Low fitness is associated with exercise abnormalities among asymptomatic firefighters

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Introduction

Physical activity and cardiorespiratory fitness (CRF) are inversely associated with future coronary heart disease. Each one metabolic equivalent (MET) increase in aerobic capacity is associated with a 13 and 15% decrease in risk of all-cause and cardiovascular disease (CVD) mortality, respectively [1].

In the context of public safety occupations that require high physiological demands, exercise testing is frequently used as a fitness screen [2–4]. However, CRF has not been investigated as a predictor of future CVD events. Among US firefighters in particular, CVD events account for 45% of on-duty deaths [4]. During fire suppression, firefighters must rapidly attain high heart rates (HR) and maintain them for prolonged...
per periods while withstanding a variety of environmental stressors [4]. Accordingly, we have found definitive statistical evidence of a marked increase in CVD event risks during firefighters’ strenuous duties as opposed to routine non-emergency work [5].

We hypothesized that lower CRF in firefighters is associated in a dose–response fashion to the risk of both electrocardiographic (ECG) and non-ECG abnormalities during maximal exercise testing.

Methods

Male career firefighters, 18 years of age and older, were recruited from 11 fire departments in three Midwestern states (USA). The study was approved by Harvard School of Public Health Institutional Review Boards (IRB) and local IRBs as appropriate; all participants gave informed consent.

The cohort has been described in detail before, including assessment of CVD risk factors and the definition used for metabolic syndrome (MetSyn [6]).

CRF was determined from symptom-limited maximal treadmill exercise testing with ECG monitoring and estimation of oxygen consumption (METS) following the Bruce protocol. The following outcome variables were measured: total treadmill time; peak METS; peak HR and blood pressure (BP); HR recovery at 1 min (HRR1 = peak HR − HR 1 min into recovery) and autonomic index (resting HR divided by HRR1). Firefighters were categorized according to their CRF into four groups: very low, low, intermediate and high fitness levels, defined as ≤10 METS, >10–12 METS, >12–14 METS and >14 METS, respectively.

Abnormal exercise tests included the following: abnormal HRR1 (HRR1 ≤ 12 beats per min); chronotropic insufficiency [peak HR ≤ 90% of the age predicted maximum (age predicted maximum is estimated as ‘220-age’ beats per minute)] exaggerated BP response (peak BP ≥ 220/90) and ECG abnormality (ST segment-elevation or depression exceeding 0.5 mm, ventricular tachycardia or other complex ventricular ectopy, sustained supraventricular tachycardia and exercise-induced left or right bundle branch block).

Baseline characteristics were described using mean (SD) and frequency. Group comparisons were performed using chi-square test and analysis of variance. The effect of CRF on exercise parameters was assessed using linear and logistic regression. Analyses were performed using SAS 9.2 (SAS Institute Inc., Cary, NC, USA) and were two sided, and a P-value of <0.05 was considered significant.

Results

Characteristics of the cohort and the unadjusted and adjusted associations among CRF categories, CVD risk factors and abnormal exercise testing are shown in Table 1. The unadjusted analyses revealed highly significant associations between CRF categories and all parameters, except for abnormal HRR1. All of these results remained highly significant after adjustment for age, body mass index (BMI) and MetSyn (data not shown).

In the lowest fitness group (METS ≤10), 64% of the population had one or more abnormal exercise stress test criteria compared with 23% in the highest fitness group.

**Table 1.** Association between baseline characteristics, abnormal exercise response and METS categories (male firefighters: n = 1149)

<table>
<thead>
<tr>
<th>METS</th>
<th>METS ≤ 10, n = 135</th>
<th>10 &lt; METS ≤ 12, n = 454</th>
<th>12 &lt; METS ≤ 14, n = 446</th>
<th>METS &gt; 14, n = 114</th>
<th>P-value</th>
<th>P-value&lt;sup&gt;a&lt;/sup&gt;</th>
<th>P-value&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (SD)</td>
<td>47.1 (7.9)</td>
<td>40.5 (7.6)</td>
<td>36.6 (7.9)</td>
<td>34.3 (7.8)</td>
<td>***</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>BMI (SD)</td>
<td>32.6 (4.8)</td>
<td>30.2 (4.2)</td>
<td>28.4 (3.6)</td>
<td>26.0 (2.4)</td>
<td>***</td>
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<tr>
<td>Max METS (SD)</td>
<td>9.1 (0.9)</td>
<td>11.1 (0.7)</td>
<td>13.4 (0.3)</td>
<td>15.1 (0.9)</td>
<td>***</td>
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<td>***</td>
</tr>
<tr>
<td>Body fat [%] (SD)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>25.1 (4.5)</td>
<td>21.5 (6.0)</td>
<td>22.1 (6.0)</td>
<td>16.4 (3.9)</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>MetSyn, n (%)</td>
<td>68 (50)</td>
<td>152 (33)</td>
<td>91 (20)</td>
<td>5 (4)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Total treadmill time, [sec] (SD)</td>
<td>509 (70)</td>
<td>577 (56)</td>
<td>662 (57)</td>
<td>804 (73)</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Per cent of maximum HR achieved during ETT (SD)</td>
<td>97 (8.1)</td>
<td>97 (7.0)</td>
<td>99 (5.5)</td>
<td>99 (5.1)</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>HRR at 1 min [bpm] (SD)</td>
<td>25.3 (10.7)</td>
<td>28.2 (10.7)</td>
<td>34.5 (13.7)</td>
<td>35.6 (13.6)</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Autonomic index mean (SD) (resting HR/HRR1)</td>
<td>3.5 (3.0)</td>
<td>2.8 (1.3)</td>
<td>2.5 (2.1)</td>
<td>2.0 (0.9)</td>
<td>***</td>
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<td>***</td>
</tr>
<tr>
<td>Chronotropic insufficiency (n%)</td>
<td>34 (25)</td>
<td>77 (17)</td>
<td>26 (6)</td>
<td>6 (5)</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Exaggerated BP, n (%)</td>
<td>45 (33)</td>
<td>100 (22)</td>
<td>124 (28)</td>
<td>19 (17)</td>
<td>**</td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>ECG abnormalities, n (%)</td>
<td>23 (17)</td>
<td>33 (7)</td>
<td>9 (2)</td>
<td>2 (2)</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Abnormal HRR at 1 min, n (%)</td>
<td>10 (7)</td>
<td>18 (4)</td>
<td>12 (3)</td>
<td>1 (1)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

