

CARDIOVASCULAR DISEASE PREVENTION IN FIREFIGHTERS

By

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To my mentors, teachers, and students who have supported me throughout this process

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LIST OF ABBREVIATIONS

BF%	BODY FAT PERCENTAGE
BMI	BODY MASS INDEX
CAP	COMMUNITY ACADEMIC PARTNERSHIP
CBPR	COMMUNITY BASED PARTICIPATORY RESEARCH
CRF	CARDIORESPIRATORY FITNESS
CVD	CARDIOVASCULAR DISEASE
EKG	ELECTROCARDIOGRAM
FFIP	FIREFIGHTER FATALITY INVESTIGATION PROGRAM
HDL	HIGH DENSITY LIPOPROTEIN
HR _{MAX}	MAXIMUM HEART RATE
IM	INTERVENTION MAPPING
LDL	LOW DENSITY LIPOPROTEIN
NIOSH	NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH
PA	PHYSICAL ACTIVITY
PAR%	POPULATION ATTRIBUTABLE RISK PERCENTAGE
PFT	PEER FITNESS TRAINERS
PHLAME	PROMOTING HEALTHY LIFESTYLES: ALTERNATIVE MODELS' EFFECTS
RPE	RATE OF PERCEIVED EXERTION
SCT	SOCIAL COGNITIVE THEORY
TTM	TRANSTHEORETICAL MODEL
VO ₂ MAX	MAXIMAL OXYGEN CONSUMPTION AT THE CELLULAR LEVEL
WFI	WELLNESS AND FITNESS INITIATIVE

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CARDIOVASCULAR DISEASE PREVENTION IN FIREFIGHTERS

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The present research addressed Cardiovascular Disease (CVD), prevention in firefighters, since it contributes to nearly half of all on-duty fatalities and injuries annually. Specifically, this research focused on three integrated studies: 1) To describe the methods used to engage firefighters in the participatory processes of planning, implementing, and evaluating a CVD prevention program utilizing Intervention Mapping (IM) and principles of Community Based Participatory Research (CBPR). 2) To evaluate the validity of the current sub-maximal protocol used to predict the true VO₂max of firefighters. 3) To examine the use of a peer-driven firefighter intervention on, improving cardiorespiratory fitness, body composition, and musculoskeletal fitness indicators in high-risk firefighters.

The process of integrating principles of CBPR into the steps of IM resulted in the creation of a Community Academic Partnerships comprised of two fire departments, a local public health department, and three health-oriented university academic departments. The integration of CBPR principles with IM proved to be an efficacious and economical approach for engaging firefighters in each phase of the research process, developing an ecological approach to CVD health promotion in firefighters,

capitalizing on community capacity; and utilizing iterative system development to guide the research process through mixed-methods evaluations.

Currently, a sub-maximal protocol is used to measure cardiorespiratory fitness in firefighters by estimating the true aerobic capacity (VO_{2max}) of firefighters; however, the sub-maximal test has not been validated. Thirty firefighters completed the sub-maximal treadmill protocol and maximal Bruce protocol. Analyses between the sub-maximal and Bruce protocol produced a significant moderate correlation ($r=0.635$, $p = 0.005$). The sub-maximal VO_2 treadmill test underestimated the true VO_{2max} in the majority of firefighters (72.4%), and overestimated the true VO_{2max} in 24.4% of firefighters.

The effects a one year community-based firefighter health intervention has on cardiorespiratory fitness, muscular fitness, and body composition in high-risk firefighters was evaluated. Aerobic capacity significantly increased from baseline to post-testing for the intervention group ($p < 0.001$), while the control group did not significantly increase VO_{2max} ($p=0.3838$). The control group significantly increased body fat percentages from baseline to post testing ($p = 0.044$), while the intervention group maintained body fat percentages ($p=0.384$).

CHAPTER 1 INTRODUCTION AND LITERATURE REVIEW

General Introduction

The following section provides a brief background on the description of the problem and significance of cardiovascular disease (CVD) in firefighters; a statement of the research purpose for the three articles included in this dissertation; and definitions of key terms and concepts.

One million people work in the fire service in the United States. Firefighters provide fire suppression and emergency medical services for 2 million individuals annually, and are a crucial part of public health and safety (Kales, Soteriades, Christophi, & Christiani, 2007). Issues related to the health and safety of firefighters are also a major public health priority, as firefighting is known to be one of the nation's highest occupational fatality and injury rates (National Institute for Occupational Safety and Health, 2001; United States Fire Service & National Fire Data Center, 2002). What is less widely known is that the most frequent cause of death among firefighters is cardiovascular disease (CVD), rather than burns or smoke inhalation (Duenas-Laita et al., 2007). CVD accounts for 46% of all on-duty deaths and disabilities among firefighters annually (National Institute for Occupational Safety and Health, 2001; Rosenstock & Olsen, 2007; United States Fire Service & National Fire Data Center, 2002). In contrast, CVD is responsible for 22% of fatalities in police, 10% in emergency medical service workers, and 11% of all deaths in the general work force (Maguire, Hunting, Smith, & Levick, 2002; National Institute for Occupational Safety and Health, 2001; United States Fire Service & National Fire Data Center, 2002).

Epidemiological studies show a high prevalence of risk factors for CVD among firefighters exists, including: inadequate physical fitness, high rates of obesity, hypertension, and unhealthy cholesterol profiles (Haas, Gochfeld, Robson, & Wartenberg, 2003; Kales, Soteriades, & Christoudias, 2003; Leiba, Baur, & Kales, 2011; Rosenstock & Olsen, 2007; Soteriades, Hauser, Kawachi, Christiani, & Kales, 2008). Even new firefighter recruits are commonly found to be overweight and have low cardiorespiratory fitness (Kales, et al., 2007; Poston et al., 2011). Despite the high rates of CVD among firefighters, more than 70% of fire departments lack programs to promote physical fitness and health, do not require firefighters to exercise regularly, or do not require firefighters to undergo periodic medical examinations to screen for CVD risk factors (Geibe et al., 2008).

The substantial health and fitness issues facing the fire service have, in large part, not been adequately addressed from the public health research community (Poston, et al., 2011). Few studies have evaluated interventions for addressing physical fitness, weight gain, high blood pressure, or unhealthy cholesterol in the fire service culture. Innovative studies are needed to determine what types of interventions would be most successful in improving health and fitness in firefighters.

Key Terms and Concepts

Community based participatory research (CBPR). Community based participatory research (CBPR) has been identified as a key strategy in effectively reducing health disparities in underserved communities (Pazoki, Nabipour, Seyednezami, & Imami, 2007). CBPR is defined as a collaborative, partnership approach to research that equitably involves, for example, community members, organizational representatives, and researchers in all aspects of the research process.

Partners contribute their expertise and share responsibilities and ownership to increase understanding of a given phenomenon, and incorporate the knowledge gained with action to enhance the health and well-being of community members (Israel, Eng, Schulz, & Parker, 2005; Pazoki, et al., 2007).

Intervention Mapping (IM). Intervention Mapping is a protocol for systematically applying theoretical and empirical evidence when designing health promotion programs. Intervention Mapping elaborates on the program development phase in Green's PRECEDE/PROCEED model for planning health promotion interventions (Green & Kreuter, 2005). Intervention Mapping includes: conducting a comprehensive needs assessment for the determinants of a health outcome formulating program objectives for the target group, selecting appropriate theoretical methods, translating methods into practical strategies an ecologically integrated program, conducting development, implementation, impact, and outcome evaluations (Bartholomew, Parcel, Kok, & Gottlieb, 2006).

Ecological model. The ecological model, as it has evolved in the behavioral sciences and in public health, focuses on the interrelated factors of the individual, interpersonal, community, environment, and policies levels that contribute to health outcomes (Glanz, Rimer, & Lewis, 2002).

Physical activity (PA). Physical activity is defined as any bodily movement produced by contraction of skeletal muscle that substantially increases energy expenditure. The dose of physical activity, or exercise, needed to bring about a particular health benefit response is described by the characteristics of frequency, duration, intensity, and type of activity. Frequency describes the number of activity

sessions per time period (e.g., day or week). Duration refers to the number of minutes of activity in each session. Intensity describes, in relative or absolute terms, the measured or estimated effort (energy cost) associated with the physical activity. Physical activity may be of a leisure time or occupational type activity. Physical fitness is defined as a set of attributes (i.e., cardiorespiratory endurance, skeletal muscle endurance, skeletal muscle strength, etc.) that relate to the ability to perform physical activity (Haskell et al., 2007; Kesanniemi et al., 2001).

Cardiorespiratory fitness. Cardiorespiratory fitness (CRF), also referred to as aerobic capacity, is defined as the functional ability of the cardiovascular and respiratory system to provide oxygen-rich blood to the musculoskeletal system to produce energy for work output over a prolonged period of time. CRF is measured in terms of maximal oxygen consumption at the cellular level ($VO_2\text{max}$) per kg body weight per minute ($\text{mlO}_2/\text{kg}/\text{min}$). Maximal oxygen consumption is a sensitive indicator of cardiovascular status, and it has important implications for sustaining dynamic physical work involved in firefighting activities. CRF is shown to be a strong predictor of fatal and nonfatal CVD events in firefighters (Mier & Gibson, 2004; Sui et al., 2007).

Background and Purpose

With one of the highest occupational rates of fatalities and injuries in the United States, firefighting has earned its reputation as a dangerous profession. What is less widely known is that the most frequent cause of on-duty deaths among firefighters is cardiovascular disease (CVD), rather than burns or smoke inhalation (Duenas-Laita, et al., 2007). CVD accounts for nearly half of all on-duty firefighter fatalities and injuries annually compared to just 12% of deaths attributable to asphyxiation (smoke inhalation) and 18% to burns and other trauma (Kales, et al., 2007). Despite this evidence, very

little research and best practice efforts to reduce risk of CVD in firefighters exist. However, recent epidemiological studies (Rosenstock & Olsen, 2007) have identified several risk factors regarding: 1) the specific on-duty tasks most commonly associated with CVD events and 2) biological-based CVD risk factors most commonly associated with CVD events in firefighters. The growing number of studies examining these risk factors is producing critical information for guiding interventions aiming to reduce CVD in firefighters.

In the past decade, studies have shown the majority of CVD events in firefighters occur when performing strenuous, physically demanding tasks (Kales, et al., 2007; Rosenstock & Olsen, 2007). Cohort, longitudinal, and cross-sectional studies find several biological indicators, including cardiorespiratory fitness (CRF), Body Mass Index (BMI), hypertension, dyslipidemia, and musculoskeletal fitness relate to CVD events in firefighters (Baris et al., 2001; Haas, et al., 2003; Kales, et al., 2007; Kales, et al., 2003; Soteriades, et al., 2008).

The considerable physiological demands of firefighting require high levels of cardiovascular endurance and physical fitness many firefighters do not possess. Promoting health-enhancing physical activity is widely advocated by firefighters, researchers, and public health officials to address the issue of CVD in firefighters (Geibe, et al., 2008; Holmer & Gavhed, 2007). Physical Activity (PA) is well-documented as an important preventive factor in the prevention of CVD (Haskell, et al., 2007; Kesanniemi, et al., 2001). Regular PA can help firefighters safely meet the strenuous physical demands of the on-duty tasks commonly linked to CVD events. Additionally, PA can help to improve the biological risk factors associated with CVD in firefighters.

Consistent PA is shown to increase cardiorespiratory fitness, mediate healthy weight management, reduce high blood pressure, increase healthy cholesterol while decreasing unhealthy cholesterol levels, and increase musculoskeletal fitness indicators (Sassen, Kok, Schallma, Kiers, & Vanhees, 2010).

Despite the calls to increase PA to reduce CVD in firefighters, there is little evidence-based research on the efficacy or effectiveness of such efforts. In addition to the lack of research, more than 70% of fire departments lack any best practice program to promote physical activity. Further, most fire departments do not require firefighters to exercise regularly, or undergo periodic medical and fitness examinations (Kales, et al., 2007). Unlike other occupations, firefighters have a distinctive work schedule and environment, in which they typically work 24-hour shifts during which they cook, eat, exercise and sleep at the fire station. Culturally, the work environment is distinguished by close social ties (known as brotherhood), primarily male population (nationwide average 96% male) (Hulett, Bendick, Thomas, & Moccio, 2008), and machismo (Staley, 2008). This unique culture and work environment of firefighters precludes the need to examine the research on promoting PA in comparable populations in this particular worksite setting, to inform similar efforts in firefighters. Decades of research examining the determinants of PA behaviors and the effectiveness of interventions to promote PA has contributed to meaningful advances in theoretical understandings of PA behaviors, and has also produced important implications for undertaking health planning efforts to reduce CVD in firefighters via PA.

Community-driven socio-ecological approaches for PA-based health promotion interventions are now widely recommended by leading researchers to reduce health

disparities. The ecological model, as it has evolved in the behavioral sciences and in public health, focuses on the reciprocal transactions of factors at the individual, interpersonal, community, environmental, and policy levels governing PA health behavior. Utilizing community driven ecological models to promote PA in firefighters may be useful due to the unique cultural characteristics, personal traits, social dynamics, environmental influences, and paramilitary work structure that are inherent in the firefighter profession.

The purpose of this research is to develop an evidence-based health promotion program to improve CVD risk factors in firefighters. This chapter presents a review of the relevant literature. This chapter details the prevalence of CVD in firefighters, describes risk factors associated with CVD in firefighters, examines the evidence of PA as protective factor against CVD, and summarizes the major findings and limitations of interventions promoting PA in firefighters and in the general population. The final section of this chapter proposes specific theory-driven models and best practice strategies for developing, implementing, and evaluating a PA-based CVD prevention program for firefighters. Chapters 2-4 describe three inter-related manuscripts based on these aims and strategies. The first manuscript describes the methods used to engage firefighters in the participatory processes of Community-Based Participatory Research and Intervention Mapping (IM). This manuscript describes methodologies used in planning, implementing, and evaluating of a CVD intervention. The second manuscript evaluates the validity of a Cardiorespiratory Fitness ($VO_2\text{max}$), assessment used to measure the aerobic fitness of firefighters. The final manuscript will describe the implementation and evaluation a pilot CVD prevention program for firefighters. Finally,

Chapter 5 of this dissertation proposal will present a synthesized conclusion of the strengths and limitations of the proposed studies.

The proposed studies are among the first efforts to describe the participatory process of community-driven health promotion research in firefighters, validate the current cardio-respiratory fitness assessment used to assess aerobic capacity of firefighters, and use theory-driven ecological strategies to intervene on risk of CVD in firefighters.

Prevalence and Incidence of CVD in Firefighters

Cardiovascular Disease accounts for 46% of all on-duty deaths and disabilities among firefighters annually (National Institute for Occupational Safety and Health, 2001; Rosenstock & Olsen, 2007; United States Fire Service & National Fire Data Center, 2002). In contrast, CVD is responsible for 22% of fatalities in police, 10% in emergency medical service workers, and 11% of all deaths in the general work force (Maguire, et al., 2002; National Institute for Occupational Safety and Health, 2001; United States Fire Service & National Fire Data Center, 2002). The disparity of CVD in the firefighter profession raises many questions about the contributing factors as it has become a major public health priority among public health officials and leading researchers (Kales, et al., 2007; MacKinnon et al., 2010; Poston, et al., 2011).

Emerging evidence from both government led commissions and epidemiological researchers has identified several risk factors associated with CVD in firefighter concerning specific on-duty tasks and biological based CVD risk factors (Duenas-Laita, et al., 2007; Leiba, et al., 2011; National Institute for Occupational Safety and Health, 2001; Poston, et al., 2011; United States Fire Service & National Fire Data Center, 2002). The National Institute for Occupational Safety and Health (NIOSH),

commissioned the Firefighter Fatality Investigation Program (FFIP), to examine summaries of all on-duty deaths and disabilities due to CVD in firefighters from 1994-2006 provided by the Federal Emergency Management Agency. The studies conducted by the FFIP were largely limited to descriptive, case series and case reports of on-duty fatalities without control conditions or other means of comparative analysis. These designs are limited because they cannot statistically associate specific occupational and personal risk factors with increased CVD risks. Therefore, many epidemiological researchers undertook internal, case-control study designs by pooling publicly available NIOSH reports of individual on-duty CVD firefighting fatalities to elucidate specific on-duty tasks and underlying biological risk factors for CVD in firefighters (Fahy, 2005; Kales, et al., 2007; Maguire, et al., 2002). This is a recommended method for occupational CVD studies as it controls for confounding variables related to non-occupational risk factors for heart disease (Steenland, 1996).

Despite the difference in statistical analysis and research design, the FFIP report and the majority of epidemiological studies produced similar findings regarding risk for CVD in firefighters. The following section provides a review these findings in terms of the task specific and the biologically based risk factors most commonly associated with CVD in firefighters.

Risk Factors of CVD in Firefighters

On-duty Task-Specific Risk Factors

Estimates of the proportion of time firefighters spent performing various duties related to CVD were obtained from a municipal fire department, from 17 large metropolitan fire departments, and from a national database (Kales, et al., 2007; United States Fire Service & National Fire Data Center, 2002). Statistical risk of CVD by on-

duty activities have been categorized into specific professional firefighting activities including; fire suppression, alarm response, physically demanding non-fire emergencies, physical training, and non-physically demanding duties (National Institute for Occupational Safety and Health, 2001). Fire suppression tasks involve lifting heavy equipment, demolition of physical structures to access fire, operating active water hoses to extinguish fires, and include search and rescue operations in fires. Physically demanding non-fire emergencies include medical based rescues and can involve extrication, heavy lifting of persons and/or equipment, and administration of continuous life support. Physical training includes any type of simulated emergency training, any job-related physical fitness activities, and physical abilities testing. Non-physically demanding duties include administrative and fire station tasks, fire prevention education, inspection, maintenance, meetings, parades, and other public relations activities (National Institute for Occupational Safety and Health, 2001; United States Fire Service & National Fire Data Center, 2002).

