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Effects of circuit exercise training on vascular health and blood pressure

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ABSTRACT

As the global burden of cardiovascular disease (CVD) rises, public health-related interventions aimed at prevention of heart disease have gained medical attention. Clinical research reports that exercise is a protective risk factor associated with CVD and that clinicians need to provide exercise recommendations to patients. Nevertheless, physical inactivity remains a public health problem. In certain populations, like firefighters (FF), increased risk of CVD is especially concerning. The workload FF face is extreme, 50% of line-of-duty deaths (LODD) in FF are cardiac-related, and research on the volunteer FF population is scarce. Government regulations do not require volunteer FF companies to have fitness testing or programming, so exercise intervention studies are necessary to improve the burden of CVD risk in this population. Therefore, this study examined the effects of a 4-week exercise circuit training (CT) intervention on vascular health and fitness in volunteer FF ($N = 27$) from the Philadelphia PA area compared to a control group of Non-FF ($N = 25$). Carotid artery intima-media thickness (IMT), brachial artery flow-mediated dilation (FMD), augmentation index, and pulse pressure (PP), brachial and central blood pressure (BP) and fitness were measured pre- and post- intervention. Overall, volunteer FF had more significant improvements ($p < 0.05$) in vascular health measures (FMD, IMT, and PP). In both groups, we also found that brachial and central BP decreased with exercise. We show that a 4 week CT program can improve vascular structure and function in the volunteer FF population, suggesting that clinicians may be able to reduce or prevent cardiac LODD by exercise.

1. Introduction

As the global burden of cardiovascular disease (CVD) rises, public health-related interventions aimed at prevention of heart disease have gained medical attention. Over the years, clinical research has shown that exercise is an independent and protective risk factor associated with CVD, blood pressure (BP), and blood vessel function (Chobanian et al., 2013; Ashor et al., 2014). In fact, population-based studies and meta-analyses have reported that any amount of exercise or a healthy lifestyle can be beneficial and reduce CVD, even reducing risk of all-cause mortality up to 40% (Kodama et al., 2009; Maessen et al., 2016). Despite this, physical inactivity remains a global public health problem and accounts for millions of deaths annually, thus the potential benefit of increased activity could be substantial.

In certain populations, increased risk of CVD is especially concerning. Many physicians and public health officials are unaware that heart disease or cardiac incidents are related to almost 50% of line-of-duty deaths in firefighters (FF) (Geibe et al., 2008). Firefighting is a dangerous occupation because of its many physical and physiological demands. In the U.S, firefighters can be either paid full-time “career FF” or they can be “regular” people who volunteer to be FF, “volunteer FF”.

Many career FF have hypertension, are obese, and have more CVD risk factors than Non-FF (Yoo and Franke, 2009). As outlined by the AHA in Non-FF, CVD risk factors include hypertension, obesity, smoking, inactivity, and abnormal glucose and cholesterol levels. Evidence suggests that career FF have increased possibility of cardiac events due to similar relative risk factors. Volunteer FF make up 70% of the total FF population, and are an understudied population. Considering the well-established fact that exercise can reduce CVD risk, it is interesting that volunteer FF companies are not required by the

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National Fire Protection Association (NFPA) to have fitness testing or a fitness program for the crew. The NFPA makes suggestions for fitness and has established that demands of FF activities on the cardiovascular system require a fitness level of a VO_{2max} of 42 ml/kg/min (NFPA 1582, 2007); however, it is estimated that only around 20% of volunteer FF meet this fitness threshold (Poston et al., 2011).

There remains a gap in the exercise literature, for the volunteer FF population that examines vascular health changes with exercise. In 2009, Williams-Bell et al. estimated that during firefighting activities, FF may work at 75–80% of their VO_{2max} level (Williams-Bell et al., 2009). Recently, we reported that BP responses to exercise were exaggerated in volunteer FF while wearing full firefighting personal protective equipment (PPE) (Feairheller, 2015) A separate study found that oxidative stress increased and DNA damage occurred in FF wearing PPE while exercising (Park et al., 2016). These studies suggest that the workload FF face is extreme, so exercise intervention studies in FF are necessary.

Exercise-induced vascular health improvements can be evaluated by a number of clinical modalities, including: flow-mediated dilation (FMD, an index of nitric oxide-mediated endothelial-dependent function), carotid artery intima-media thickness (IMT, an index of common carotid artery plaque and atherosclerotic potential), and arterial stiffness measured by pulse pressure (PP) and augmentation index (AIx, an index of arterial stiffness that quantifies the reflected wave at the aorta) (Polak and OLeary, 2016; Harris et al., 2010; Perk et al., 2012). There is not yet a clear consensus on which type of exercise (aerobic, resistance, or combination) has a better effect on CV health overall, but recently it has been suggested that combination training has a greater effect on vascular health, arterial stiffness, BP and VO_{2max} when compared to aerobic or resistance training (Ho et al., 2012). Circuit training (CT), one form of combination training incorporates aerobic movement and resistance type exercises. Clinical research that examines improvements in CVD risk factors with CT exercise are scarce, and few studies are published with only 4 weeks of exercise. In some research, adults who underwent 10–12 weeks of aerobic exercise, but not resistance training, had improvements in FMD and IMT (Beck et al., 2013; Casey et al., 2007). Recently we reported that adults who completed 6 months of aerobic exercise training had improvements in IMT and FMD (Feairheller et al., 2014). Shorter exercise training studies are needed.

