Firefighters With Higher Cardiorespiratory Fitness Demonstrate Lower Markers of Cardiovascular Disease Risk

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Objective: High cardiorespiratory fitness (CRF) is associated with reduced markers of oxidative stress and cardiovascular disease (CVD) risk factors; however, this relationship has not been elucidated in firefighters. The purpose of this study was to examine differences in markers of CVD risk between firefighters who have either high or low levels of CRF. **Methods:** Forty-six firefighters participated in a maximal graded exercise test and a dual-energy x-ray absorptiometry scan and provided a fasted blood sample. $\dot{V}O_{2max}$ values were categorized based on American College of Sports Medicine guidelines to establish high- and low-fitness groups. **Results:** High fitness firefighters demonstrated significantly higher high-density lipoprotein cholesterol and lower markers of CVD risk: cholesterol, triglycerides, low-density lipoprotein cholesterol, insulin, homeostatic model assessment for insulin resistance, C-reactive protein, and advanced oxidation protein products concentrations. **Conclusion:** Firefighters are encouraged to maintain high CRF to reduce risk of CVD.

Keywords: fire community, cardiometabolic health, oxidative stress, inflammation, lipids

Firefighters are at risk for premature mortality due to sudden cardiac death while on duty.[1,2] In fact, approximately 50% of all firefighter mortality is attributed to a cardiovascular-related event.[3] This trend has led to a number of recent studies investigating risk factors for cardiovascular disease (CVD) in professional firefighters.[4–6] Appropriate exercise and dietary interventions can be effective methods to mitigate risk for developing CVD. Recent work from Waldman et al[7] and McAllister et al[8] have demonstrated that dietary interventions such as carbohydrate restriction and time restricted eating can improve biomarkers of CVD risk in professional firefighters; however, more data are still needed. Furthermore, additional work has shown the importance of maintaining high levels of cardiorespiratory fitness (CRF) to mitigate CVD risk among firefighters.[9–12]

Clinical screening for CVD risk typically involves conducting a lipid panel (high-density lipoprotein cholesterol [HDL-C], low-density lipoprotein cholesterol [LDL-C], triglycerides, total cholesterol, etc.) and an analysis for markers of insulin resistance including fasting blood glucose or glycated hemoglobin A1C concentrations. It is also important to assess other CVD risk factors such as sedentary lifestyle, smoking, hypertension, diabetes, dyslipidemia, family history for CVD, and body mass index. However, firefighters have been shown to be occupationally exposed to oxidative stress and inflammation.[13,14] Chronic exposure to oxidative stress and inflammation has been widely recognized as predominate mechanisms contributing to manifestations associated with cardiometabolic dysfunction, such as atherosclerosis and insulin resistance.[15–17] In fact, biomarkers such as advanced oxidation protein products (AOPP) and C-reactive protein (CRP) have been shown to be directly involved in atherosclerotic plaque development and/or endothelial dysfunction.[18–20] As such, markers of oxidative stress and inflammation may serve as key indicators to cardiometabolic health and should be used in conjunction with the aforementioned markers to better gauge CVD risk.[21–24] Although some studies have aimed to improve aspects of cardiometabolic health among firefighters by improving antioxidant status and reducing oxidative stress susceptibility,[8,25] more data are needed regarding the impact of CRF on these biomarkers in the firefighter community.

Chronic exercise training has been shown to result in a number of improvements to aspects of cardiometabolic health including improvements to endothelial function,[26] reductions in blood pressure,[27] improvements to blood lipids[28] and insulin resistance,[28] and improvements in antioxidant status and reduced susceptibility to oxidative stress.[29] The criterion standard for measuring CRF is by analyzing pulmonary gas exchange during a graded exercise test (ie, $\dot{V}O_{2max}$/$\dot{V}O_{2peak}$).[30] Extensive data have shown that improvements to aerobic exercise capacity and CRF provide numerous health benefits, including reduced likelihood for developing cancer and depression, as well as various aspects of CVD such as hypertension, heart failure, and coronary artery disease.[31] Higher CRF is associated with lower markers of oxidative stress and inflammation, and reduced risk of developing CVD.[32] In addition, the assessment of CRF can serve as a useful tool to predict CVD risk.[33–36] Although data examining this relationship in firefighters are lacking, recent correlational data demonstrated inverse relationships between CRF and CVD risk factors in firefighters.[11] Specifically, Strauss et al[11] reported lower body mass index (BMI), waist circumference, body fat percentage, blood pressure, and blood triglyceride concentrations associated with higher CRF in male German firefighters.