The majority of CVD deaths and disabilities in firefighters occur during activities requiring strenuous bouts of physical exertion; suppressing a fire (36%), performing physically demanding non-emergency duties (15%), responding to an alarm (13%), engaging in physical training (12%) (Geibe, et al., 2008; National Institute for Occupational Safety and Health, 2001; Rossi, 2003; United States Fire Service & National Fire Data Center, 2002). Firefighters are least likely to experience a CVD event when performing non-physically demanding duties, as they account for only 10% of the total activities linked CVD in firefighters (Duenas-Laita, et al., 2007; Glendhill & Jamnik, 1992; S. N. Kales, et al., 2007). In contrast of the odds of death from CVD during duties

involving little physical demands, the odds were 12.1 to 13.6 times as high during fire suppression, 2.8 to 14.1 times as high during alarm response, 2.2 to 10.5 times as high during physically demanding non fire emergencies, and 2.9 to 6.6 times as high during physical training (Burgess et al., 2001; Kales, et al., 2007; Rosenstock & Olsen, 2007; D. L. Smith, Manning, & Petruzzello, 2001).

Biological Risk Factors for CVD in Firefighters

The following section reviews the findings of studies examining various biologically plausible risk factors associated with fatal and nonfatal CVD events in firefighters and include: cardiorespiratory fitness, Body Mass Index and other body composition measures, hypertension, lipid profiles, and general physical fitness indicators (Friel & Stones, 1992; Guidotti, 1992; Kales, et al., 2007; Melius, 2001; Poston, et al., 2011; D. L. Smith, et al., 2001; Soteriades, et al., 2008).

Smoke and chemical exposure

Research shows there is a weak relationship between smoke and chemical exposure and CVD events in firefighters (Geibe, et al., 2008; Kales, et al., 2007; United States Fire Service & National Fire Data Center, 2002). Investigators assert this is most likely due to the widespread use of self-contained breathing apparatus that nearly eliminates all exposure to carbon monoxide, particles, and other toxins from being inhaled (Butcher, Mayne, Jones, Hartley, & Peterson, 2007).

Cardiorespiratory fitness

The majority of fatal and non-fatal CVD events in firefighters occur during prolonged bouts of strenuous exertion under the stress of heat (Burgess, et al., 2001; Geibe, et al., 2008). During these circumstances, firefighters work at near maximal heart rates for prolonged periods of time under the stress of extreme temperatures and using

heavy equipment (Rossi, 2003). Heat stress and fluid loss during the conditions CVD events occur in firefighters is believed to be the result of a decreases in cardiac output despite sustained tachycardia (Reichelt & Conrad, 1995). Subsequently, the relationship between the fitness of the cardiovascular and respiratory systems has received considerable attention regarding CVD in firefighters (Glendhill & Jamnik, 1992; Holmer & Gavhed, 2007; Poston, et al., 2011).

Cardiorespiratory fitness, also referred to as aerobic capacity, is defined as the functional ability of the cardiovascular and respiratory system to deliver oxygen-rich blood to the musculoskeletal system to produce energy for work output over an prolonged period of time (Rosenstock & Olsen, 2007). CRF is measured in terms of maximal oxygen consumption, or $VO_2\text{max}$. Maximal oxygen consumption ($VO_2\text{max}$), is a sensitive indicator of cardiovascular status, and it has important implications for sustaining dynamic physical work, and is also linked to the ability to sustain work in a hot environment (Mier & Gibson, 2004; Sothmann et al., 1990).

An increasing volume of literature implicates low cardiorespiratory fitness as a major modifiable risk factor for premature mortality and morbidity due to CVD (Donovan et al., 2009). In fact, research is showing CRF may be the most important biological factor for CVD (Murphy, Bond, Beaton, Murphy, & Johnson, 2002), as it is shown to be a stronger predictor of fatal and nonfatal CVD in firefighters than obesity, which is already significantly associated with CVD (Harvey, Kraemer, Sharratt, & Hughson, 2008; P. N. Peterson et al., 2008; Poston, et al., 2011). A longitudinal cohort design study, controlling for BMI, found individuals who could not achieve 85% predicted cardiorespiratory capacity had significantly more fatal and nonfatal myocardial

infarctions, unstable angina, and hypertension than those who could achieve 85% predicted cardiorespiratory capacity (Harvey, et al., 2008; Peterson, et al., 2008). This finding is consistent with investigations implicating low CRF levels as a strong triggering factor for CVD, especially among physically inactive persons (Poston, et al., 2011; Sui, LaMonte, & Blair, 2006; Sui, et al., 2007).

Rates of low CRF are highly prevalent among the firefighter population (Mier & Gibson, 2004; Rhea, Alvar, & Gray, 2004). Studies show 25% of firefighters fail to achieve a generally accepted minimum cardiorespiratory fitness level of 42.0 mlO₂/kg/min (Harvey, et al., 2008). Levels of cardiorespiratory fitness are also highly associated with the presence of other biological based CVD risk factors such as hypertension, cholesterol, and obesity (Haskell, et al., 2007; Kesanniemi, et al., 2001). This association has important implications for intervention efforts for promoting CRF as practical and economic way to intervene on multiple CVD risk factors simultaneously (MacKinnon, et al., 2010). Surprisingly, many fire departments do not require firefighters to exercise regularly (Kales, et al., 2007; Kales, et al., 2003). Therefore, researchers, public health officials, and concerned firefighters recommend 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 (Kales, et al., 2007; MacKinnon, et al., 2010; National Institute for Occupational Safety and Health, 2001).

Results of this review suggest stress tests for persons in physically demanding occupations, such as firefighting, is strongly recommended (Geibe, et al., 2008; Mier & Gibson, 2004). An abnormal CRF exercise test can be an important prognostic

indicator, especially when combined with the presence of other CVD risk factors such as elevated blood pressure (Sui, et al., 2007). A recent prospective study of over 25,000 asymptomatic men demonstrated that abnormal CRF exercise tests are highly predictive of subsequent cardiac death, and the association increases for each additional risk factor present (Haskell, et al., 2007; Swain & Franklin, 2006). No clear guidelines exist, however, for stress testing in asymptomatic individuals, even for public safety professionals such as firefighters (Harvey, et al., 2008). Further research is needed to determine the most appropriate and effective strategy for exercise testing (Mier & Gibson, 2004; Swain & Franklin, 2006).

Body mass index and body composition measures

Substantial research shows being categorized as being overweight or obese Body Mass Index (defined as a BMI ≥ 25 kg/m² and ≥ 30 kg/m² respectively), is significantly related to rates of mortality and morbidity due to CVD (Kesaniemi, et al., 2001; Soteriades, et al., 2008). Results from the FFIP report found that 90% of all CVD fatalities occurred in firefighters who were either classified as being overweight or obese ranges (United States Fire Service & National Fire Data Center, 2002). Firefighters with high BMIs demonstrate impaired cardiovascular function, are more likely to exhibit high-risk CVD profiles, and have substantially lower cardiorespiratory fitness and physical activity levels than their non-obese counterparts (Kales, Polyhronopoulos, Aldrich, Leitao, & Christiani, 1999; Poston, et al., 2011; Soteriades, et al., 2008).

The association of elevated BMI and CVD in firefighters is concerning because nationally representative longitudinal studies examining the rates of obesity among firefighter populations are producing alarming distributions of BMI (Poston, et al., 2011; Soteriades, et al., 2008; Soteriades et al., 2005). Several studies found prevalence

rates of firefighters being classified as either being overweight or obese exceeds those rates seen in the U.S. general population of adults, even after standardizing for age in order to facilitate comparison estimates (Flegal, Carroll, Ogden, & Curtin, 2010). Further research shows prevalence rates between 75-88% of firefighters classified as being either overweight or obese, compared to 66% in the general population (Haskell, et al., 2007; Mancuso, 2003; Poston, et al., 2011). The mean BMI of firefighter populations is reported to be between 29.0-29.7 kg/m², slightly below the obesity classification of a BMI \geq 30 kg/m². Several studies estimate 53% of all firefighters are overweight, 35% are obese, 2.5% are extremely obese (BMI \geq 40), and only 12% of firefighters are at a normal BMI (18.5 kg/m² \geq BMI < 25 kg/m²) (Clark, Rene, Theurer, & Marshall, 2002; Fahs, Smith, & Horn, 2009; Yoo & Franke, 2009). This research is counterintuitive to what many health professionals believe because firefighting is not considered to be a sedentary profession.

These findings confirm additional research showing rates of obesity are high in firefighters regardless of how obesity was measured (Fahs, et al., 2009; Poston, et al., 2011; Tsismenakis et al., 2009). Body Fat percentages (BF%), calculated by skin folds protocols, and waist circumference have also been used to measure rates of obesity in firefighters (Poston, et al., 2011). The highest estimates for obesity prevalence rates are found when using BF% skin fold measures. It is worth noting BF% is widely considered to have greater validity than other obesity measures such as BMI (Haskell, et al., 2007; Rubiano, Nunez, & Heymsfield, 2000).

Hypertension

Research shows hypertension (defined as blood pressure at rest \geq 140/90) is a significant and strong predictor of on-duty CVD events in firefighters (Geibe, et al.,

2008; National Institute for Occupational Safety and Health, 2001; Soteriades et al., 2002; United States Fire Service & National Fire Data Center, 2002). Firefighters meeting hypertensive criteria are 3.8 times more likely to suffer a CVD event than firefighters who are not hypertensive (Fahs, et al., 2009; Geibe, et al., 2008). An investigation found 56% of the autopsies performed on firefighters dying from CVD had evidence of left ventricular hypertrophy (Poston, et al., 2011), a sign of high blood pressure that also significantly increases the risk of arrhythmia and is a strong predictor of cardiovascular mortality (Benjamin & Levy, 1999; Haider, Larson, Benjamin, & Levy, 1998).

The association of high blood pressure and CVD events is alarming when considering rates of hypertension in firefighters are known to be very high (Geibe, et al., 2008; Kay, Lund, Taylor, & Herbold, 2001; Soteriades, et al., 2002; Yoo & Franke, 2009). Dr. Adi Leiba from Harvard Medical School recently presented the results of a study to the American Society of Hypertension 2011 Scientific Meeting, showing 30% of firefighters had elevated blood-pressure levels, placing them at increased risk of cardiovascular events (Leiba, et al., 2011). These findings are consistent with other research showing one-third of firefighters have high blood pressure (Geibe, et al., 2008; Kales, et al., 2007; Poston, et al., 2011; Yoo & Franke, 2009).

Investigators attribute uncontrolled hypertension to the association for case fatality rates of CVD in firefighters, since studies show high blood pressure is often untreated in the majority of hypertensive firefighters (Poston, et al., 2011; Soteriades, et al., 2005). Hypertensive firefighters experience an excessive blood-pressure response to physical exertion, and tend to be less physically fit than firefighters who have a normal blood-

pressure response (Leiba, et al., 2011). Therefore, researchers believe in addition to periodic blood pressure screenings, fire departments should promote aggressive risk factor reduction strategies, such as promoting PA, to control for the high rates of hypertension in firefighters.

Lipid profiles

The high prevalence of elevated total cholesterol (≥ 240 mg/dl), among firefighters is well-documented (Friel & Stones, 1992; Kales, et al., 2003; Rhea, et al., 2004; Soteriades, et al., 2005). A first of its kind prospective cohort study examining lipid panels among firefighters found pervasive and abnormally high total Low Density Lipoprotein cholesterol levels (LDL), and abnormally low High Density Lipoprotein levels among firefighters at baseline and during follow-up (Ide, 2000; Rosenstock & Olsen, 2007; Soteriades, et al., 2005; Soteriades, et al., 2002). High total cholesterol, high LDL, and low HDL are significant predictors of CVD incidents in firefighters and in the general population (Guidotti, 1995; Kales, et al., 2003; Soteriades, et al., 2002). The high prevalence of elevated total cholesterol in firefighters, along with its known relationship to CVD, strongly support suggestions by leading researchers to include lipid profiles in annual medical examinations, along with prevention and treatment programs addressing unhealthy cholesterol levels in firefighters (Kales, et al., 2003; National Fire Protection Association, 2000; Soteriades, et al., 2002).

Musculoskeletal health indicators

Evidence supporting the health benefits of activities that increase muscular strength and muscular endurance has accumulated rapidly in recent years (Braith & Stewart, 2006; Haskell, et al., 2007; Pollock, Franklin, Balady, & AHA Science Advisory Committee, 2000). Recent observational studies have suggested an inverse association

between risk of all-cause mortality from CVD and other chronic disease with various components of muscular strength or endurance (Fitzgerald et al., 2004; Haskell, et al., 2007; Katzmarzyk & Craig, 2002; Poston, et al., 2011). Musculoskeletal PA promote the development and maintenance of metabolically active lean muscle mass, which is particularly important for enhancing glucose metabolism (Ivy, Zderic, & Fogt, 1999; Jurca et al., 2005). The emerging evidence on musculoskeletal health benefits (Haskell, et al., 2007; Pollock, et al., 2000), illustrates the need for promoting muscular fitness to support efforts to reduce CVD in firefighters. Many incumbent firefighters lack the minimum exercise tolerance thought necessary to safely perform the most demanding tasks (Donovan, et al., 2009; Leiba, et al., 2011; Poston, et al., 2011). Even new firefighter recruits are overweight and have low-to-normal aerobic capacities (Clark, et al., 2002). Surprisingly, most fire departments do not require firefighters to exercise regularly (S. N. Kales, et al., 2007; Poston, et al., 2011). According to the 2008 International Association of Firefighters report concerning the fire service Joint Labor Management Wellness and Fitness Initiative; few fire departments require veterans to maintain the physical standards required of new hires, most firefighters do not receive medical examinations, or are required to participate in on-duty PA and fitness activities (International Association of Firefighters, 2009).

Summary of CVD risk factors

To summarize, firefighters are most likely to experience CVD while performing physically demanding tasks. Biologically-based CVD factors, namely CRF, obesity, high blood pressure, unhealthy cholesterol levels, and poor musculoskeletal fitness are all interrelated and significantly increase the risk for CVD in firefighters (Lakka et al., 2002; Sassen, Kok, et al., 2010). The results of these studies suggest that comprehensive

preventive programs are needed to address CVD risk factors in firefighters.

Investigators of these studies universally recommend regular PA and exercise as a critical component for reducing CVD in firefighters.

Physical Activity as a Protective Factor against CVD

The following section presents the evidence for PA as a protective factor for CVD risk factors mentioned in the previous section. First, a brief overview of the common terminology used in the health sciences regarding the aspects of physical activity is provided.

It is well documented that regular PA has a positive health impact on each of the biological CVD risk factors (Berlin & Colditz, 1990; Nocon et al., 2008; Sofi, Capalbo, Cesari, Abbate, & Gensini, 2008). Additionally, regular PA can help firefighters develop the physical fitness required to safely meet the strenuous physical demands of the on-duty tasks most commonly linked to CVD events. In addition to the favorable impact PA has on the task-specific and biological risk factors, PA is a low-cost, feasible, safe therapy with minimal adverse side-effects (Elliot et al., 2007).

The prevalence and incidence rates of mortality and morbidity due to lack of PA are alarming. Lack of physical activity and is now considered the second leading cause of preventable death in the United States (Antikainen & Ellis, 2011; Myers et al., 2002; Wannamethee & Shaper, 2001). Physical inactivity is a leading contributor to morbidity and disability, accounting for 22% of coronary heart disease, 22% of colon cancer, 18% of osteoporotic fractures, 12% of diabetes and hypertension, and 5% of breast cancer (Mokdad, Marks, Stroup, & Gerberding, 2004; Myers, et al., 2002; Nocon, et al., 2008). The calculation of a Population Attributable Risk percentage (PAR%) provides a useful estimate of the burden of a particular disease or condition attributable to a given

exposure—in this case, the percentage of specific mortality or morbidity that is attributable to physical inactivity. Using this approach, it has been estimated that the PAR% of cardiovascular disease mortality due to physical inactivity is approximately 35% (Kesanniemi, et al., 2001).

According to Mokdad (Mokdad, et al., 2004), who authored *Actual Causes of Death*, yearly incidence rates of death from 1990-2000 due to physical inactivity increased faster than death rates attributable to smoking. Annual death rates attributed to smoking increased from 400,000 in 1990 to 435,000 in 2000 (an increase of 35,000 deaths). Annual deaths rates attributed to physical inactivity grew from 1000,000 in 1990 to 165,000 in 2000 (a net increase of 65,000 deaths) (Mokdad, et al., 2004). In other words, the yearly incidence rates of death due to physical inactivity were nearly double the rates of death due to smoking (65,000 vs. 35,000 respectively).