Actual clinical exercise intervention studies in the volunteer FF population do not exist. In career FF, it has been reported that 12 or 16 week CT programs which simulate fire-ground activities have beneficial effects on fitness and body composition (Roberts et al., 2002; Pawlak et al., 2015). Also, FF fire suppression training drills are similar to CT and focus on cardiovascular endurance and muscular strength (Rhea et al., 2004). Nevertheless, exercise-induced improvements in vascular health in FF have yet to be measured. Therefore, the purpose of this study was to compare the effects of a 4 week CT program on CV risk factors between a group of volunteer FF and a group of Non-FF. Taking into consideration that guidelines require career fire departments mandate health, wellness, and fitness programs, career FF inherently may be more fit or healthy, so we chose a comparison group of Non-FF instead of career FF. Volunteer FF are “everyday” people who sign up to get fire and rescue training, respond to any number of calls, and are allowed to volunteer as much as they can or have time to, thus a better comparison group to this would be Non-FF. Volunteer FF make up over 70% of the entire FF population, they respond to many fire/rescue calls every year and it needs to be examined how their health compares to the general population. A comparison of career FF to volunteer FF would not be beneficial. Due to the lack of wellness and fitness regulations in volunteer fire stations, the volunteer FF population has worse health than career FF. The question that needs to be addressed is how volunteer FF health compares to “everyday” people.

2. Methods

This was a quasi-experimental pre-post intervention with a comparison group of Non-FF matched by age. Criteria for inclusion were: no more than one BP medication, no cholesterol medications, other medications were allowed, no prior cardiovascular incidents, no diagnosed heart disease or diabetes, non-smoker, no physical limitation that would preclude an exercise program, and > 70% adherence to the CT intervention. Each participant gave informed consent and completed a general health history form. The protocol was approved by the Ursinus College Institutional Review Board, and all procedures were in accordance with the ethical standards of the Helsinki Declaration.

All enrolled participants completed pre-testing, underwent a 4 week CT intervention, and then completed post-testing which was a repeat of all baseline tests. The pre- and post- data collection included two visits each, a fasted visit and a fitness test. For the fasted visit, all participants would report to the laboratory following an overnight fast. The visit took place in a quiet, temperature controlled room. Participants were asked to refrain from exercise for 24 h prior and from any food, drink, medication, and caffeine for at least 10 h prior to the test. Participants were also asked to remove any jewelry and other accessories prior to the measurements.

2.1. Circuit training program

The 4 week CT program was completed 3 times per week. Each CT workout involved 6 stations which were completed 3 times per workout. Before the training period, all participants underwent an exercise familiarization session to ensure proper execution of technique. The 6 stations included a 40 lb. carry for 100 ft., 3-min stair climb, 45 s plank pose, 20 lb. carry with a fast walk for 100 ft., right and left single leg stands for as long as balance was maintained, and a 15 lb. carry up and down 30 stairs.

2.2. Blood pressure measurements

Brachial BP measurements were obtained in accordance with JNC-7 guidelines by laboratory personnel on multiple visits using an aneroid sphygmomanometer (Medline Industries, Mundelein, IL) (Chobanian et al., 2013). BP measurements were performed in triplicate with the average of the three values used as the representative BP for that visit. The mean systolic and diastolic BP across the clinical visits is reported as the brachial BP.

2.3. Radial pulse wave analysis (PWA) measurements

Radial artery PWA measurements were collected after the participant had rested supine for 15 min. BP was measured immediately before measurement, and peripheral pulse waveforms were captured using a hand-held tonometer probe (Millar/AtCor Medical pressure tonometer, Houston, TX). The tonometer was applanated (applied to flatten the artery but not occlude it) at the radial artery with the wrist supported and in an extended position. The shape of the peripheral pulse wave was collected electronically with a laptop which was linked to the SphygmoCor PW system (SphygmoCor CPV, software version 8.2, AtCor Medical, Sydney, Australia). Data from quality pulse waveforms were considered acceptable, and this was assessed by the software's internal quality control index (operator index > 80%). The average of 3 measures is reported. PWA is reliable and provides measurement of several main indices: central aortic systolic and diastolic BP, AIx adjusted to heart rate (HR) of 75 beats per minute, PP and subendocardial viability ratio (SEVR) (Crilly et al., 2007). In our laboratory, we have calculated the intraclass correlation coefficient (ICC) for PWA measurements at > 0.97.