Given the high rates of CVD among firefighters and the documented benefits associated with high CRF, more work is needed to examine the impact of CRF on markers of CVD such as body fat percentage, blood lipids, oxidative stress, inflammation, and insulin resistance. Therefore, the purpose of this study was to compare firefighters of high and low CRF with respect to various markers of CVD.

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MATERIALS AND METHODS

Subjects and Experimental Design

The present study involved an analysis using a subset of data from a larger-scale study examining correlational relationships between numerous fitness and demographic measures with respect to markers of CVD risk among a larger sample of professional firefighters (data not yet published). $\dot{V}O_{2max}$ scores were calculated based on treadmill time to exhaustion (subsequently described). To establish a high-fitness group and low-fitness group, subjects were categorized based on their age and $\dot{V}O_{2max}$ using American College of Sports Medicine guidelines[30] similarly done in previous work.[37] Specifically, subjects with $\dot{V}O_{2max}$ scores rated as above average or good were categorized as high fitness, and subjects with $\dot{V}O_{2max}$ scores rated as poor or very poor were categorized as low fitness. Thus, the present study used a 2-arm, cross-sectional design to analyze differences in CVD risk factors between the low- and high-fitness groups. The study procedures were approved by the Texas A&M Institutional Review Board. Each participant provided written informed consent before participation. Subjects also completed a lifestyle and health history questionnaire.

Experimental Procedures

Subjects arrived at the laboratory for experimental testing and anthropometric data collection subsequently described. Body mass and height were recorded using a physician grade scale (Seca Model 00, Hamburg, DEU). Hip and waist circumference data were obtained following standardized guidelines.[38] Body composition was obtained via dual-energy x-ray absorptiometry (Hologic Horizon A, Marlborough, MA). Finally, subjects completed a maximal graded exercise test, which incorporated the Bruce protocol.[39] $\dot{V}O_{2max}$ was calculated using the subjects' time to exhaustion and the Foster equation.[40]

Blood Sampling and Analysis

Serum samples of approximately 8.5 mL were collected from an antecubital vein using serum preparation tubes (BD Vacutainer; Becton, Dickinson and Company, Franklin Lakes, NJ) via venipuncture in a 12-hour fasted state. Samples clotted at room temperature for 30 minutes and were subsequently centrifuged for 15 minutes at 2500 rpm at a temperature of 4°C. One aliquot of serum was immediately placed on ice and transported to a clinical laboratory for analysis of total cholesterol, HDL-C, LDL-C, glucose, and triglycerides. A second aliquot was frozen at −80°C, and subsequently thawed and analyzed in duplicate for concentrations of insulin, AOPP, and high-sensitivity CRP using commercially available assays (insulin: IN374S, Calbiotech, El Cajon, CA; AOPP: Cell Biolabs, San Diego, CA; and CRP: Eagle Biosciences, Amherst, NH). Absorbance was detected using a BioTek colorimetric plate reader (Winooski, VT). Homeostatic model assessment for insulin resistance (HOMA-IR) was calculated by fasting glucose (mg/dL) × fasting insulin (μU/mL)/405.[41]

Statistical Analysis

All statistical analyses were conducted via Stata v.16.1 (College Station, TX). Because of the small sample sizes, nonparametric Mann-Whitney *U* tests were the primary analysis technique to assess mean differences between the high- and low-fitness groups. Effect sizes are reported as Hedge *g*.[42]

RESULTS

Sample Characteristics

Data are shown as mean ± SD. A total of 46 subjects were categorized into high (n = 19) and low CRF groups (n = 27).[30] There was no observable difference between the two groups as related to years of experience (high fitness, 11 ± 9 years; low fitness, 11 ± 8 years; $z = 0.49$; $P = 0.63$) or age (high fitness, 36 ± 9 years; low fitness, 38 ± 9 years; $z = 0.65$; $P = 0.52$). All subjects were male.