Cardiovascular disease (CVD) is the leading cause of morbidity and mortality in the developed world (Farag et al., 2010; Ignarro, Balestrieri, & Napoli, 2007). The top two indicators are physical activity and overweight/obesity. Lack of physical activity has been shown to be a strong independent risk factor for death from coronary heart disease (Mokdad, et al., 2004; Myers, et al., 2002). Conversely, those who are physically active have a reduced risk of developing CVD (Bauman, 2004; President's Council on Physical Fitness and Sports, 2002). In a meta-analysis, Berlin and Colditz (Berlin & Colditz, 1990; Pazoki, et al., 2007) calculated a 1.9-fold increased relative risk for CVD mortality associated with a sedentary lifestyle compared with a vigorously active lifestyle. Cross-sectional studies have found associations between physical activity and a number of health-related variables, including blood pressure, high density

lipoprotein cholesterol, and obesity (Haskell, et al., 2007; Kesanniemi, et al., 2001; Pazoki, et al., 2007).

Cardiorespiratory fitness, lipid/lipoprotein profiles, blood pressure, postprandial lipidemia, and weight control, all appear to be affected beneficially with intermittent bouts of physical activity (Donnelly, Jacobsen, Heelan-Snyder, Seip, & Smith, 2000; Haskell, et al., 2007; Kesanniemi, et al., 2001; Murphy, et al., 2002; Sui, et al., 2007). New science has added to our understanding of the biological mechanisms by which physical activity provides health benefits and in terms of the dosage of the physical activity performed (type, intensity, amount) and that is associated with enhanced health and quality of life (Haskell, et al., 2007; Kesanniemi, et al., 2001). Economic costs are associated with physical inactivity levels in addition to the health impact, physical inactivity accounts for about 2.4% of U.S. health care costs, or approximately \$24 billion a year (Pratt, Macera, & Wang, 2000).

Review of Physical Activity-Based Interventions

The following section provides a background on determinants of physical activity in firefighters, background on previous evidence based efforts to promote physical activity in firefighters, a review physical activity based intervention efforts in comparable populations (adults), a review of work site physical activity interventions, and provides a summary of the key elements for physical activity based intervention efforts to help inform future health promotion efforts to reduce CVD in firefighters.

Given the substantial research linking the health benefits of PA to improved aerobic capacity, blood pressure, lipid profiles, and body composition in firefighters and the general population, investigators assert successful physical activity behavioral changes in is a critical component to reduce CVD risk factors (Donnelly, et al., 2000;

Elliot, et al., 2007; Haskell, et al., 2007; Kales, et al., 2007; Kesanniemi, et al., 2001; Murphy, et al., 2002; Soteriades, et al., 2005; Sui, et al., 2007). However, limited research exists on intervention efforts to adequately promote regular aerobic PA to reduce risk factors related to CVD in firefighters (Elliot, et al., 2007; Kales, et al., 2003). The need for efficacious and effective evidence-based health promotion efforts are now becoming a major public health priority given the disproportionately high rates of CVD deaths, disabilities, and risk factors in firefighter populations has remained unchanged over the past decades (Geibe, et al., 2008; Poston, et al., 2011).

Researchers and public health officials are calling for the development of theory-driven ecological models targeting the multiple levels of interrelated factors that were identified and reviewed in the previous section (Biddle & Nigg, 2000; Booth, Owen, Bauman, Clavisi, & Leslie, 2000; Owen, Leslie, Salmon, & Fotheringham, 2000). Theory-driven ecological models have important applications for firefighters because of the unique work structure inherent in the firefighter profession (McLeroy, Bibeau, Steckler, & Glanz, 1988; Peterson & Aldana, 1999). Unlike traditional professions, firefighters are characterized by unique individual traits inherent to their profession, rely heavily upon the social dynamics of team work, are present in the work environments for longer periods of time (24-hour shifts), and are governed by paramilitary style institutional policies of job performance, conduct, and behavior (Elliot, et al., 2007).

Determinants of Physical Activity Behaviors in Firefighters

Little research has examined the unique socio-cultural and normative factors influencing firefighter health behaviors, especially regarding the factors contributing to PA behaviors and overall fitness in the firefighter culture (Elliot, et al., 2007; Poston, et al., 2011). To date, studies specifically examining the unique determinants of PA in

firefighters is nearly nonexistent. The literature is so sparse that it is uncertain if PA and physical fitness is a core value held by the majority of firefighters. The only research related specifically to determinants of PA behavior comes from a dissertation on ascertaining factors that facilitate overall firefighter physical fitness and the cultural meaning of physical fitness. This study was guided by a social ecological framework and provides significant insights to assist health promotion efforts and fire departments to improve the effectiveness of workplace fitness programs, and change the culture of fitness and low coronary risk salience.

Interventions in Firefighters

Few studies have evaluated interventions for promoting PA, addressing obesity, and other physical fitness in the fire service culture. The only known evidence based interventions to date, PHLAME (Promoting Healthy Lifestyles: Alternative Models' Effects), is a prospective randomized control trial among 599 firefighters in the northwest region of the United States (Elliot, et al., 2007). Many researchers and practitioners regard this study as a logical starting point for further inquiry into evidence based efforts to implement effective, easily exportable, and economically feasible health promotion interventions to reduce CVD in firefighters.

The objective of PHLAME was to assess and compare two strategies to promote healthy lifestyles in firefighters. Firefighters were randomized by fire station into either a team-centered curriculum, or to an individual based curriculum or into control conditions. Assessment included physical activity, cardiorespiratory fitness, BMI, nutrition, and general well-being at baseline and 12 months. The team and MI programs did not increase physical activity levels or cardiorespiratory fitness compared to the

control group. However, both treatment groups experienced significantly less weight gain and significantly increased fruit and vegetable consumption (Elliot, et al., 2007).

Although PA and aerobic capacity was not significantly affected, this study provides important insights into future PA based intervention efforts. Elliot and colleagues uncovered several lessons in regards to working within the firefighter culture and unique work structure. First the authors found team centered and individual-level paradigms are both effective strategies for delivering health programs to firefighters. The authors reported high participation rates, low attrition rates, high fidelity, and sufficient reach of both strategies. Elliot suggest future research is recommended to assess a mix method designs utilizing both individual and team centered strategies to address the broader range factors in the firefighter culture influencing health behaviors (Elliot, et al., 2007).

More innovative studies are needed to determine what types of interventions would be most successful in improving health and fitness in firefighters(Poston, et al., 2011). Due to the sparse evidence for PA based health promotion efforts in firefighters, it is necessary to examine the known determinants of PA and to review PA based intervention efforts in demographically comparable populations and in similar settings. Extrapolating findings from this research is critical for the development, implementation, and evaluation of future efforts to reduce CVD in firefighters.

Interventions in General Population Adults

The process promoting PA involves a multitude of complex variables, including personal, programmatic, social, environmental and related factors. To achieve long term changes in health-related PA behaviors, these factors must be addressed collectively (Sallis, Kraft, & Linton, 2002). As opposed to traditional PA interventions targeting one

level of influence, the strategies of efficacious PA interventions target multiple levels of influence including individual, interpersonal, community, environmental, and/or policy factors simultaneously. Intervening on multiple levels of influence grew out of research demonstrating social and environmental barriers contributing to inhibiting physical activity participation even among the most motivated persons (Kahn et al., 2002; Sallis, et al., 2002).

Results from earlier PA based interventions generally report little success, with high rates of recidivism of participants to previous levels of pre-intervention inactivity, especially if the duration of the program extended beyond several months (O'Neal & Blair, 2001; Oldridge, Ragowski, & Gottlieb, 1992; Oldridge & Steiner, 1990; Sassen, Kok, et al., 2010). It is frequently reported that 50% of sedentary adults who begin an PA or exercise program will drop out within 6 months, and that 80-90% will drop out within one year (Antikainen & Ellis, 2011; Haskell, et al., 2007). Evidence from four meta-analyses of RCTs shows physical activity interventions produce short-term moderate changes in self-reported physical activity (the odds ratio for achieving increased PA ranged from 1.2 to 1.3 in treatment groups), and cardio-respiratory fitness on an average of only 6 months before participants return to pre-intervention levels (Foster, Hillsdon, & Thorogood, 2005; Galani & Schneider, 2007; Greaves et al., 2011). These studies are supported by lower quality evidence from six meta-analyses of RCTs, and from three systematic reviews, that interventions only sustain an increase of self-reported physical activity of an average of up 6 weeks to 19 months of follow-up (Douketis, Macie, Thabane, & Williamson, 2005; Eakin, Glasgow, & Riley, 2000; Greaves, et al., 2011; Norris et al., 2007).

Interventions with an explicitly stated theoretical basis such as Social Cognitive Theory (Bandura, 1986), or Theory of Planned Behavior (Ajzen, 1991), were more effective in producing changes in either weight or in physical activity outcomes (Antikainen & Ellis, 2011; Greaves, et al., 2011). Four meta-regression analyses (all medium quality associative analyses) in two reviews (Dombrowski et al., 2000; Michie, Abraham, Whittington, McAteer, & Gupta, 2009), did find an association between the use of a theoretically specified cluster of 'self-regulatory' intervention techniques (specific goal-setting, prompting self-monitoring, providing feedback on performance, goal review) and increased effectiveness in terms of weight loss and change in physical activity outcomes.

The limited long term success of these interventions is largely believed to be due to only intervening on one of the multiple levels of influence for contributing to PA behaviors (Antikainen & Ellis, 2011; Greaves, et al., 2011; Kok, Schaalma, Ruiter, van Empelen, & Brug, 2004). For example, the majority of PA interventions in the 1980's and 1990's targeted the individual-level of influence and were primarily based on educational strategies. Although the results from some recent interventions have been encouraging, the psychological physiological, social, community, environmental, and policy based factors influencing the adoption of a physically active require additional research (Kahn, et al., 2002; Klem, Wing, Lang, McGuire, & Hill, 2000; Lee, Blair, & Jackson, 1999; I. M. Lee & Skerrett, 2001). Future efforts to promote physical activity must consider how people interact with their social and environment influences (Heath et al., 2006).

Worksite Physical Activity Interventions

The workplace is an important social environment that influences health behavior by its norms, policies, and job characteristics (Murphy, et al., 2002; Wilson, Holman, & Hammock, 1996). One occupational group with a relatively unique work and social environment is that of professional firefighters (Corneil, 1995; Elliot, et al., 2007). In most U.S. cities, firefighters have become the first responders to medical emergencies and rely on teamwork in both fire suppression and medical emergencies. Employees who engage in teamwork are more likely to spend off-duty time together than those whose jobs require more independence (Fillmore, 1992).

The Department of Health and Human Services report to the Surgeon General, and the Center for Disease Control and Prevention Health People national objectives for public health in the United States, have targeted worksites as important settings for interventions to increase physical activity. Worksites offer unique opportunities to encourage adults and their families to increase levels of physical activity. Most adults spend half their waking hours at the workplace (Murphy, et al., 2002). Hence, exposure to mass reach approaches and behavioral interventions potentially can be more substantial than in many other community settings (Dishman, Oldenburg, O'Neal, & Shephard, 1998).

Researchers cite many reasons for the limited evidence of effective worksite health promotion interventions to increase physical activity and healthy nutrition, and to reduce CVD risk factors. Quantitative synthesis of the literature indicates most interventions are not theory-driven and lack evidence based principles of behavior modification (Kahn, et al., 2002; Pignone, Ammerman, & Fernandez, 2003). While it is widely believed multi-level influences (individual traits, social dynamics, environmental

factors, and institutional policies) play an essential role in health behaviors (French, Story, & Jeffery, 2001; Stokols, 1996), relatively few interventions systematically intervene upon or assess the impact these influences have on health outcomes (Glanz, et al., 2002). Studies show most health intervention efforts are not designed to simultaneously address the broad range of influences over the performance of health behaviors. Additionally, most interventions lack rigorous experimental design, implementation protocols, and objective measures for intervention effects (Kahn, et al., 2002).

Elements of Efficacious Physical Activity Interventions

Future efforts to promote physical activity must consider how individuals interact with their social and environment influences (Sassen, Gerjo, Schaalma, Kiers, & Vanhees, 2010). Multiple level strategies for increasing PA in adults include individually tailoring behavioral modification techniques, fostering social supports, developing community capacity to support PA, providing environmental prompts to be PA, and implementing policies promoting PA in the workplace (Booth, et al., 2000; Sallis, et al., 2002).

Many of the activities developed for each the multiple levels of influence focus on overcoming barriers to PA. Individually-tailored efforts included motivational techniques, addressing personal interests, needs, and schedules. Interpersonal intervention efforts largely address dynamics of social influences from family, friends, and co-workers. Providing access to PA supportive environments and alternatives for PA opportunities during inclement weather and when traveling (Haskell, et al., 2007).

Limitations of Physical Activity Interventions

Despite widespread attempts to target worksites as a setting for interventions to promote increased physical fitness and healthy nutritional practices, there is little attention given to the firefighter profession (Elliot, et al., 2007). Subsequently, there is limited scientific evidence supporting an effective approach for interventions promoting health behavioral changes to reduce physiological CVD risk factors in firefighters. Furthermore, findings from several systematic scientific reviews of universal worksite interventions show most do not adequately promote physical activity behaviors, or reduce risk factors associated with CVD in participants (Dishman, et al., 1998).

Understanding the many limitations of evidence based and best practices to promote PA is critical for the continued efforts to develop, implement, and evaluate health promotion research. The following sections reviews the limitations of current PA research regarding measurements, research design, use of health theory, applying health planning models, and threat to external validity.

Measurements of Physical Activity

Studies collectively did a poor job of measuring physical activity, relying mainly on non-validated self-reports of physical activity and submaximal estimates of VO_{2max} , which can be influenced by learning, habituation, or motivation to perform. Several of the studies that used submaximal estimates of VO_{2max} failed to habituate their subjects; this led to large apparent gains of fitness in control groups or, in the absence of a control group, to spurious gains of fitness in the experimental group. The problem of measurement of physical activity is not unique to worksite interventions. Questions about the validity of self-reported physical activity are illustrated by one study in which a

subgroup of the intervention condition reported a 20% increase in physical activity, but VO₂max decreased by 6% (Dishman, et al., 1998).

Experimental Design

Most interventions lack rigorous experimental design, implementation protocols, and objective measures for intervention effects (Kahn, et al., 2002). Many of the studies did not adhere to either an experimental or quasi-experimental design that included control groups. Most studies also relied solely on self-reported measures rather than more objective measures such as physiological based indicators. Another limitation in some studies was a lack of outcome results and the amount of impact they had on individual behavior (Matson-Koffman, Brownstein, Neiner, & Greaney, 2005).

Dishman and colleagues (Dishman, et al., 1998) developed a multiple linear regression model including with the key moderating variables for PA intervention effectiveness and found research design had the only independent influence on the size of intervention effects. The quasi-experimental design studies yielded larger effects sizes compared with randomized experimental designs. Dishman asserts this may reflect difficulties in organizing and executing a well-designed and large scale randomized controlled trial. Other quantitative reviews confirm Dishman's findings and are noted in previous review articles.

Health Theory and Planning Models

A quantitative synthesis of the literature (Pignone, et al., 2003) indicates most interventions are not theory-driven, lack evidence based principles of behavior modification, and rarely report of utilizing a planning model for health programming (Kahn, et al., 2002). Researchers cite many reasons for the limited evidence of effective PA health promotion interventions to increase physical activity and to reduce CVD risk

factors. While it is widely believed multi-level influences (individual traits, social dynamics, environmental factors, and institutional policies) play an essential role in health behaviors (French, et al., 2001; Stokols, 1996), relatively few interventions systematically intervene upon or assess the impact these influences have on health outcomes (Glanz, et al., 2002). Antikainen and colleagues conducted an extensive review on PA interventions and found the vast majority targeted individual-levels only, most which had small effects sizes and insignificant results on PA outcomes (Antikainen & Ellis, 2011). This is consistent with other reviews and research showing the limitations on individual only efforts to promote health, underscoring the need to intervene on multiple levels simultaneously.

The majority of conceptual models used in PA research only target one level of the ecological perspective, mainly the individual or community level. There have been limited attempts to develop approaches that target multiple levels of analysis and can stimulate basic and applied research. Epstein and Matson-Koffman found few studies of policy and environmental interventions to increase physical activity (Epstein, 1998; Matson-Koffman, et al., 2005). These types of intervention efforts are relatively new public health paradigms for increasing physical activity. Further research is needed to evaluate the added value of policy and environmental interventions with and without more traditional individual educational and community messaging interventions.

Representativeness of Sample to Target Population

The facet of reach is important for determining public health impact and appropriateness of a program for translational research. The representativeness of the study participants to the target population is critical in generalizability. Unfortunately, only a few physical activity interventions reviewed in this literature review reported on

the representativeness of the participants to the target population. Future researchers should report the characteristics of their participants as compared with the whole target population and determine if demographic differences exist in intervention efficacy.

Reporting on inclusion and exclusion criteria in the target population is rare in the literature. The practical importance of reporting inclusion criteria and exclusion rate for translational research is twofold. First, researchers need to know who was excluded to determine if the results can be generalized to a potential population and setting, and second, researchers need to know how many people were excluded based on these standards to determine the feasibility of the intervention for a given target population (Antikainen & Ellis, 2011).

Future researchers should consider the impact a strict focus on internal validity has on the external validity of their study as they provide limited information for practitioners looking to implement the intervention in real-world settings where such factors cannot be controlled.

