cardiorespiratory fitness were found to be associated with improved metabolic profiles in male firefighters, regular endurance-based physical activity should be a critical component of a comprehensive approach to cardiovascular disease risk reduction in this population. Furthermore, this proactive approach to risk reduction should be initiated long before a sufficient number of metabolic abnormalities accumulate to result in a clinical diagnosis of the metabolic syndrome. Fire departments without specific minimum fitness standards should consider such a policy, as the health-related benefits of increased cardiorespiratory fitness may be mediated, in part, by an overall improved metabolic profile. Additional mechanistic and longitudinal studies will be needed to determine whether or not the observed relationships between cardiorespiratory fitness and the metabolic syndrome are directly linked to the high prevalence of sudden cardiac death among firefighters.

**Key points**

- Of the 214 firefighters evaluated, 15% met diagnostic criteria for the metabolic syndrome and 25% had an estimated cardiorespiratory fitness level below that deemed necessary for safe and effective job performance.
- Increased levels of cardiorespiratory fitness in firefighters were associated with a decreased number of metabolic abnormalities identified in this study.
- All fire departments should consider incorporating annual fitness evaluations, exercise guidance and minimum fitness standards as part of a comprehensive cardiovascular disease risk reduction strategy in this occupational group.

**Conflicts of interest**

None declared.

**References**