Group Comparisons

Table 1 presents mean comparisons between the high-fitness and low-fitness groups for $\dot{V}O_{2max}$, BMI, body fat %, glucose, cholesterol, triglycerides, HDL-C, LDL-C, and risk ratio, which was calculated as the ratio of LDL-C to HDL-C (ie, LDL-C/HDL-C). Mean insulin and HOMA-IR data are shown in Figures 1A and B, respectively. Mean CRP and AOPP data are shown in Figures 2A and B, respectively. Subjects classified as high fitness had significantly higher $\dot{V}O_{2max}$ and HDL-C values coupled with significantly lower body fat percentage, cholesterol, triglycerides, LDL-C, insulin, HOMA-IR, CRP, and AOPP concentrations. Approximately half of the statistically significant observed differences corresponded with a Hedge *g* of <0.8 (ie, LDL-C, insulin, HOMA-IR, CRP, AOPP), whereas the other observed differences corresponded with a Hedge *g* of >0.8 (ie, $\dot{V}O_{2max}$, body fat percentage, cholesterol, triglycerides, HDL-C, LDL-C/HDL-C risk ratio). Glucose was the only marker where the observed difference was not statistically significant ($z = 0.67$).

DISCUSSION

The primary findings from this study demonstrate significant differences in numerous risk factors for cardiometabolic disease between high- and low-fitness firefighters. Firefighters with higher levels of CRF demonstrated significantly lower body fat percentage, as well as blood concentrations of cholesterol, insulin, triglycerides, LDL-C, CRP, and AOPP in addition to lower HOMA-IR and lower risk ratio (LDL-C/HDL-C). Although these data are supported by a large number of similar trials,[43–47] to our knowledge, this is the first study to examine comparisons in traditional markers for CVD risk, as well as inflammation and oxidative stress markers between firefighters demonstrating high and low levels of CRF.

Having a high level of CRF has been shown to reduce CVD risk factors such as dyslipidemia.[43] Past work has shown inverse relationships between CRF and non–HDL-C concentrations.[44] Chronic exercise training can increase HDL-C and reduce non-HDL-C by favoring cholesterol efflux (ie, HDL-C) transportation of cholesterol to the liver for excretion.[48] High-density lipoprotein cholesterol levels are dependent on exercise with more exercising training and higher intensity exercise training generally resulting in greater increases in HDL-C.[49,50] Moreover, a combination of resistance and aerobic exercise training has been shown to positively affect both LDL-C and HDL-C concentrations.[50] With respect to triglyceride concentrations, past work

TABLE 1. High- Versus Low-Fitness Group Comparisons

	Low Fit		High Fit			
	Mean	SD	Mean	SD	*Z*	Hedge *g*
$\dot{V}O_{2max}$, mL/kg/min	28.2	4.9	44.7	5.2	−5.72*	3.17
BMI kg/m^2	31.4	6.1	26.7	3.0	−3.22**	0.90
Body fat %	27.0	5.0	19.9	2.6	−4.59*	1.67
Glucose, mg/dL	93.6	11.7	91.4	7.3	−0.67	0.21
Cholesterol, mg/dL	196.4	34.5	169.8	6.0	−2.40***	0.84
Triglycerides, mg/dL	173.9	127.6	79.9	33.4	−3.72*	0.92
HDL-C, mg/dL	42.5	11.1	52.4	13.5	-2.53***	0.80
LDL-C, mg/dL	125.2	33.3	100.3	29.5	−2.34***	0.77
RR LDL/HDL	2.9	0.8	2.1	1.0	−2.76**	0.81

BMI, body mass index; HDL, high-density lipoprotein; HDL-C, high-density lipoprotein cholesterol; LDL, low-density lipoprotein; LDL-C, low-density lipoprotein cholesterol; RR, risk ratio.