Sample Size Issues

Antikainen and colleagues (Antikainen & Ellis, 2011) found in their RE-AIM evaluation of theory based PA interventions widespread difficulties in recruiting adequate numbers of participants or having limited resources to include large samples are additional factors that impact the results and efficacy of intervention studies. In the studies Antikainen and colleagues reviewed, sample sizes ranged from 20 to 2087 with a median sample size of 126. In addition, 35.2% of the studies had less than 100 participants. However, Antikainen and colleagues defended the lack of large sample sizes in the research they reviewed by asserting the focus should not necessarily be on recruiting large numbers of people for a single intervention, because in real-world

settings few programs or organizations have the funding to reach thousands of people. These researchers suggest future studies, need to focus on program evaluations of intervention protocol, results, and effects of interventions rather than focus only on the efficacy of a single program. This would provide the information needed for future reviews and meta-analyses to determine the actual public health impact and efficacy of interventions. Shifting focus in this manner would also encourage the publication of studies that are well-designed and described and can be translated to real-world settings, but that may lack statistically significant findings because of a small sample size (Antikainen & Ellis, 2011).

External Validity

Antikainen and colleagues conducted the first study to review the external validity and translatability of theory-based physical activity interventions targeting various populations (Antikainen & Ellis, 2011). The physical activity interventions included in this review were much more likely to report on issues of internal, rather than external validity. The practical implication of this is that the translation of many of the interventions into practice would be difficult or impossible. In addition, most studies included motivated, healthy participants reducing the generalizability of the interventions to real-world settings that provide services to diverse populations.

Program Evaluations

Only a few of the interventions in this literature review reported any information on process evaluation. Several explanations for this lack of reporting have been proposed by Antikainen et al. and include: 1) The complexity and time consuming nature of current behavior change programs is largely believed to cause investigators to forgo either conducting process evaluations, or to not report on them. 2) The space limitations

of most scientific journals have led to brief descriptions of programs and a lack of reporting on process evaluation (Antikainen & Ellis, 2011). If the intervention was not delivered as originally intended, the reader should be made aware of the changes that took place so they can evaluate the effectiveness of the program based on the actual process rather than a description of an ideal scenario. Process evaluation data can also provide practitioners with information about how flexible a given program is to changes while still maintaining efficacy.

Expanded descriptions of the interventions would allow readers to better understand their scope and complexity, the strategies used to establish them, and what they could accomplish. When evaluating reach of an intervention, few studies reported the intended target population. Future researchers should identify a specific target population and report the number of people targeted to provide other researchers or practitioners the ability to evaluate the potential reach of an intervention (Antikainen & Ellis, 2011).

Review of Health Theories and Planning Models for PA-based Interventions

This section reviews the health behavior theories and health promotion planning models most commonly used to predict, explain, and intervene on the determinants of PA presented in the previous section. Interventions showing significant increases in long term PA and physical fitness incorporated distinct systematic theory driven strategies and techniques during the recruitment, screening, and intervention phases of programs. Theories and the use of health planning models are extremely important for developing effective interventions. When translating theoretical methods into practical strategies, planners have to consider the theoretical parameters very carefully. Examples of adequate theory application include the Ecological Model, Social Cognitive

Theory (SCT), and using the health planning model Intervention Mapping (IM). The Ecological Model, SCT, and the IM planning model will be described in the following section since they have been empirically shown to be effective and maybe particularly useful in health programs for firefighters. This section concludes with a review on the use of Community Based Participatory Research and Intervention Mapping to promote regular PA, and is proposed as efficacious approaches for use in firefighter communities.

A health promotion program is most likely to benefit participants and communities when it is guided by social and behavioral science theories of health behavior and health behavior change (Eakin, et al., 2000; Michie, et al., 2009). Long term changes in individual and group PA behaviors are frequently accompanied by theories and the use of planning models to guide the development, implementation, refinement, and evaluation of interventions (Greaves, et al., 2011). Effective theory-driven PA health promotion programs require the operational and practical applications that are tailored to the target population (Glanz, et al., 2002).

Researchers and public health officials are calling for the development of theory-driven ecological models targeting the multiple levels of interrelated factors that were identified and reviewed in the previous section (Biddle & Nigg, 2000; Booth, et al., 2000; Owen, et al., 2000). Theory-driven ecological models have important applications for firefighters because of the unique work structure inherent in the firefighter profession (McLeroy, et al., 1988; T. R. Peterson & Aldana, 1999). Unlike traditional professions, firefighters are characterized by unique individual traits inherent to their profession, rely heavily upon the social dynamics of team work, are present in the work environments

for longer periods of time (24-hour shifts), and are governed by paramilitary style institutional policies of job performance, conduct, and behavior (Melius, 2001; National Institute for Occupational Safety and Health, 2001).

The Ecological Model

The ecological model, as it has evolved in the behavioral sciences and in public health, focuses on the interrelated factors of the individual, interpersonal, community, environment, and policies levels that contribute to PA health behaviors. A number of recent studies suggest ecological models may help to increase PA and enhance physical fitness activities (Baker, Brennan, Brownson, & Houseman, 2000; Bartholomew, et al., 2006). Research indicates several determinants exist at each level of the ecological model that are responsible for participation in PA and promotion of physical fitness (Owen, et al., 2000; Renisow, 1997; Sallis, Prochaska, & Taylor, 2000). These findings are providing insight towards integrating the most relevant health behavior theory at each level of the ecological model (Glanz, et al., 2002). The following sections include a brief overview of the determining factors associated with PA behavior in adults within each of the levels of the ecological model.

Individual-level factors

Personal factors such as, age, gender, ethnicity, educational level, socio-economic status, and various personal traits are shown to significantly influence PA behaviors in adults. Research shows PA levels tend to decrease as age increases, males are more likely to be PA than females; white people are more physically active than other ethnicities; more educated adults are likely to be physically active; adults of higher socioeconomic status are more likely to be physically active than those of lower socioeconomic status (Owen, et al., 2000; Renisow, 1997; Sallis, et al., 2000).

Personal traits have received the most attention in health promotion research as it is widely considered to be the most modifiable of the individual-level factors related to PA behavior. Personal traits, particularly motivation, behavioral skills, and self-efficacy are significantly related to PA behaviors in adults. Research shows adults who are motivated intrinsically, who have the behavioral capability to be proficient in PA, and who demonstrate moderate to high self-efficacy are more likely to engage in PA. These personal traits are believed to contribute to an individual's ability to overcome barriers of participating in PA (Owen, et al., 2000; Renisow, 1997; Sallis, et al., 2000).

Interpersonal-level factors

Both quantitative (cross-sectional and longitudinal) and qualitative studies show the importance of social support in enhancing physical activity (Baker, et al., 2000; Bartholomew, et al., 2006). Social variables that are associated with physical activity include; social context of surroundings in which many people were exercising, having friends who encouraged exercise, and having at least 1 friend with whom to exercise. Among interpersonal factors influencing PA behaviors, social support for exercise from family, friends, or exercise program staff is the most clearly established determinants (Baker, et al., 2000; Bartholomew, et al., 2006). Social support can be direct and tangible (e.g., providing a non-driver with a ride to an exercise class), or informational (sharing information about physical activity and encouraging a friend to participate).

Environmental and policy levels

A systematic literature of the effects for modifying environmental and policy worksite levels of influence can improve physical activity and fitness (Matson-Koffman, et al., 2005). Matson-Koffman and colleagues found that nearly all of the 10 studies meeting the inclusion criteria for their review addressing environmental and policy

factors related to PA demonstrated positive effects on participant's fitness outcomes. Matson-Koffman et al. found worksite intervention efforts that utilized on-site exercise equipment and facilities had a positive effect on participants' cholesterol levels and systolic blood pressure, fitness levels and frequency of self-reported exercise. One study showed that creating a work environment supportive of physical activity increased employees' levels of physical activity. Another study showed that organizational policy support for exercise increased significantly after human-resource managers attended training on building and developing a wellness committee. Post intervention results yielded excellent improvements in administrative support for worksite resources to promote on-duty physical activity. Three interventions at worksites created environmental modifications by providing changing facilities to increase physical activity among employees. A study of one of these interventions showed that installing locker rooms led to an increase in the number of employees walking or bicycling to work. Two of the worksite intervention studies showed that providing counseling and health promotion activities (e.g., organized physical fitness activities or health education classes), was more effective in increasing employees' physical fitness than providing staffed on-site exercise facilities alone (Matson-Koffman, et al., 2005).

Common Health Behavior Theories

Research based on the various theories that have been applied in attempts to explain human behavior has its roots in classical learning theories. The most commonly used health theories include the Health Belief Model, Transtheoretical Model, Social Cognitive Theory, Theory of Planned Behavior, and the ecological perspectives (Ajzen, 1991; Bandura, 1986; Biddle & Nigg, 2000; Oldridge & Steiner, 1990). All of these theories have been used successfully in physical activity interventions (Antikainen &

Ellis, 2011; Glanz, et al., 2002). Researchers suggest the use of many theories is needed to match the unique characteristics within the multiple levels of the ecological model influencing PA behavior, (individual, interpersonal, community, environmental). To design more effective interventions, researchers suggest using several theories, building the intervention around several mediators, and measuring the change in theory-based mediators (Kok, et al., 2004).

However, multiple theory approaches have most likely led to the mixed results from experimental or quasi-experimental research makes it difficult to determine the effectiveness of any single theory or model (Seefeldt, Malina, & Clark, 2002). Although there are inconsistencies in the existing data, several characteristics are common to the various theories and models. To be effective, individual needs, personal level of fitness, readiness for a change in PA behavior, personal confidence in PA and its expected outcome, social support from family, peers, and community seem to promote adherence to physical activity in structured and free-living situations (Seefeldt, et al., 2002).

To date, the Transtheoretical Model (TTM) demonstrates the highest efficacy at the individual-level of behavior for physical fitness (Marshall & Biddle, 2001). Social Cognitive Theory (SCT) is demonstrating the most promise for effectively intervening on the social, environmental, and institutional policy levels (Booth, et al., 2000).

It is well documented that an individual's motivational level is a high predictor for engaging in physical activity and nutritional health behavior (Marcus & Lewis, 2003; Marshall & Biddle, 2001; T. R. Peterson & Aldana, 1999). The TTM assesses an individual's motivational readiness to perform a behavior, and assigns the individual into one of five Stages of Change: pre-contemplation stage, contemplation stage, planning

stage, action stage, or maintenance stage. The TTM then customizes several Process of Change strategies based upon the individuals specific Stage of Change to induce the performance of a health behavior (Prochaska & Velicer, 1997).

Social Cognitive Theory

Studies show Social Cognitive Theory (SCT) holds promise for the development of effective health worksite interventions targeting the social, environmental, and institutional policy levels (Booth, et al., 2000; Conn, 1998; Kim, Kim, Park, & Kim, 2009; Sheeshka, Woolcott, & Mackinnon, 1993). SCT proposes that the reciprocal interactions of a person's behavior, social influences, and environment (reciprocal determinism) play a critical role in the performance of health behaviors (Bandura, 1986). SCT rationalizes that social factors such as peer influences, role-modeling of behaviors, and vicarious learning are significant mechanisms involved in physical activity (Seefeldt, et al., 2002). Firefighters are required to work with one another as one unit for nearly all of their time spent performing on-duty tasks. Therefore, SCT will play an even more profound role in health behaviors of firefighters due to the team centered interactions inherent in the firefighter population (Elliot, et al., 2007).

One of the strongest determinants emerging from social cognitive theory is self-efficacy as it has been consistently been reported as positively associated with physical activity in adults (Conn, 1998) adherence to structured programs, and in those with injuries or disabilities (Seefeldt, et al., 2002). Research has shown 23% of the variance in physical fitness could be predicted by self-efficacy for physical active behavior, and has been shown to be a mediator for the intensity of physical activity performed. (Seefeldt, et al., 2002). Additionally, social cognitive variables are useful predictors of physical active behavior and of the intention to engage in physical activity for 60

minutes every day (Kim, et al., 2009). Social-cognitive variables accounted for 52% of the variance in physical active behavior and 39% of the variance in intention to engage in physical activity (Fallon, Wilcox, & Ainsworth, 2005). A review of the literature showed that social-cognitive variables accounted for 27% of the variance in behavior and 39% of the variance in intention (Kim, et al., 2009).

SCT also accounts for the environmental influences of health behavior (Bandura, 1997). These include factors that are external to the individual. Firefighters work in the fire station environment for most of their 24-hour shift. Fire stations typically have access to physical fitness equipment. The environmental work structure of the typical fire station provides universal access to resources that can be utilized to promote physical activity behaviors through SCT applications. The external influence of policies governing firefighter behavior in the work environment has a significant impact on health behaviors (Glanz, et al., 2002). Exercise programs are not required by all fire departments. However, firefighters from fire departments that do require physical training demonstrate higher rates of overall physical activity levels when compared to firefighters from fire departments that do not require physical training (D. Smith, 2011). The paramilitary style of policies regarding job performance, conduct, individual behavior, and team work predisposes the firefighter profession as a fully capable organization to institutionalize health related policies (Elliot, et al., 2007).

Review of Health Planning Models used in Physical Activity Interventions

As mentioned earlier in this literature review, adequate application of behavioral science theories is essential for effective behavior change interventions, therefore planning and evaluation are key elements in developing health promotion programs. Theories and empirical evidence form the basis for decisions during the planning

process, by helping to answer questions about the problem, the behavioral and environmental factors involved the determinants of behavior, the objectives of the program, appropriate methods and strategies, program implementation and evaluation (Kok, et al., 2004). In practice, however, applying theories for interventions is rather difficult (Green & Kreuter, 2005).

Greaves and colleagues assert “the use of established, well-defined behavior change techniques are associated with increased effectiveness, and should be integrated into a coherent intervention planning model” (Greaves, et al., 2011). Therefore, a planned approach to intervention design is recommended, and utilizing a health planning model to guide theoretical applications, such as PRECEDE-PROCEED or Intervention Mapping, is essential to address targeted behavior change processes that are tailored for the target population and setting of interest (Greaves, et al., 2011; McEachan, Lawton, Jackson, Conner, & Lunt, 2008).

Health promotion is a planned activity (Kok, et al., 2004). A widely used health promotion planning framework is Green and Kreuter’s *PRECEDE/PROCEED* model (Green & Kreuter, 1999). The PRECEDE model starts with analyses of quality of life, health, behavior and environmental factors, and predisposing, reinforcing and enabling determinants (correlates) of behavior and environmental factors. In PROCEED a health promotion intervention is developed, implemented and evaluated. The options for a useful program evaluation depend on the quality of program planning. Rossi, Freeman and Lipsey argue that it would be a waste of time, effort and resources to estimate the impact of a program that lacks measurable goals or that has not been implemented in a proper way (Rossi, 2003).

Intervention Mapping

Evidence-based health promotion programs are founded on empirical data and theory. While a broad range of social and behavioral science theories are available, the actual application of these theories in program design remains a real challenge for health promotion planners (Kok, et al., 2004). Intervention Mapping describes a protocol for the development of theory- and evidence-based health promotion programs. It provides guidelines and tools for the selection of theoretical foundations and underpinnings of health promotion (Bartholomew, et al., 2006).

Intervention Mapping is a protocol for systematically applying theoretical and empirical evidence when designing health promotion programs. Intervention Mapping elaborates on the program development phase in Green's PRECEDE/PROCEED model for planning health promotion interventions (Green & Kreuter, 2005). Intervention Mapping includes: conducting a comprehensive needs assessment for the determinants of a health outcome formulating program objectives for the target group, selecting appropriate theoretical methods, translating methods into practical strategies an ecologically integrated program, conducting development, implementation, impact, and outcome evaluations (Bartholomew, et al., 2006).

Intervention Mapping provides a protocol for selecting and applying theories that may improve our understanding of health behaviors and health behavior change (Bartholomew, et al., 2006). Intervention Mapping describes the process of health promotion program development in six steps: (1) needs assessment (2) the definition of proximal program objectives based upon scientific analyses of health determinants; (3) the selection of theory-based intervention methods and practical strategies to change determinants of health-related behavior; (4) the production of program components,

design and production; (5) the anticipation of program adoption, implementation and sustainability; and (6) the anticipation of process and effect evaluation. Intervention Mapping is the product of its authors' frustration in teaching students the processes in developing theory and evidence-based health promotion. It maps the path from recognition of a need or problem to the identification of a solution. Although Intervention Mapping is presented as a series of steps, the planning process is iterative rather than linear (Bartholomew, et al., 2006). Intervention Mapping guarantees that: (1) each program objective is grounded on empirical evidence and theory; (2) the final materials and activities are linked both with theory and have clearly specified objectives; (3) all important objectives are covered; (4) the program is compatible with the target population; and (5) diffusion issues are anticipated throughout the process (Kok, et al., 2004).

It can be argued that the strengths of Intervention Mapping also represent its weaknesses. (McEachan, et al., 2008). The theory- and evidence-based intervention development of IM is a complex and time-consuming process (Kok, et al., 2004). Needs assessments, creation of the matrices of change objectives, performance objectives, and the process of evaluations is particularly time consuming (Bartholomew, et al., 2006). McEachan et al. comment that the intervention mapping protocol is typically applied to simple and uni-dimensional behaviors, and can become overwhelming when applied to multi-dimensional behaviors, such as physical activity. McEachan and colleagues cited a study to underscore this wherein a workplace intervention to increase PA in young adults decided not to create matrices of change objectives (step 2 of Intervention Mapping), instead focusing on clear theoretical steps matched with clearly

identified strategies to change PA. This may be a useful short-cut for researchers developing interventions targeting complex and multi-dimensional behaviors such as PA. Additionally, the comprehensive development of IM work is typically carried out without the necessary funding and intervention are not given sufficient consideration prior to implementation, and may help to explain why interventions are often not theoretically rounded or evidence based (McEachan, et al., 2008).