*Presented mean and SD for continuous variables, number and percentage for numerical variables. *P < 0.05, **P < 0.01 and ***P < 0.001.

ETT, exercise testing time; n/a, not applicable; Max METS, maximal achieved metabolic equivalent; NS, not significant.

<sup>a</sup>Adjusted for age.

<sup>b</sup>Adjusted for age and BMI.

<sup>c</sup>Total number of observations available (n = 509).
Excluding exaggerated BP, the prevalence of abnormalities in the lowest fitness group was 47% versus 7% in the highest fitness group (P-value <0.001, after adjustment for age and MetSyn) (data not shown).

Logistic regression results for exercise test abnormalities as a function of CRF (continuous METS) are presented in Table 2. Consistent with categorical analyses, each additional MET achieved, reduced the odds ratio of chronotropic insufficiency and ECG abnormalities, with and without adjustment by 29–31% and 37–34%, respectively (Table 2, model 4).

**Discussion**

We showed strong inverse associations between CRF and the prevalence of abnormal exercise testing results. Considering all criteria, the prevalence of abnormalities was over 60% of the participants in the least fit group, and about 3-fold greater than the prevalence among their most fit colleagues. Our results are in line with literature that emphasizes aerobic stress testing as a comprehensive cardiovascular assessment tool [7]. The borderline positive association of exaggerated BP response and CRF is in accordance with an evolving understanding that elevated exercise BP response can either be a sign of cardiovascular risk (decreased arterial dilation at exercise) or be an expression of cardiovascular reserve (ability to mount a high cardiac output [8]).

A major strength of our study is the large sample size representing urban and suburban departments from three different US states. We had comprehensive demographic, anthropometric and metabolic characteristics comparable to other career public safety professionals in the USA [9,10], allowing generalization of our results. Occupational hazards and the relative cardiovascular risk of firefighters might be different in Europe due to differences in work practices, physical training and screening. Nonetheless, we expect the physiological effects of low CRF and its association with abnormalities during maximal exercise to be similar to any population with a similar distribution of CRF levels.

A minor limitation of the present results is that they are cross-sectional. As we gather prospective data, we plan to validate and further examine these associations. Also, due to the very small number of participating women firefighters, only males were included.

Firefighters' work involves long stretches of relative inactivity, spiked with unpredictable bursts of exertion, with higher demands on the cardiovascular system estimated to require at least 12 METS to perform duties safely [2]. Thus, it is notable that firefighters who fail to exceed 12 METS and especially those not achieving more than 10 METS were more likely to exhibit the most ominous exercise abnormalities—abnormal HRR1 and ECG abnormalities. This could indicate higher future risk of CVD. Therefore, firefighters with low CRF (≤12 METS) merit interventions to improve their CRF as part of a balanced strategy of aggressive CVD risk factor reduction.

**Key points**

- Lower cardiorespiratory fitness is related in a dose–response fashion to the risk of electrocardiographic and non-electrocardiographic abnormalities in male career firefighters; these abnormalities occur during maximal stress tests and recovery and remain statistically significant even after adjustment for age, body mass index and metabolic syndrome.
- These important results may provide greater specificity for predictions of future cardiovascular disease morbidity and mortality and for identifying firefighters that may benefit from more aggressive risk reduction.
- The fire service should be advised to mandate physical training aimed at improving and maintaining cardiorespiratory fitness.

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### Table 2. Logistic regression with METS as a continuous exposure

<table>
<thead>
<tr>
<th></th>
<th>Model 1&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Model 2&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Model 3&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Model 4&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P-value</td>
<td>OR (95% CI)</td>
<td>P-value</td>
<td>OR (95% CI)</td>
</tr>
<tr>
<td>Chronotropic</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>insufficiency</td>
<td>***</td>
<td>0.70 (0.64–0.78)</td>
<td>***</td>
<td>0.69 (0.62–0.78)</td>
</tr>
<tr>
<td>Exaggerated BP</td>
<td>NS</td>
<td>0.94 (0.88–1.01)</td>
<td>NS</td>
<td>0.98 (0.90–1.06)</td>
</tr>
<tr>
<td>ECG abnormalities</td>
<td>***</td>
<td>0.63 (0.55–0.73)</td>
<td>***</td>
<td>0.71 (0.60–0.82)</td>
</tr>
<tr>
<td>Abnormal HRR at 1 min</td>
<td>*</td>
<td>0.81 (0.69–0.96)</td>
<td>NS</td>
<td>0.89 (0.74–1.08)</td>
</tr>
</tbody>
</table>

<sup>a</sup>Crude.  
<sup>b</sup>Adjusted for age.  
<sup>c</sup>Adjusted for age and BMI.  
<sup>d</sup>Adjusted for age and MetSyn.

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*P < 0.05, **P < 0.01 and ***P < 0.001. NS = not significant.
Acknowledgements

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Conflicts of interest

S.N.K. has served as an expert witness in legal cases involving firefighters and is also under contract to revise the Heart Disease Manual of the International Association of Fire Fighters.

References