*$P \leq 0.001$; **$P \leq 0.01$; ***$P \leq 0.05$.

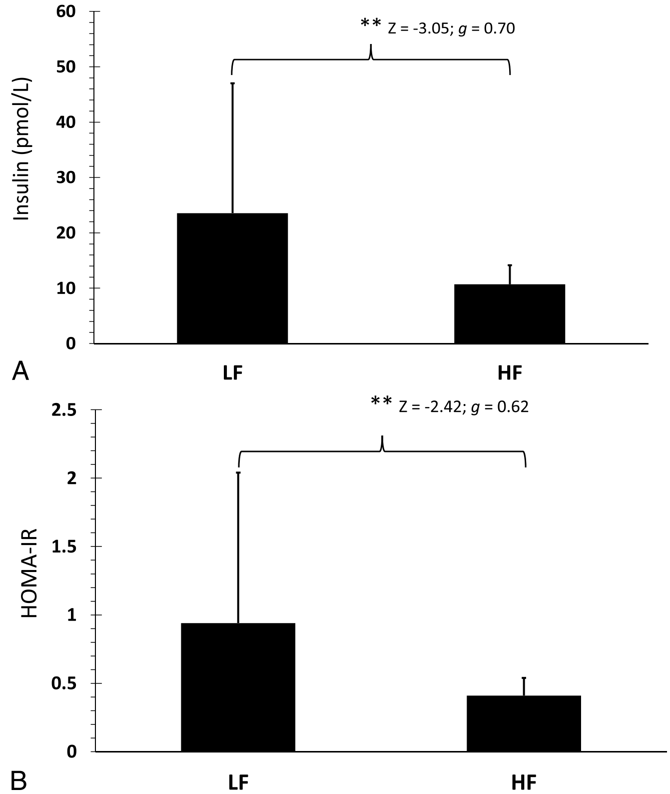

FIGURE 1. Insulin (A) and HOMA_IR (B) data are shown as mean ± SD. $^{**}P \leq 0.01$. *g*, Hedge *g*; HF, high-fitness group; HOMA-IR, homeostatic model assessment for insulin resistance; LF, low-fitness group.

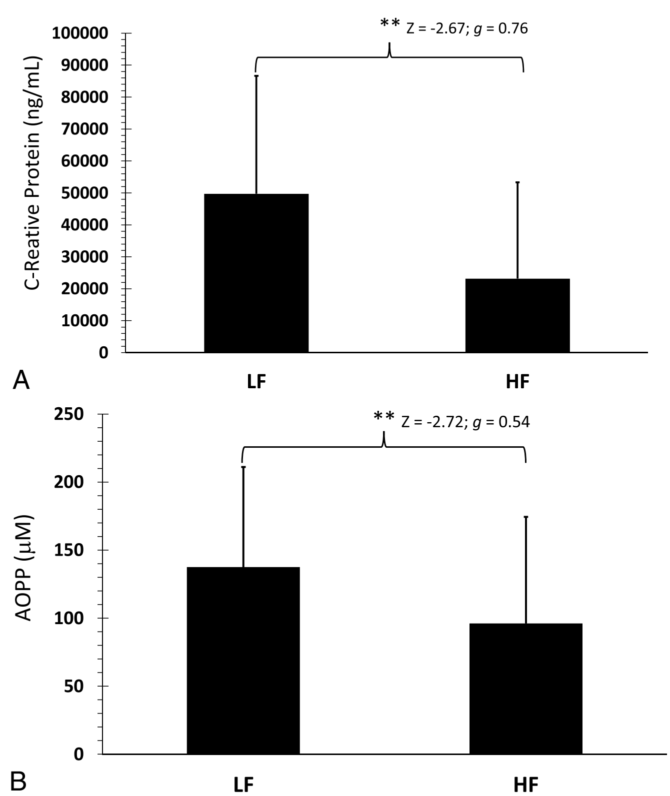

FIGURE 2. Creactive protein (A) and AOPP (B) data are shown as mean ± SD. $^{**}P \leq 0.01$. AOPP, advanced oxidation protein products; *g*, Hedge *g*; HF, high-fitness group; LF, low-fitness group.