Community Based Participatory Research

In the past, based on a medical research model, physical activity research has focused on clinically significant results leading to highly controlled, short-term interventions with healthy, motivated participants (Task Force on Community Preventive Services, 2002). These types of programs are difficult and costly to maintain and virtually impossible to adopt in real-world settings where participants are more likely to have a variety of health issues and be less motivated to engage in physical activity (Task Force on Community Preventive Services, 2002).

The role of community-based interventions to promote physical activity has emerged as a critical piece of an overall strategy to increase physical activity behaviors among the people of the United States (Task Force on Community Preventive Services, 2002). To date, community-based interventions to increase physical activity have not been summarized in an evidence based process (Goh et al., 2008). Community Based Participatory Research (CBPR) has been identified as a key strategy in effectively reducing health disparities in underserved communities (Pazoki & Nabipour, 2007; Wallerstein & Duran, 2006). CBPR is defined as a collaborative, partnership approach to research that equitably involves, for example, community members, organizational representatives, and researchers in all aspects of the research process (Israel, 2001).

Partners contribute their expertise and share responsibilities and ownership to increase understanding of a given phenomenon, and incorporate the knowledge gained with action to enhance the health and well-being of community members (Israel, 2001).

Community-based participatory research (CBPR) has quickly entered the discourse of research methodologies within the past decade, spawning requests for proposals from the Centers for Disease Control, Office of Minority Health, multiple institutes within the National Institutes of Health, and other state or foundation sources that have attracted hundreds of applicants (Green & Kreuter, 2005; Task Force on Community Preventive Services, 2002). There is considerable evidence suggesting that numerous resources, strengths and skills exist within communities (e.g. supportive interpersonal relationships, community-based organizations), that can be engaged in addressing problems and promoting health and well-being (Goodman, Speers, & McLeroy, 1998; Heaney & Isreal, 1997; Israel & Shchurman, 1990; Kretzman & McKnight, 1993; Steuart, 1993). This understanding of the factors associated with health and disease has contributed to calls for more comprehensive and participatory approaches to public health research and practice (Israel, 2001). CBPR intervention research is based on two primary assumptions for improving health outcomes and reducing disparities: 1) that interventions can be strengthened if they benefit from community insight and incorporate community theories of etiology and change into the empirical science base; and 2) that there is an added value to participation itself for enhancing health (Wallerstein & Duran, 2006).

More pointedly, CBPR has been framed as an orientation to research that focuses on relationships between research partners and goals of societal transformation (Isreal,

2002), rather than a specific set of research methods or techniques. CBPR, however, is not simply a community outreach strategy but represents a systematic effort to incorporate community participation and decision making, local theories of etiology and change, and community practices into the research effort (Farag, et al., 2010).

Numerous advantages of advantages include that it: enhances the relevance and use of the research data by all partners involved; joins partners with diverse skills, knowledge and expertise in addressing complex problems; improves quality and validity of research buy-incorporating the local knowledge of the people involved; provides resources (e.g. funds, training and possible employment opportunities) for communities involved can reduce dependency on health professionals, can help ensure cultural and local sensitivity, can facilitate sustainability, enhances productivity and effectiveness of health programs (Isreal, 2002; Wallerstein & Duran, 2006).

Actively involving the community in all stages of the research project and providing directly benefit to the community being studied makes CBPR an attractive research model for health promotion in firefighters. Firefighter communities are distinguished by unique socio-culture characteristics that make CBPR an appealing approach to PA intervention efforts. Firefighters work cohesively as a unit in a paramilitary type structure, work together as a unit during in 24-hour shifts, have access to shared resources, are influenced by similar environmental factors, and are governed by the same policies.

Recommendations for PA Intervention Research in Firefighters

Although many limitations exist in the field of PA health promotion, the information gleamed from these efforts have produced important information for guiding future research and practice. The following section provides a brief overview of several

recommendations I am proposing based upon the limitations described earlier in this review that are relevant for promoting PA in firefighter populations.

As mentioned earlier in this review, few interventions are grounded in health behavior theory. Therefore basing interventions on contemporary and relevant health theories of behavioral change or organizational change is critical. When selecting an appropriate theory, it is critical to specify the presumed mechanisms for behavioral change and the outcome measures used in evaluating their impact. Incorporating a socio-ecological intervention based on changes at the individual, interpersonal, organizational and environmental levels would be a logical conceptual model for PA promotion in firefighters given their unique individual traits, social dynamics, shared environmental influences, and paramilitary style of organizational procedures regulating conduct and behavior. Practical strategies may include support for counseling to increase physical activity, promote peer social support, provide skill-based education to build self-efficacy, increase access to PA at the fire stations by making environmental modifications, and provide opportunities for engaging in physical activity while on-duty through policy changes.

Applying the use of community-based approaches to health promotion that address the firefighter worksite culture and encourage fire department management to initiate and support peer-group leadership of PA behavior modification may be an excellent approach to use in firefighter populations. Firefighters are known to be a tight knit community who actively participate communal living while on-duty, adhere to commonly held traditions of conduct, and are known to spend off duty hours with one another. Collaboration of firefighters with researchers in the design, implementation,

and evaluation of PA intervention efforts may produce more “buy-in” from firefighters than expert only approaches to promoting PA, and may lead to more sustainable health program efforts.

The use of the principle of variety in physical fitness to foster motivation and emphasize the broad spectrum of physical activity involved in firefighter tasks may also be a critical aspect for PA intervention efforts in firefighters. The recent popularity of functional fitness is relevant for the type of strenuous on-duty activities experienced by firefighters. For example, exercise routines could be developed that focus on climbing ladders, dragging heavy equipment (like a body drag), running fire hose lines may be more engaging and practical for developing the fitness related to the type of activities involved in firefighting.

As mentioned earlier in this literature review, the use of accurate evaluations for assessing physical fitness and intervention effectiveness is a pervasive and historic limitation of PA research. Use validated measures of physical fitness or physical activity, administered under standardized conditions is essential for the evaluation of PA research. For example, cardiorespiratory fitness as a critical indicator for aerobic fitness and is related to risk of CVD in firefighters. Use of an accurate assessment for measuring aerobic capacity would then be essential for intervention efforts aimed at improving this component of fitness in firefighters.

Sufficient statistical reporting of intervention efforts in addition to validated instruments is essential (and as mentioned earlier in this literature review often not reported), and include: reporting sample sizes, means, standard deviations or frequencies, before and after an intervention for both experimental and control groups.

When regression, covariance, or multivariate analysis is used, report the aforementioned data sufficiently to permit calculation of simple or main effects between intervention and control groups is useful for meta-analysis efforts.

Limitations from previous research identified in this literature review provide information to guide recommendations for improving the external validity of PA interventions. One of the limiting factors for increasing external validity can be the lack of dissemination or adoption of an intervention from one setting to another, and appears to be the least reported dimension of external validity of interventions (Antikainen & Ellis, 2011). Future researchers who recruit from community or workplaces should report the number of sites that were screened or invited to participate in the study (Antikainen & Ellis, 2011). The current trends of basing interventions on theory, writing separate articles on intervention design, efficacy, and process evaluation, and focusing on long-term maintenance of behavior change are encouraged by researchers to provide more meaningful information necessary for translational research. To determine if a given intervention is feasible and effective in translational research and not only effective under highly controlled conditions, more information must be reported in future studies about the factors that affect external validity. This detailed reporting for PA intervention efforts in firefighters will be critical for improving the likelihood similar efforts could be adopted or disseminated to other fire departments that are more geographically and ethnically diverse than the one an intervention originated.

Strengths and Limitations of Proposed Research

The following section provides a synopsis of the strengths and limitations of the current research.

Strength. A major strength is the uniqueness of the proposed studies as it is among the first efforts to describe the participatory process of community-driven health promotion research in firefighters, to validate the current cardiorespiratory fitness assessment used to measure cardiorespiratory fitness of firefighters, and to pilot test the use of theory-driven ecological strategies to reduce CVD risk factors in firefighters.

Strength. The use of health behavior theory and health planning models is a major strength of this research since studies show interventions using planning models that are grounded in health theory to be more efficacious and effective than those that are not. Social Cognitive theory and Intervention Mapping were theory and planning model selected for this study respectively. Social Cognitive Theory was mutually selected by firefighters and researchers as a relevant theory to use based on its concept of reciprocal determinism; “an individual influences and is influenced by social factors and the environment”(Bandura, 1986). This concept resonated with the firefighters who asserted the interaction of a firefighter’s behavior is largely effected by social influences of other firefighters, and the environmental conditions present at the fire station they are assigned to work. Academic partners also found SCT to be particularly useful as they learned more about the unique culture and work structure inherent in the firefighter profession (McLeroy, et al., 1988; T. R. Peterson & Aldana, 1999). Unlike some other occupations, firefighters tend to embrace masculine expectations for individual behaviors (94% of the profession is male), firefighting requires proficiency and confidence in performing specific skills, firefighting relies heavily upon the social dynamics of team work, firefighters are present in the work environments for longer periods of time (24-hour shifts), and are governed by

paramilitary style institutional policies of job performance, conduct, and behavior (Elliot, et al., 2007).

Utilizing Intervention Mapping is a major strength since it is designed to systematically apply the use of health theory into the development, implementation, and evaluation of health promotions. The use of Intervention Mapping is a strength since: it advocates for using logic models to identify determinants of health, developing objectives targeting the identified determinants, for creating specific strategies and methods based on health theory, and its use of a comprehensive iterative evaluation processes to provide critical information as to the formative, process, impact, and outcome evaluations of health program and intervention efforts.

Strength. A strength of this research is the use of a socio-ecological approach towards identifying determinants of health outcomes in firefighters and intervening upon these factors contributing to CVD events in firefighters. Incorporating a socio-ecological intervention based on changes at the individual, interpersonal, organizational and environmental levels is a logical conceptual model for PA promotion in firefighters given their unique individual traits, social dynamics, shared environmental influences, and paramilitary style of organizational procedures regulating conduct and behavior. Practical strategies may include support for counseling to increase physical activity, promote peer social support, provide skill based education to build self-efficacy, increase access to PA at the fire stations by making environmental modifications, and provide opportunities for engaging in physical activity while on-duty through policy changes.

Strength. A major strength of this research is the use of Community Based Participatory Research in its approach towards health promotion efforts. The orientation of CBPR has never been studied in promoting health in the fire service even though firefighters are known to be a tight knit community who actively participate communal living while on-duty, adhere to commonly held traditions of conduct, and are known to spend off duty hours with one another. Collaboration of firefighters with researchers in the design, implementation, and evaluation of PA intervention efforts may produce more “buy-in” from firefighters than expert only approaches to promoting PA, and may lead to more sustainable health program efforts.

Strength. A major strength of this research is the use of program evaluations (formative and process), to help create, guide, and if necessary modify, eliminate or incorporate strategies and methods for developing or delivering intervention efforts. Formative and process evaluations can lead to changes that need to take place during the development or implementation of the intervention to improve success. Further, these evaluations can be used to identify the program components that are attributable to the impacts and outcomes of the intervention. These formative and summative evaluation results are critical to addressing threats to the internal and external validity of the entire research project. This detailed reporting of health program evaluation in firefighters will be critical for improving the likelihood similar efforts being adopted or disseminated to other fire departments that are more geographically and ethnically diverse than the one an intervention originated.

Limitation. The nature of Community Based Participatory Research and the process of developing, implementing, and evaluating theory driven health programs

utilizing Intervention Mapping is time consuming and challenging. Examples of these efforts include; identifying and networking with gatekeepers and key informants; building partnerships; developing community capacity; leveraging material and human resources; training of community and academic program planners; and development of a comprehensive iterative evaluation plan.

Limitation. The proposed sample size for the treatment group and control groups is small. Twenty four of the least fit firefighters will be recruited into either treatment (n=12), or control group (n=12). A small sample size limits the statistical power to show significance and hinders the generalizability of the results to other firefighter populations.

Limitation. Another limitation is the availability of fitness equipment and environments to participate in physical activity between fire stations are different. This variability will be measured and controlled for in the analysis and taken into consideration in the interpretation of the findings. Additionally, the CVD intervention will tailor efforts to advocate for environmental and policy changes to improve accessibility to fitness equipment, as it is a component within the ecological approach of the research design.

Limitation. Another limitation is that the instrumentation for assessing cardiorespiratory fitness in firefighters has not yet been previously validated. This is a major concern as cardiorespiratory fitness is strongly associated with CVD in firefighters, and is a main health outcome of the proposed research. To control for this limitation, the submaximal cardiorespiratory fitness VO_{2max} protocol used to predict the true VO_{2max} of firefighters will be validated. There is no funding for this proposed

research. Without incentives, the firefighters who participate in the study may have distinguishing characteristics from those who choose not to participate. Therefore, participants and non-participants will be characterized on demographic features, physical activity levels, and reasons why they choose to or not to participate in the study will be ascertained.

Limitation. Testing changes caused by testing rather than the experiment may further threaten the internal validity of the study. For instance, firefighters may improve pre-tested fitness levels based on knowing they will be post-tested on a specific date. However, this limitation should be present to a similar extent in the comparison group, thus minimizing the impact on the effect estimate.

Limitation. Selection bias may also exist due to potential systematic differences in characteristics of groups selected for treatment and control.

Limitation. Attrition is a major threat to internal validity, especially considering the small sample size. Dropout of participants may occur, especially considering the highest risk firefighters will be recruited into the intervention. Attrition or low rates of participation may not be a random effect (may be an underlying reason or distinct characteristic participants are dropping out from the intervention). Issues of missing data may negatively affect statistical analysis and compromise confidence in the results and interpretation of findings.

Limitation. Contamination and diffusion of intervention into the control group is a threat to the internal validity of the intervention. The firefighter community is a network of team-centered social structures. Firefighters who are in the treatment and control conditions will intermix periodically due to the nature of the profession. Participants in

both treatment and control conditions will be assessed on whether diffusion or contamination of the intervention occurred.

Limitation. The external validity of this research is limited. The generalizability of results may be limited to other firefighter populations that are geographically different and/or do not possess the same demographic characteristics represented in the North Central Florida firefighters who participate in this proposed research project.

Statement of Purpose

The overall objective of the proposed research project is to implement an efficacious peer mentor-based worksite health promotion program to significantly improve the risk factors of cardiovascular disease (CVD) in firefighters. To achieve this objective, three integrated research studies are proposed in chapters 2-4.

The purpose for the first study is to identify the methods for fostering community academic partnerships and utilizing Intervention Mapping (IM) in a firefighter community. Community Based Participatory Research has never been applied in the fire service for health promotion efforts, yet it may be an effective approach in the shaping and delivery of CVD health promotion programs in firefighters. Therefore, the purpose of this study is to describe the methods used to engage firefighters in the participatory processes of planning, implementing, and evaluating a CVD prevention program utilizing IM.

The purpose of the second study is to validate the cardiorespiratory fitness assessment used to assess aerobic fitness in firefighters. The majority of CVD events occur during prolonged bouts of strenuous exertion that require a high level of cardiorespiratory fitness. Cardiorespiratory fitness, as measured via expired gases, is significantly related to on-duty CVD events in firefighters. Currently, a submaximal

cardiorespiratory fitness protocol is used to estimate the maximal aerobic capacity ($VO_2\text{max}$) of firefighters; however, it has not yet been validated. Firefighters identified the need to validate the instrumentation used to assess cardiorespiratory fitness of firefighters as a high priority. Therefore, the purpose of the study is to evaluate the validity of the submaximal $VO_2\text{max}$ protocol used to predict the true $VO_2\text{max}$ of firefighters.

The purpose of the third study is to evaluate the efficacy of a pilot cardiovascular disease prevention program in firefighters. The purpose of this is to examine the use of a peer-driven firefighter worksite health promotion intervention on increasing physical activity, improving cardiorespiratory fitness, body composition, and other physical fitness indicators in unhealthy firefighters failing to meet “fit-for-duty” requirements.

Significance

Epidemiological studies show a high prevalence of risk factors for CVD among firefighters exists, including: inadequate physical fitness, high rates of obesity, hypertension, and unhealthy cholesterol profiles (Haas, et al., 2003; Kales, et al., 2003; Leiba, et al., 2011; Rosenstock & Olsen, 2007; Soteriades, et al., 2008). Even new firefighter recruits are commonly found to be overweight and have low cardiorespiratory fitness (S. N. Kales, et al., 2007; Poston, et al., 2011). Despite the high rates of CVD among firefighters, more than 70% of fire departments lack programs to promote physical fitness and health, do not require firefighters to exercise regularly, or do not require firefighters to undergo periodic medical examinations to screen for CVD risk factors (Geibe, et al., 2008). The substantial health and fitness issues facing the fire service have, in large part, not been adequately addressed from the public health research community (Poston, et al., 2011). Few studies have evaluated interventions for

addressing physical fitness, weight gain, high blood pressure, or unhealthy cholesterol in the fire service culture.

The significance of this research is that these studies are among the first efforts to describe the participatory process of community-driven health promotion research in firefighters, validate the current cardiorespiratory fitness assessment used to assess aerobic capacity of firefighters, and use theory-driven ecological strategies to intervene on risk of CVD in firefighters.

Research Aims

This study was designed to understand the methodology of health promotion efforts to increase physical activity and reduce risk of CVD in firefighters, to investigate the validity of the current aerobic capacity assessment used in firefighters to predict their true aerobic capacity, and to evaluate the effectiveness of health intervention on CVD in high-risk firefighters. Therefore, the specific aims of this research this as follows:

Aim 1. To describe how the principles of Community Based Participatory Research were integrated and operationalized into each of the six steps within Intervention Mapping.

Aim 2. To evaluate the validity of the firefighter Wellness Fitness Initiative sub-maximal VO_2 test to predict the true VO_2 max of firefighters.

Aim 3. To evaluate the use of a peer-driven firefighter worksite health promotion intervention on increasing physical activity, increasing VO_2 max, decreasing body fat percentage, and increasing musculoskeletal physical fitness indicators in unhealthy firefighters.

Chapters 2-4 describe three inter-related manuscripts based on these aims and strategies. The first manuscript describes the methods used to engage firefighters in the

participatory processes of Community-Based Participatory Research and Intervention Mapping (IM). This manuscript describes methodologies used in planning, implementing, and evaluating of a CVD intervention. The second manuscript evaluates the validity of a Cardiorespiratory Fitness ($VO_2\max$), assessment used to measure the aerobic fitness of firefighters. The final manuscript will describe the implementation and evaluation a pilot CVD prevention program for firefighters. Finally, Chapter 5 of this dissertation proposal will present a synthesized conclusion of the strengths and limitations of the proposed studies.

CHAPTER 2 METHODS FOR FOSTERING COMMUNITY ACADEMIC PARTNERSHIPS AND UTILIZING INTERVENTION MAPPING IN A FIREFIGHTER COMMUNITY

Background

Firefighting is a dangerous profession as it has one of the highest occupational fatality and injuries rates in the United States annually (Kales, et al., 2007; National Institute for Occupational Safety and Health, 2001; United States Fire Service & National Fire Data Center, 2002). What is less commonly known is cardiovascular disease (CVD), rather than burns or smoke inhalation, constitutes the most frequent cause of death and disability in firefighters (Duenas-Laita, et al., 2007; Geibe, et al., 2008; Rosenstock & Olsen, 2007). CVD accounts for 46% of all on-duty fatalities in firefighters, compared to 22% of fatalities in police, 10% in emergency medical service workers, and 11% of all deaths in the general work force (Kales, et al., 2007; Soteriades, et al., 2008). The disproportionate rates of CVD in the firefighting profession have emerged as a major public health concern in recent years.

Over the past decade epidemiological studies have worked to identify the on-duty tasks and biological-based risk factors most commonly related to CVD in firefighters. Studies show the majority of CVD events occur during activities requiring strenuous physical exertion; suppressing a fire (36%), performing physically demanding medical emergency duties (15%), responding to an alarm (13%), and engaging in physical training (12%) (Geibe, et al., 2008; Murphy, et al., 2002). These types of on-duty activities require firefighters to work at near maximal heart rates for prolonged periods of time, under the stress of high temperatures, while using heavy equipment (Geibe, et al., 2008; Holmer & Gavhed, 2007; Rossi, 2003). Therefore, the relationship between physical fitness and CVD during the performance of firefighting duties has received

considerable attention among concerned firefighters, public health officials, and researchers (Leiba, et al., 2011; National Institute for Occupational Safety and Health, 2001; Poston, et al., 2011; United States Fire Service & National Fire Data Center, 2002).

Biological risk factors related to CVD events in firefighters include poor cardiorespiratory endurance (also referred to as VO₂max or aerobic capacity), having high percentage of total body fat, an overweight or obese Body Mass Index classification (BMI), hypertension, dyslipidemia, and poor musculoskeletal fitness profiles (Harvey, et al., 2008; Leiba, et al., 2011; Rhea, et al., 2004; Soteriades, et al., 2008; Yoo & Franke, 2009). Rates of low VO₂max are shown to be highly prevalent among the firefighter population as studies find 25% of firefighters fail to achieve a the current minimum standard for VO₂max of 42.0 ml/kg/min in firefighters (Harvey, et al., 2008; Mier & Gibson, 2004; Poston, et al., 2011). Research finds 90% of all CVD fatalities occurred in firefighters who were classified as being either overweight or obese. This is concerning since several studies show 53% of all firefighters are overweight, 35% are obese, 2.5% are extremely obese, and only 12% of firefighters have a healthy body fat percentage or BMI (Clark, et al., 2002; Fahs, et al., 2009; Yoo & Franke, 2009). A high prevalence of having one or more of these biologically based CVD risk factors exists in firefighter populations (Donovan, et al., 2009; Leiba, et al., 2011; Poston, et al., 2011). Even new firefighter recruits are commonly found to be overweight and have low-to-normal aerobic capacities and lack the minimum exercise tolerance thought necessary to safely perform physically demanding on-duty tasks (Clark, et al., 2002; Leiba, et al., 2011; Poston, et al., 2011).

A large body of evidence shows regular aerobic Physical Activity (PA) is a protective factor against developing CVD as it increases $VO_2\text{max}$, is a critical component in weight management and reducing body fat, and is shown to both prevent and manage hypertension and cholesterol levels (Braith & Stewart, 2006; Fitzgerald, et al., 2004; Haskell, et al., 2007; Kesanniemi, et al., 2001; Nocon, et al., 2008; Sofi, et al., 2008). Regular PA is also necessary to develop the physical fitness required to safely meet the strenuous demands on-duty tasks most commonly linked to CVD events in firefighters (Fahy, 2005; Holmer & Gavhed, 2007; Rossi, 2003). Therefore, researchers, public health officials, and concerned firefighters recommend programs promoting regular PA, physical fitness evaluations, and annual CVD screenings as part as part of a comprehensive effort to reduce CVD risk in firefighters (Kales, et al., 2007; Leiba, et al., 2011; National Institute for Occupational Safety and Health, 2001; Poston, et al., 2011; United States Fire Service & National Fire Data Center, 2002).

Despite the protective factors PA offers, most fire departments do not require firefighters to exercise regularly (Kales, et al., 2007; Kales, et al., 2003). According to the 2008 International Association of Firefighters report more than 70% of fire departments lack programs promoting PA or cardiovascular health, do not require firefighters to exercise on-duty, do not require incumbent firefighters to maintain physical fitness standards, and do not require medical examinations to screen CVD risk factors (Geibe, et al., 2008). Additionally, little evidence based research exists regarding the use of PA health promotion programs as a means to reduce CVD risk factors in firefighters (MacKinnon 2010, (Elliot, et al., 2007; Kales, et al., 2003; Poston, et al., 2011). The lack of programs and studies promoting PA in firefighters underscores the

need for researchers and firefighter communities to collaborate on best practice and evidence based efforts to reduce CVD in firefighters.

Decades of research examining the determinants of PA behaviors and the effectiveness of interventions to promote PA provides meaningful insight towards identifying the appropriate theoretical understandings and health planning models to use for increasing physical fitness via PA firefighters (Biddle & Nigg, 2000; Farag, et al., 2010; Greaves, et al., 2011; Kahn, et al., 2002; Sallis, et al., 2000). Theory-based health promotion efforts are more likely to succeed when delivered through a well-designed health planning model (Green & Kreuter, 2005). Intervention Mapping (IM) is a protocol specifically designed for systematically applying theoretical strategies when designing, implementing, and evaluating health promotion programs (Bartholomew, et al., 2006; Kok, et al., 2004). Incorporating principles of Community Based Participatory Research (CBPR) may be an efficacious orientation for guiding firefighter community involvement in the application of IM in the development, delivery, and evaluation of health programming since studies show worksite health promotion efforts involving the target community in the research process has been successful for increasing physical activity (Israel, et al., 2005; Pazoki & Nabipour, 2007).

The purpose of this study is to describe how CBPR was integrated into the steps of IM to engage firefighters in the participatory process of screening for CVD risk factors, developing and delivering a CVD intervention for high-risk firefighters, and in validating instrumentation used to assess cardiorespiratory health in firefighters. This study describes the participatory processes between firefighter and academic partners in health program planning, implementation, and evaluation processes. This study is

among the first efforts to describe the participatory process of community-driven health promotion research in firefighters.

The information presented in this manuscript includes a brief background on how a Community Academic Partnership (CAP) was formed, a brief background on CBPR and IM, the results section describing how CBPR principles led to participatory outcomes within each step of IM, and a discussion section on the strengths and limitations of integrating IM and CBPR in health promotion efforts to reduce CVD in firefighters.

Methods

Formation and Structure of the Community Academic Partnership

A CAP between firefighters and researchers was formed by integrating the orientation of CBPR principles with IM methods to develop and disseminate a worksite health promotion program targeting CVD risk factors in firefighters. The CAP was comprised of two fire departments, a local public health department, and three health-oriented university academic departments. This collaboration was initiated when local firefighters recognized a need for better physical fitness in their department and approached the researchers of this study for assistance in developing and delivering an effective health program for promoting physical activity. Soon after, the firefighters and academic partners jointly created their CAP and developed contractual agreements regarding equal involvement and guidelines for communication between all partners at the onset of this collaboration. The formal creation of the CAP itself resulted from stakeholder meetings between fire chiefs, firefighters, and the principal investigators of the study. These formative meetings were conducted over a span of six months and were integral in creating the infrastructure for the CAP and in facilitating partnerships from the needs assessment and throughout each step of the IM planning process.

Selection of CBPR & IM Process

CBPR is recognized as a critical orientation in efforts to effectively reduce health disparities in underserved communities (Pazoki & Nabipour, 2007) and is defined as “a collaborative partnership approach to research that equitably involves community members, organizational representatives, and researchers in all aspects of the research process” (Wallerstein & Duran, 2006). Community members and partners contribute their expertise and share responsibilities and ownership to increase understanding of a given phenomenon, and to incorporate the knowledge gained with action to enhance the health and well-being of community members (Wallerstein & Duran, 2006). The orientation of CBPR is based on nine interrelated principles and are described in Table 2-1 and include recognizing the community as a unique unit, involving the community in all phases of the research process, promoting co-learning, building on the strengths of the community, emphasizing local relevance and an ecological approach to health, iterative system development, and long term commitment to sustainability, the balance between research and action via information and learning are shared equally by all members, and disseminates findings and knowledge gained to all partners. CBPR was selected as an approach towards health promotion efforts in firefighters since they expressed interest in being involved in all aspects of the research processes as they believed it would lead to more ‘buy-in” from the rest of the fire department. Additionally, CBPR was seen as a logical fit for based on the social dynamics characterizing the firefighter community including the high emphasis on team work, communal style living routines, being present in the work environment with one another for 24-hour shifts, and the use of paramilitary style policies governing job performance, conduct, and behavior.

IM is a health promotion planning model that describes the process of program development, implementation, and evaluation in six iterative steps and is described in Table 2-2: (1) needs assessment (2) creating matrices of program objectives based upon scientific analyses of health determinants; (3) the selection of theory-based intervention methods and practical strategies to change determinants of health-related behavior; (4) developing program design, components, and materials; (5) the program adoption, implementation and sustainability; and (6) the evaluation process. IM is presented as a series of steps, however, the planning process is cyclical (iterative), rather than linear (Bartholomew, et al., 2006). For example, planning for step 6 (evaluation), is typically the first step to be undertaken when using IM. The use of IM was selected because researchers advocated for the use of health behavior theories since health promotion programs are more likely to succeed when grounded in theory, and IM is a planning model that is specifically designed for surfacing and applying relevant theories in health promotion. Additionally, the comprehensive iterative evaluation of IM provides critical information as to the formative, process, impact, and outcome evaluations intervention efforts, and allows changes to take place during the development or implementation of the intervention to improve the success of health promotion efforts.

Both CBPR and IM are founded upon the ecological model, wherein as it has evolved in the behavioral sciences and in public health, the ecological model focuses on influential factors at the individual, interpersonal, community, environmental, and policy levels of health. Incorporating CBPR and IM in promoting health of firefighters may be an effective strategy due to the unique characteristics inherent in the firefighter

profession. Compared to most other professions, firefighter have distinct personality traits, rely more heavily upon the social dynamics of team work, have unique cultural norms, are present in the work environments for longer periods of time (24-hour shifts), and are governed by paramilitary style institutional policies of job performance, conduct, and behavior(Elliot, et al., 2007). Therefore, the orientation of CBPR and Intervention Mapping may have practical applications for guiding health promotion efforts to reduce CVD in firefighters.

Results

The following sections describe results in the context of how the CBPR principles and the participatory outcomes of the CVD program were operationalized within each of the 6 steps in the IM process. Table 2-3 identifies the specific CBPR principles that were integrated into each step of the IM steps. Six principles of CBPR were primarily and consistently used throughout the IM steps process. The most frequently utilized principles of CBPR was the promotion of co-learning and capacity building as it was integrated into 5 IM steps (integrated into IM Steps 1-4 and 6). Three CBPR principles were integrated into 4 steps of IM and included facilitating partnerships in all phases of the research process (Steps 1, 2, 5, and 6), building upon the strengths of the community (Steps 1 and 3-5), and involving system development through iterative process (Steps 1, 2, 4, 6). Emphasizing local relevance and an ecological approach to the determinants of health was incorporated into 3 IM steps (Steps 2-4). Involving a long term commitment was primarily emphasized in one step of IM (Step 5: Program Adoption, Implementation, and Sustainability). The CBPR principle of recognizing the community as a unit is an inherent fixture of the efforts undertaken by the CAP and was implied throughout the whole process of health promotion efforts. The balance between

research and action was seen mostly in the engagement phase of the CAP, however, is not explained in this study. The dissemination of findings is not relevant since the results of this study are now just emerging and will be ready to disseminate in the near future.

IM Step 1. Needs Assessment

The needs assessment step of IM integrated the CBPR principles of “involving system development through cyclical and iterative processes, facilitating partnerships in all phases of the research, promoting co-learning and capacity building, and building on strengths of community.” Involving system development through cyclical and iterative process was demonstrated by operationalizing Steps 2 and 6 of IM (Developing Matrices of Change and Evaluations respectively), in conjunction with the needs assessment. The steps of conducting the needs assessment, developing matrices of change, and evaluations occurred simultaneously since each of these steps in IM are interdependent upon one another’s processes and outcomes.

Planning for the needs assessment was integral in facilitating partnerships between firefighter’s and academics as it was the initial focus of the CAP collaborative. The needs assessment was developed through strategic planning meetings and was conducted in several phases: understanding the health concerns of CVD in local firefighters, identifying risk and protective factors related to CVD in firefighters, selecting and validating instruments used to measure risk factors for CVD, and conducting screenings to assess CVD risk factors for all firefighters in the department.

Co-learning occurred during the initial strategic planning meetings since the focus of them was in understanding the health needs of firefighters. These meetings resulted in identifying the promotion of PA to reduce risk of CVD as a primary health concern for

firefighters. Next, the CAP meetings focused on understanding the relationship between PA behaviors and CVD in firefighters. Academic partners provided expert advice and results of systematic literature reviews on the topic of PA behavior and CVD to firefighter stakeholders including: how CVD is the leading cause of death and disability in firefighters, the majority of CVD occurs while performing strenuous activity, CVD risk factors are highly prevalent in the firefighter population and include poor physical fitness, hypertension, obesity, and dyslipidemia. The firefighters then provided feedback on the relevancy of how this evidence-based information could be applied towards conducting a needs assessment and developing a health promotion program in their department. Firefighters explained to academics screening for CVD in firefighters is rare and little efforts are undertaken to promote PA in firefighters. The firefighters expressed the desire to conduct CVD screening throughout the entire department as part of the needs assessment.

CAP meetings then focused upon building capacity via selecting specific measurements for assessing CVD risk factors in firefighters. The CAP agreed to build upon the strengths of the firefighter community by utilizing the firefighter Wellness Fitness Initiative (WFI), for determining the protocols used in the physical fitness and CVD needs assessment. The WFI was developed by the Fire Service Joint Labor Management Task Force, and is specifically tailored for assessing the physical health of the firefighter population. The CVD risk factors and physical fitness assessments selected for the needs assessment included: a sub-maximal cardiorespiratory fitness treadmill test (measures aerobic capacity or $VO_2\text{max}$), blood pressure, Body Mass Index, total percent body fat (via skin fold analysis), arm strength, leg strength, hand

grip strength, and abdominal endurance. Additional measures for the needs assessment included self-reported frequency, intensity, and duration of physical activity.

The firefighters and academics partners worked together to pool the material resources and equipment needed for conducting the needs assessments. The CAP built upon the strengths of the firefighter community by designating them with the responsibility of administering the CVD screenings as it capitalizes on their expertise in administering medical-based procedures (i.e.-measuring blood pressure or heart rate). Firefighter partners identified, recruited, and trained 8 firefighters to administer the WFI assessments. The CAP agreed criteria for selecting these firefighters should be based on those who were seen as positive role-models among their peers, who were pro-health conscious, and for those who could commit to administering screenings in the foreseeable future to ensure consistency in data collection. The selected firefighters received training from both stakeholder firefighters and academic partners on how to administer each of the assessments to also ensure consistency and accuracy.

The firefighters then conducted WFI assessments on all 144 firefighters in their department over a 3-week period. A 100% rate of participation was achieved because of the cooperation with the fire department administration in requiring mandatory screening for all firefighters, and because they were conducted during on-duty shifts. On average, the time required to run one firefighter completely through the battery of assessments was 30 minutes. Typically 3-4 trained data collectors would run a crew of 3-4 firefighters through the assessment simultaneously, thus reducing the amount of time each fire crew was out of service to run emergency calls.