has shown a relationship between HDL-C and triglyceride, and the triglyceride/HDL-C ratio has been shown to be lower among individuals with higher CRF levels.[45,46] The present study demonstrated that firefighters with higher CRF levels had significantly lower LDL-C, cholesterol, and triglycerides concentrations, as well as higher HDL-C concentrations, compared with the lower fitness group. All blood lipid data corresponded with a large effect size, underscoring the importance of CRF in relation to reducing CVD risk. The present findings are not unexpected, considering previous research has shown similar relationships; however, these relationships have yet to be clearly shown in firefighters.

Elevated CRP concentrations are associated with increased CVD risk among apparently healthy individuals.[51–53] A cross-sectional study by Church et al[54] noted an inverse association between CRF and CRP concentrations that were independent of body composition or fat distribution. Moreover, when accounting for the fitness levels of overweight and obese individuals, individuals categorized as higher fitness had lower CRP concentrations compared with their lower fitness counterparts.[54] In the present study, the subjects categorized as higher fitness also had significantly lower CRP concentrations compared with the lower fitness group. To the best of our knowledge, this is the first study assessing the association of fitness levels and CRP concentration among professional firefighters. Considering that CRP is an important risk factor for CVD events[55–57] and sudden cardiac death accounts for approximately 50% on-duty deaths among firefighters,[58] this finding highlights the importance of maintaining a higher level of fitness to mitigate CVD risk among the fire community.

The presenting findings also support an inverse relationship between CRF and markers of oxidative stress, inflammation, and HOMA-IR. In addition, waist circumference was inversely related to AOPP and HOMA-IR. The present findings are similar to data reported by Arsenault et al[47] in that overweight individuals with low CRF demonstrate higher risk for increased inflammatory biomarkers. Chronic exposure to oxidative stress and inflammation has been shown to be a major factor contributing to the development of CVD and insulin resistance.[15] Therefore, these findings provide major implications for firefighters given the high prevalence of CVD among the firefighter community.[3] A recent review by Ruiz-Ramie et al[48] summarizes the effects of chronic exercise training on CVD risk in relation to HDL-C, cholesterol transport, and antioxidative/anti-inflammatory mechanisms. Considering these findings, firefighters should be encouraged to engage in regular physical activity and maintain higher CRF to improve cardiometabolic health profiles.

A major limitation to the study is that body fat percentage could impact the measured CVD risk markers. Extensive work has shown body fat percentage contributes to dyslipidemia and elevations in markers of inflammation and oxidative stress.[59] However, it should be noted that, although the present findings do show significant differences in body fat percentage between the high- and low-fitness groups, all of the high-fitness subjects were categorized as "elevated" or "high" adverse health risk based on their BMI, and 47% of the high-fit subjects were in the poor fitness category based on their body fat percentage.[30] Moreover, it is important to note that 52% of the high-fit firefighters reported participating in more than 3 hours per week of vigorous physical activity, whereas only 27% of the low-fitness group reported engaging in such activity. Regardless, it is possible that body fat percentage and other lifestyle (ie, diet/physical activity levels) or occupational factors (eg, stress related calls, etc) can impact the results and should be viewed as a limitation. In addition, the present study did not account for other potential risk factors for CVD such as family history for CVD and smoking. This could be viewed as a limitation because these can impact selected biomarkers.

In summary, our data demonstrate significant differences among several CVD risk factors between high- and low-fitness firefighters. Professional firefighters categorized with high CRF demonstrate lower body fat percentages, cholesterol, insulin, triglycerides, LDL-C, CRP, AOPP, HOMA-IR, and the LDL-C/HDL-C risk ratio. In addition, firefighters in the high-fitness group exhibited higher HDL-C levels compared with the low-fitness group. Considering the present findings, firefighters should be encouraged to maintain higher levels of CRF and lower body fat percentages to attenuate CVD risk and on-duty cardiac events. These findings may aid future development and implementation of exercise programming to optimize overall health and fitness status as well as promote occupational readiness and reduce the risk of CVD among the firefighter community.

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