After the screenings, the CAP determined that in addition to a department-wide effort to promote PA, a research based intervention specifically tailored towards high-risk firefighters was critical. The CAP also identified the need to validate the protocol used to measure cardiorespiratory fitness of firefighters in the needs assessment. The validity of this test was called into question since it is a sub-maximal treadmill test used to predict their true maximal cardiorespiratory fitness ($VO_2\text{max}$). The firefighters believed the sub-maximal test may not be accurate based on antidotal evidence and observation, and academic partners suggested validating it with laboratory based standardized protocols for measuring true $VO_2\text{max}$. Subsequently, strategic planning meetings were conducted to develop research priorities (community-wide PA health promotion program, research based pilot intervention for high-risk firefighters, and validation of the sub-maximal $VO_2\text{max}$ test), according to the methods involved in creating matrices of change in Step 2 of IM.

IM Step 2. Developing Matrices of Change Objectives

The second step of IM integrated CBPR principles of “facilitating partnerships in all phases of the research process, promoting co-learning and capacity building, iterative process to system development, and emphasizing local relevance and an ecological perspective.” The inherent process of the CAP mutually developing matrices of performance and change objectives was integral in facilitating collaboration between firefighters and academic partners. Additionally, the process of creating objectives based on the ecological perspective of health relevant to needs of local firefighters fostered co-learning for all those involved in developing the matrices. Co-learning and information gleaned from the use of the ecological perspective helped to identify

relevant health theories to use in program planning, and led to the iterative processes of system development since theory selection is Step 3 in IM.

This IM step provided the foundation for developing a department-wide PA health program, a pilot test intervention for high-risk fire firefighters, and led to planning for validating the WFI sub-maximal VO_2 max test. The process for creating the matrices involved identifying determinants of PA behavior in firefighters from an ecological perspective (gathered from the literature review and feedback from the firefighters during the needs assessment), followed by specifying change and performance objectives to address these determinants at the individual, interpersonal, environmental, and policy levels. Co-learning occurred as academics studied the individual characteristics, social dynamics, cultural norms, work structure, environmental factors, and who the agents of change were within the fire department. Information gained from this co-learning helped to identify relevant health behavior theories to use in the creation of change objectives. Social Cognitive Theory (SCT) was selected among the theories deliberated by the CAP and is discussed further in the next section (Step 3 in IM).

Matrices of performance and change objectives were created to both address determinants of PA in firefighters and for the logistics required to build capacity for the department-wide health program and intervention for high-risk firefighters. Firefighters learned to create specific, time-oriented, and measurable performance and change objectives based off of individual, interpersonal, environmental, and policy factors of PA related to SCT. Performance objectives regarding logistics for developing capacity to implement the community wide and pilot intervention were developed on how to identify, recruit, and train firefighters to serve as peer mentors. Objectives based on criteria for

selection peer mentors included recruiting: firefighters who possessed a strong working knowledge and commitment to physical fitness, those who were well-respected among their peers, and those who have a sincere desire to enhance the physical fitness of their co-workers. Objectives were then developed regarding methods and strategies for training peer mentors and included creating a 40 hour training program based on the American Council on Exercise “Peer Fitness Trainer” (PFT), program, and from health behavior theory based curriculum developed by the investigators of this study. The American Council on Exercise training program focused on teaching education based information regarding the components and principles of physical fitness. Performance objectives were created to provide training for peer mentors on how to apply behavioral change strategies to firefighters that were consistent with SCT and included: the modeling of health behaviors (observational learning), goal setting (expectancies), skill building techniques (behavioral capability), motivational reinforcement strategies, and methods for building confidence (self -efficacy). Change objectives were created to focus on addressing the pros and cons of firefighters held regarding participating in PA (expectancies), developing PA regiments based on preference for PA, current fitness level of participation in PA (behavioral capability), and for building self-efficacy via overcoming common barriers towards participation in PA (such as time management).

Change objectives regarding the training of peer mentors also included strategies based on the community, environmental, and policy levels within the ecological model to create positive social normative attitudes towards aerobic fitness, ideas for modifying environmental factors to encourage PA, and methods to advocate for policies in promoting on-duty PA in the fire department. Capacity-building objectives focused on

environmental modifications at each fire station for promoting health-enhancing behaviors to reduce risk of CVD. Change objectives were created to identify fitness equipment needs at each of the individual station's gyms. Performance objectives were created to obtain internal city funding to purchase new fitness equipment, and to also allow firefighters to build equipment their own fitness equipment based on the needs at each fire station (such as pull-up bars and functional training equipment). These objectives were aimed at maximizing environmental changes with limited financial resources.

Matrices of performance and change objectives for policies governing firefighter behavior in the work environment were based on evidence they have a significant impact on health behaviors in firefighters (Kales, et al., 2007; Leiba, et al., 2011; National Institute for Occupational Safety and Health, 2001; Poston, et al., 2011; United States Fire Service & National Fire Data Center, 2002). The paramilitary style of policies regarding job performance, conduct, individual behavior, and team work predisposes the firefighter profession as a fully capable organization to institutionalize health-related policies. Policy-based change objectives included institutionalizing annual fitness and CVD screenings, creating minimum performance standards for the screenings, requiring on-duty physical activity (workout time), and providing quarterly health education classes delivered at the worksite (physical fitness and nutrition skill-and knowledge-building experiences). Policy objectives included encouraging firefighters to advocate for the aforementioned policies to increase PA within the department and targeted agents of change including the fire chief, station chiefs, and the firefighter union representatives.

Additional details regarding the specific strategies and methods created from the performance and change objectives for the design and implementation of the community wide health program and high-risk pilot intervention are explained in greater detail in Steps 4 and 5 of IM (Program Development and Program Adoption, implementation, and Sustainability respectively).

Matrices of objectives were created to validate the WFI sub-maximal VO_2 max assessment used to predict the true VO_2 max of firefighters. Matrices of performance objectives were created wherein firefighters took the lead role in identifying and recruiting firefighters to participate (serve as subjects), in the validation of the VO_2 max assessment. Firefighters who volunteered for the validation study had to complete both the WFI sub-maximal VO_2 and Bruce VO_2 max protocol (laboratory-based protocol), on two separate occasions within one week of one another. Performance objectives were created wherein academic partners took the lead role in administering and collecting data of the WFI sub-maximal and Bruce VO_2 max protocol, as well as the lead in managing and analyzing the data.

IM Step 3. Selecting Theory-Informed Intervention Methods and Practical Strategies

The IM step of selecting theory-informed methods and strategies integrated the CBPR principles of “promoting co-learning and capacity building, building upon strengths of the community, and emphasizing local relevance and the ecological perspective.” The iterative process of system development in CBPR was illustrated in the selection of theory since this step of IM was initiated during the matrices of change when ecological determinants were being investigated in order to inform the development of change and performance objectives. Building on the strengths of the

community is demonstrated through utilizing peer mentors based on the applications of SCT for program development and implementation.

As part of the co-learning process, academics explained to firefighters a health promotion program is more likely to benefit participants and communities when it is guided by health behavior theory (Green & Kreuter, 2005).

Academics provided background on how theory is specifically tailored to the target population and how it is translated into meaningful and practical strategies (Bartholomew, et al., 2006). Researchers shared several relevant health behavior theories with firefighter partners to select from based on the ecological determinants identified in Steps 1 and 2 of IM that could serve as the underpinnings for designing specific methods and strategies for the department wide health program and pilot intervention for high-risk firefighters. The health behavior change theories shared with firefighters included the Health Belief Model, Theory of Planned Behavior, TTM, and SCT. After careful review of these theories, a consensus was reached that SCT held the most promise for promoting PA to reduce CVD risk factors in firefighters. The decision by the CAP to use SCT was largely based the concept of reciprocal determinism wherein “an individual influences and is influenced by social factors and the environment” (Bandura, 1986). This concept resonated with the firefighters who asserted the interaction of a firefighter’s behavior is largely effected by social influences of other firefighters, the individual traits that are commonly found to characterize firefighter personalities, and the environmental conditions present at the fire station they are assigned to work. Academic partners also found SCT to be particularly useful as they learned more about the unique culture and work structure inherent in the firefighter

profession (McLeroy, et al., 1988; T. R. Peterson & Aldana, 1999). Unlike some other occupations, firefighters tend to embrace masculine expectations for individual behaviors (94% of the profession is male), firefighting requires proficiency and confidence in performing specific skills, firefighting relies heavily upon the social dynamics of team work, firefighters are present in the work environments for longer periods of time (24-hour shifts), and are governed by paramilitary style institutional policies of job performance, conduct, and behavior (Elliot, et al., 2007).

Firefighters and academics also found SCT to be the most applicable theory for translating concepts into practical strategies because of its use of increasing confidence to be physically active (self-efficacy), through role-modeling of behaviors (observational or vicarious learning), by addressing firefighter beliefs regarding outcomes for participating in PA (outcome expectations and outcome expectancies), use of skill building experiences (behavioral capability), and for its focus on addressing environmental factors for promoting PA. Subsequently, the CAP worked to build confidence in firefighters to be physically active via using peer mentors, addressing firefighter expectations about PA, participating in skill building PA related to firefighter tasks, and by modifying fire stations to make PA more accessible.

Academics learned firefighters expected PA would result in improved health and job performance (outcome expectations), and placed a high value on achieving a healthy physical fitness (Outcome expectancies). However, most firefighters placed a higher value on muscular strength (the ability to exert a maximal amount of force through one repetition of movement) than cardiorespiratory fitness (the ability of the heart and lungs to work efficiently for prolonged periods of time) because they thought

muscular strength was more important for performing firefighting skills effectively. Academic partners worked to change these expectations by providing overwhelming evidence cardiorespiratory fitness is a critical component of fitness since most CVD events occur when performing tasks for prolonged periods of time (Geibe, et al., 2008; Holmer & Gavhed, 2007; Rossi, 2003). Academics also learned firefighters believed possessing muscular strength was seen as being more masculine than being aerobically fit, as this type of fitness was seen as being more feminine in nature. Subsequently the CAP created strategies to change these social normative attitudes held by firefighters via using role-model firefighters, famous athletes, and celebrities who possessed high levels of aerobic fitness and who were also seen as being masculine.

The concept of observational learning in SCT contends a person learns a behavior by observing other individuals receiving the negative or positive consequences of performing a behavior (Bandura, 1986). The CAP operationalized this construct via utilizing influential firefighters to serve as a Peer Fitness Trainers (PFT), for role-modeling “heart healthy” physical fitness to their co-workers, and to help lead intervention efforts aimed at high-risk firefighters. The PFT worked to increase the behavioral capability of firefighters to improve cardiorespiratory fitness through leading skill-building experiences focused on sustaining efficient loco motor movements on a wide variety of activities involved in firefighter tasks. The PFT demonstrated and led activities involving self-paced learning of basic movements that became progressively more complex to perform. Firefighters were taught a wide variety of activities by PFT that constantly changed over time as to maintain interest and motivation to perform PA.

The environmental factors affecting behavior as postulated by the concept of reciprocal determinism within SCT was addressed by taking an inventory of each fire station within the department (8 fire stations). Fire station environments varied in terms of accessibility to participate in PA and PFTs took charge of identifying fitness equipment needs at each of the individual station's gyms and used this information to modify the work environment to increase PA. The specific changes to fire station environment are explained in further detail in steps 4 and 5 of IM (Program and Adoption, Implementation, and Sustainability respectively). The modifications to the work environment was designed to be the culmination of the efforts to increase the self-efficacy of firefighters to engage in aerobic fitness through addressing their expectations and expectancies of PA, using vicarious reinforcements of role-model peer mentor firefighters, and buy-increasing their behavioral capability via skill building experiences to engage in aerobic activity.

IM Step 4. Producing Program Components and Materials

Step 4 of IM incorporated the CBPR principles of “involving system development through iterative and cyclical process, builds on strengths and resources of the community, emphasizes local relevance and ecological perspective on multiple determinants of health outcomes, and promotes co-learning and capacity building.” The CAP’s efforts in the previous IM steps culminated into the shaping of an ecologically based CVD department-wide health program and pilot intervention for high-risk firefighters. This following section describes how building upon the strengths of the firefighter community led to the training of PFT’s and to the strategies and methods utilized within the multi-component health programs.

Ten fire fighters meeting criteria for becoming a peer mentor created in Step 2 of IM (firefighters who possessed a strong working knowledge and commitment to physical fitness, were well-respected among their peers, and have a sincere desire to enhance the physical fitness of their co-workers), were identified and recruited, with a total of 8 firefighters agreeing to participate in the training, development, and implementation of the health program. Once formally recruited, the 8 firefighters received 40 hours of training based on the American Council on Exercise “Peer Fitness Trainer” (PFT) program, and from curriculum developed by the academic partners. The PFTs received additional training provided by the academic partners on behavioral change strategies including motivational interviewing, modeling of health behaviors, goal setting, skill building techniques, reinforcement techniques (i.e. verbal cues, incentives), and methods for building confidence. Training from academics also included strategies PFTs could use to create positive social normative attitudes towards aerobic fitness, ideas for modifying environmental factors, and methods to advocate for policies promoting PA.

Once certified through this training, the CBPR principle of system development through iterative and cyclical process was operationalized as the PFTs were invited by the CAP to participate in the development of a second wave of performance objectives for matrices of change (step 2 of IM). The PFTs were encouraged to build upon the strengths and resources of their community through using the knowledge and skills they received from their training to develop, implement, and objectively evaluate a firefighter-driven PA program to reduce CVD in both high-risk firefighters and in the entire fire department. The PFTs worked to select protocols and establish standards for the

annual department-wide CVD screenings, developed criteria for identifying firefighters at highest risk of CVD, created experimental methods for pilot testing a one-on-one peer-driven CVD intervention tailored for high-risk firefighters, strategies for implementing policy changes to increase physical activity to improve fitness, and improving environmental access to PA equipment.

Department-wide PA program

One PFT was assigned to each of the 8 fire stations. The department-wide program focused on the effects of team-centered approaches for promoting PA, addressing social norms towards participating in aerobic PA, making environmental modification to increase opportunities for PA, and advocacy approaches implementing policies regarding PA. Each of the PFTs provided quarterly health education classes delivered at their assigned station (physical fitness and nutrition skill-building experiences). In addition, the PFTs encouraged firefighters at each of their stations to engage in weekly team-centered workout challenges and monthly department-wide fitness competitions. The team-centered approach worked to incorporate the “workout of the month” created by each station and was posted in each of the gym areas at the respective fire stations. Each fire station was encouraged to engage in their workouts in a manner of friendly competition between themselves and the other fire stations.

Peer Fitness Trainers worked to build upon the strengths of the firefighter community by identifying fitness equipment needs at each of the individual station’s gyms based on their observations and from feedback of firefighters assigned to these stations. The PFTs determined each of the fire stations should receive a variety of aerobic functional training exercises equipment. Aerobic functional training equipment is relatively inexpensive, has been shown to improve aerobic capacity (Barwick et al.,

2011), and is specific to firefighter job duties that require physical exertion. Instructions for using the aerobic functional training equipment and environmental modifications were provided by the PFTs in the quarterly health education sessions. The equipment was acquired through a combination of financial support from the department chief (who allocated a fixed budget for equipment purchases), and was built by the trainers themselves or obtained through low-cost methods. For example, pull-up bars were built outside of each station by PFTs and large tires for functional training were collected from junkyards for free.

The PFTs worked to build community capacity via encouraging firefighters and upper-level management to support policy change aimed at institutionalizing annual CVD screenings, creating minimum standards for CVD risk factors and physical fitness, requiring on-duty physical activity (workout time), and for providing the quarterly health education classes delivered by the PFTs at their assigned fire stations. The PFTs collaborated with the union leadership and fire department leadership to come to a consensus on creating policy change targeting firefighter health and fitness. For example, they came to the consensus that a policy supporting annual fitness and health screenings and compliance with the program would be acceptable to the union as long as it was non-punitive in nature. Another policy change made at the organizational level is the implementation of mandatory on-duty physical fitness training. Policy was established requiring firefighters to participate in one hour of physical activity of their choice each shift, with an emphasis on aerobic fitness training. Working together with relevant stakeholders, the PFTs were able to develop and implement various policy

changes within the fire department that protected the interests of the union and department leadership while promoting the overall health and fitness of the firefighters.

In addition to policy and environmental changes, the PFTs targeted extrinsic motivation at the individual level. They obtained agreement from the department leadership to allocate a fixed amount of money to be spent on incentives to for firefighters who maintain a healthy range of physiological results for aerobic fitness, blood pressure, lipid profiles, and body composition at annual testing. Additionally, firefighters who do not fall within ideal standards for CVD measures, but have shown improvement from previous assessments were also awarded the incentives. For example, stainless steel water bottles, and workout clothes with firefighter logos were given out as incentives in the first year of the program.

Pilot intervention for high-risk firefighters

The aim of the pilot study was to assess the effects of one-on-one counseling with PFTs has on CVD and physical fitness indicators in high-risk firefighters. Every firefighter from the fire department (n=144), completed the needs assessment to identify firefighters who met the criteria for classifying firefighters as high-risk for CVD. The criteria for identifying high-risk firefighters was based on possessing both a $VO_2\text{max}$ score below 40 $\text{mlO}_2/\text{kg}/\text{min}$ (recommended $VO_2\text{max}$ of 42 $\text{mlO}_2/\text{kg}/\text{min}$ is recommended to safely perform fire fighter duties), and possessing a percentage of body fat >25% (considered to be obese). The $VO_2\text{max}$ values and body fat percentages were used as the discriminating risk factors because they are highly associated to CVD events in firefighters (Kales, et al., 2007; Leiba, et al., 2011; National Institute for Occupational Safety and Health, 2001; Poston, et al., 2011; United States Fire Service & National Fire Data Center, 2002). Firefighters identified as high-risk (n=24), were then

recruited into the study and randomly assigned into either treatment or control groups. The treatment group was exposed to a one-year peer mentor intervention delivered by firefighters and based on SCT and the ecological model. Both intervention and control groups completed three month and one-year follow up post-testing from the baseline measures taken during the needs assessment.

The pilot intervention consisted of one-on-one meeting between the high-risk firefighters and PFT was based on custom-tailoring exercise plans individualized to fitness levels, preferences for PA, role-modeling experiences, and motivational reinforcements to be physically active. The PFT met with their assigned participants in bi-weekly sessions and followed up with them over the phone weekly to monitor the progress of their individually established goals. The bi-weekly sessions were 90 minutes and involved 3-5 interactive activities based on promoting physical activity (specifically aerobic fitness), and healthy nutritional behaviors. Sessions included establishing personal goals with supportive activities designed to be skill building, interactive, enjoyable, and consistent with principles of adult education; emphasizing relevance, active learning, and application of new skills. These educational and skill building activities involved the use of several key theoretical constructs belying SCT including role-modeling (observational learning), addressing belief structures (expectations, expectancies), enhancing skills related to PA behavior (behavioral capability), and confidence building (self-efficacy).

IM Step 5. Planning Program Adoption, Implementation, and Sustainability

The CBPR principles of “Builds on strengths and resources of the community, involves long term commitment to community health promotion, and facilitating partnerships in all phases of research” were utilized in Step 5 of IM planning for

program adoption, implementation, and sustainability. Facilitating partnerships in all phases of research involved coordinating the efforts of academics with policy-makers, firefighters administering CVD screenings, and PFT's in the process of adopting and implementing the health program throughout the fire department. Long term commitment to sustainability of the health program included the collaboration on grant writing efforts between firefighters and academic partners, the use of voluntary involvement of undergraduate and graduate research assistants, and use of economically viable approaches to promote PA such as creating equipment for PA.

The CAP adopted the health program efforts via building upon the strengths of the community regarding the paramilitary structure of the firefighter profession in order to adopt policies requiring annual CVD screenings, requiring on-duty PA, providing funding for training firefighters to become certified as PFT, and for providing environmental modifications to promote PA at each of the fire stations. The CVD program was adopted during the start of the department-wide CVD screenings and physical fitness assessments. Firefighters administering the CVD screenings informed firefighters receiving the testing a program to promote PA to reduce risk of CVD was being initiated throughout the entire fire department. Firefighters getting the screenings received information from the PFTs administering the screenings regarding the high rates of CVD in firefighters, the risk factors associated with CVD in firefighters, and the importance of PA, especially cardiorespiratory fitness, in preventing CVD in firefighters. After the screenings, firefighters learned quarterly sessions would be held about promoting PA lifestyles and one hour of on-duty PA would be required during each shift of work. Firefighters were also asked to give feedback concerning the type of environmental

modifications they would need to promote PA at their respective fire station. Finally, firefighters were introduced to their co-workers who were certified as PFT, and were encouraged to utilize them as resources for promoting PA behaviors.

The peer mentors firefighters took the responsibility to adopt and implement the intervention following the needs assessment. The PFTs embarked on both a department-wide initiative and on a specific pilot intervention for 24 of the highest risk firefighters based on the results of the WFI assessment. Policy makers were integral in the adoption of the health program because they allocated funds from the fire departments annual budget to compensate for the 40 hours of training firefighters needed to become certified as a PFT. The time required to become certified as a PFT was in addition to their normal firefighter responsibilities, and was often compensated at overtime pay rates. The CAP acknowledged paying firefighters for overtime training is costly, and in doing so underscores the long term commitment by the fire fighter policy makers to adopt a sustainable program for promoting PA and preventing CVD in their firefighters. The firefighter policy makers making this decision believed greater costs would be incurred in the future without a CVD health program due to increased missed days of work, treating high blood pressure, dislipidemia, and by having to hire new firefighters to replace firefighters retiring early or going to light duty because of poor physical fitness or risk of CVD. Even with this costs benefits point of view, both the fire fighter policy makers and academics agreed allocating funds for a CVD health program may be unrealistic for other fire departments due to budget constraints and the current economic climate. These economic challenges underscore the need for grant and subsidies to adopt, implement, and sustain CVD prevention programs in firefighters

Emphasis on the long term commitments was also demonstrated through collaboration between academic partners and the fire department on grant writing efforts to provide additional funding for sustaining the PA and CVD prevention program in their department, and for disseminating it to the broader firefighter population. Federal, state, private, and intramural university level grants are actively being developed and submitted to secure funding for efforts to sustain and improve the current health program, as well as to disseminate similar health programs to other fire departments.

Sustainability and long term commitment was also fostered by the use of firefighter centered involvement in the planning, implementation, and evaluation of the CVD intervention. The CAP believed this approach would lead to more involvement, investment, and ownership of by the fire department than expert-centered approaches, and thus would lead to long-term sustainability. Utilizing low cost strategies (making PA equipment, use of policies, and utilizing unpaid research assistants), are examples of how the intervention could be sustained with minimal economic investments and not be solely dependent upon external grant funding for sustainability. The involvement of unpaid qualified graduate and undergraduate research assistants was integral in capitalizing on the strengths of the academic community, and it also demonstrated a long term commitment by academic partners to firefighter partners. Interdisciplinary graduate and undergraduate students participated in the CAP efforts and their efforts included assistance in training the PFT trainers, validating field-based and laboratory based cardiorespiratory fitness in firefighters, and in working as liaisons between the university and firefighters. Use of voluntary research assistants contributed towards

reducing costs associated with hiring paid research assistants. Academic research assistants were incentivized by gaining meaningful research experience, experience in health promotion efforts, satisfying academic requirements (use of interns, practicum hours, receiving course credit for completing research hours), opportunities for co-presenting in conferences, and for co-authoring manuscripts.

IM Step 6. Planning for Evaluation

The evaluation step in IM incorporated the CBPR principles of “facilitates partnerships in all phases of the research process, involves system development through iterative and cyclical process, and promotes co-learning and capacity building.” It is important to emphasize the evaluation portion of IM is iterative in nature since it was the first step to be undertaken by the CAP when planning the needs assessment, evaluation was used to inform each step of IM, and evaluation guided all aspects of the research process. This iterative process of evaluation was a critical component in fostering collaboration and facilitating partnerships between the firefighter community and academics. Furthermore, the information produced during from the evaluation process contributed to the co-learning experiences between firefighters and academic partners. The following section briefly describes the outcomes from the evaluations of the community wide health program, the pilot intervention, and in validating the WFI sub-maximal cardiorespiratory fitness assessment.

In addition to the needs assessments, the CAP conducted multiple evaluations including establishing annual CVD screenings, pre and post testing of the CVD intervention on the highest risk firefighters, validating field-based assessments of cardiorespiratory fitness, and conducting health programming evaluations (formative and process evaluations). The CVD screenings used for the needs assessment were

institutionalized and are now used to annually track CVD and physical fitness indicators in firefighters over time, for identifying high-risk firefighters, to evaluate intervention efforts for high-risk firefighters, and to reward firefighters for improving CVD risk factors and physical fitness. Establishing annual CVD screenings is an example of the long term commitment by the CAP to the health of firefighters and is likely to be sustained since firefighters take the lead role in administering the annual CVD assessments, and academic partners take the lead role in the management and analysis of data collected from firefighters.

All 144 firefighters in the department completed the baseline needs assessments to identify high-risk firefighters, and 24 firefighters were identified for a high-risk sample in the pilot intervention. Table 3-1 describes the pilot sample and department-wide baseline health measures and shows that the sample recruited for the study were older, had a lower average VO_2 max, and higher body fat composition than the department as a whole. The sample was randomly assigned to intervention and control groups (n=12 for each group). Baseline equivalence was tested prior to intervention with a paired samples t-test on all health factors assessed between the treatment and control groups and revealed both groups were similar (not significantly different at the $p=0.05$ level). Three month and one-year follow-up testing of the pilot intervention across a broad range of health outcome measures including the WFI sub-maximal aerobic capacity assessment, BMI, body fat percentage, hand grip strength, arm and leg strength, push-ups, abdominal static plank and a sit-and-reach test. Statistical analyses using the independent and paired samples t-tests examined if health measures significantly changed from baseline to post-testing both within and between groups (Table 4-4).

Sub-maximal aerobic capacity significantly increased from a baseline of 37.38 mlO₂/min/kg to 39.98 mlO₂/min/kg at post-testing for the intervention group ($p < 0.001$) while the control group did not significantly increase VO₂max ($p = 0.3838$). The control group significantly increased body fat percentages of 28.71% at baseline to 29.53% at post testing ($p = 0.044$), while the intervention group maintained body fat percentages from 30.48% at baseline to 30.20% at post-testing ($p = 0.384$). No significant increases or decreases were detected in any of the musculoskeletal health measure in either treatment or control group from baseline to post-testing.

The efforts in validating the field-based cardiorespiratory assessment fostered co-learning and capacity-building between firefighters and academic partners. The purpose of these efforts was to evaluate the accuracy of the current WFI sub-maximal treadmill test used in firefighters to predict their true VO₂max with the laboratory based standardized VO₂max Bruce Protocol test. Twenty-nine firefighters (86% male), completed both the field-based WFI sub-maximal and laboratory-based true VO₂max tests on two separate occasions. The validation process fostered engagement between academics and firefighters since both collaborated on recruiting firefighters to participate in the study and for administering the tests to firefighters who volunteered to participate. The facilitation of a partnership within the CAP was strengthened in the endeavor to validate the WFI sub-maximal test because firefighters were exposed to a wide variety of academics including faculty, research assistants, and volunteer graduate and undergraduate students.

The findings of the validation study produced important information regarding the accuracy of identifying firefighters at risk for on-duty CVD. The sub-maximal test was

shown to be moderately correlated in its ability to accurately predict the true VO_2max of firefighters ($r=0.635$, $p = 0.005$). A moderate correlation may be considered low for a physiologically-based prediction test, and is often not acceptable for clinical applications. The sub-maximal VO_2 treadmill test underestimated the true VO_2max in the majority of firefighters (72.4%), and over-estimated the true VO_2max in 24.4% of our sample. Participants whose true VO_2max was overestimated by the WFI submaximal test tended to have a significantly higher body fat composition than those who were underestimated by the WFI protocol. This finding is concerning given the main purpose for using this test is to identify firefighters at risk for on-duty CVD events. A test that over-predicts the true VO_2max of less fit firefighters will not identify those at greatest risk for on-duty CVD, and preclude the opportunity to intervene in these high-risk firefighters.

The range of VO_2 values and standard deviations between the predicted and true VO_2max values varied greatly (35.4 to 50.9 vs. 28.6 to 58.4 $\text{mlO}_2/\text{kg}/\text{min}$, and standard deviation of 3.91 vs 7.22 respectively). This suggests the prediction formula for the sub-maximal test compresses the VO_2max values into a more narrow range than what is true. This finding is concerning because a firefighter with a low true VO_2max is likely to produce a higher predicted VO_2max on the WFI sub-maximal test than what is actually true, thus limiting the ability of the WFI test to identify firefighters who are at a high-risk for CVD. This co-learning process led both firefighters and academics to conclude further research is needed to validate this sub-maximal test in firefighters of varying fitness levels (most firefighters who participated were relatively physically fit), with a larger sample size including more female participants, in a wider range of age groups, and in more ethnically diverse populations.

Involving systems development through iterative and cyclical process was operationalized by conducting programming evaluations on the department-wide health program and pilot intervention. Academic partners provided consultation to firefighters on how to conduct formative and process evaluations for assessing the development and implementation of the health program. The PFT and fire chief gathered formal and informal feedback from their own perspectives regarding the quality of program planning and development. The PFTs assessed the formative phase of the intervention including tracking the recruitment and participation rates of high-risk firefighters into the intervention, assessing the quality of peer training, and assessing the quality of activities and equipment being developed for the intervention. This information was used to maintain, modify, and eliminate strategies used in the intervention efforts.

The PFTs conducted process evaluations via tracking the fidelity, dosage delivered and reached for the throughout the implementation of the CVD health program and pilot intervention. The PFT kept and tracked attendance records for the one to one counseling sessions for high-risk firefighters, for the quarterly department wide health education classes, and for meetings held with fire administrators to advocate for policy and environmental changes within the department to promote PA. The PFT also monitored participation and adherence rates for the mandatory on-duty PA at each of the fire stations. Feedback from firefighters collected during the process evaluations contributed to informing strategies used by the PFT including: the importance of addressing social norms regarding aerobic exercise held by firefighters, utilizing functional training exercise, and tailoring exercise prescriptions based on individual characteristics (fitness level, motivation for PA, preference for various forms of PA).

Discussion

To our knowledge, this is the first study to apply principles of Community Based Participatory Research towards health promotion efforts in firefighters. From our experience, we believe Intervention Mapping and utilizing the orientation and principles of CBPR is a useful model for developing, implementing and evaluating health promotion programs for firefighters. The overlapping core concepts between IM and CBPR (Table 2-3) may account for the synergy of integrating these approaches to health promotion in firefighters. Both IM and CBPR are guided by similar conceptual frameworks concerning health promotion efforts including: involving the participation of the community in all phases of research, utilizing the ecological approach towards understanding and intervening upon health outcomes, developing capacity via capitalizing on assets within the community, and in using an iterative process in program development, implementation and evaluation. The congruency of these concepts complemented the efforts of integrating the systematic and well-structured methods of IM with the orientation of CBPR.

Actively involving the community in all stages of the research project and providing direct benefit to the community being studied makes CBPR and IM an attractive research model for health promotion in firefighters. Firefighter communities are distinguished by unique socio-culture characteristics that make CBPR an appealing approach to PA intervention efforts. Firefighters rely heavily upon cohesive team work, are present in the work environment for long periods of time (24-hour work shifts), operate under a communal structure, have access to shared resources, are influenced by similar environmental factors, and are governed paramilitary policies concerning conduct and behavior.

The core process of IM advocates for the use of logic models involving an ecological approach to health promotion, and a principle for CBPR emphasizes applying an ecological approach towards understanding and intervening upon multiple determinants of health. Use of the ecological model was operationalized in this study when it was used to guide the process for the literature review conducted in Step 1 the needs assessment and in Step 2 of IM developing matrices of change objectives for the individual, interpersonal, environmental, and policy level factors for promoting PA in firefighters. Individual level determinants were identified and intervened upon including developing self-efficacy for PA via observational learning from peer mentors, building capabilities to perform PA, and reinforcements to foster positive expectancies to perform PA. Interpersonal level factors included identifying and training peer mentors to promote department wide PA and for one on one counseling for high-risk firefighters. Interpersonal factors also included advocacy efforts to fire administrators to create policy and environmental modifications for promoting PA in firefighters. Policy factors included institutionalizing annual CVD screening and physical fitness assessments, requiring on-duty PA during each shift of work, and requiring attendance for quarterly health education sessions. Environmental factors were addressed by taking an inventory of workout areas at each fire station and modifications were made to improve access to exercise by building fitness equipment and acquiring low cost equipment for functional training.

Developing capacity via capitalizing on assets within the community was integral in the success of collaborative efforts in the CAP and in the development, implementation, and evaluation of the health programs. Using role model firefighters to serve as peer

mentors was integral in getting the other firefighters to “buy-into” efforts in promoting PA, and was believed by all those involved this approach was much more effective than if it would have been delivered by non-firefighter “experts”. The use of peer mentors builds upon the team centered culture that is inherent in the firefighter profession. Utilizing firefighters for the evaluations process in administering physical fitness and CVD screenings capitalized on their expertise and knowledge in conducting medical based assessments (measuring blood pressure, heart rate, etc.). Building upon their paramedic skills is particularly useful for this type of data collection when evaluating firefighter health. Empowering firefighters to take charge of these types of evaluations also increases the likelihood of sustaining regular physical fitness and CVD screenings for the long term. The implementation and adherence to policies regarding PA builds upon the strength of the paramilitary nature of the firefighter profession that regulates conduct and behavior.

The iterative process of health program development was a commonly used core concept shared by IM and CBPR. Examples of how the iterative process was utilized included applying evaluations throughout each step of IM. Although evaluation is Step 6 of IM, it was the first process to be undertaken, it was critical for developing the needs assessment (Step 1), informing the objectives created for the matrices of change (Step 2), and was essential for conducting formative and process health program evaluations and led to modifying strategies undertaken during program development and implementation (Steps 4 and 5 respectively). The informed selection of theory (Step 3) began when the matrices of change were being developed. Identifying Social Cognitive Theory to serve as the underpinnings for the health program during Step 2 was

essential for guiding the development of performance and change objectives. The iterative process also occurred when a second wave of matrices of change objectives were created during program development (Step 4). The second wave of matrices of change was created after the PFT were recruited and were developed based on the 40 hours of training they received. The performance objectives created by the PFT's primarily focused on developing specific strategies and methods on how they intended to implement and evaluate their peer based program to the entire fire department and to the high-risk firefighters.

Limitations

It can be argued that the strengths of Intervention Mapping also represent its weaknesses. The theory- and evidence-based intervention development of IM is a complex and time-consuming process. Needs assessments, creation of the matrices of change objectives and performance objectives, and the process of evaluations is particularly time consuming. Intervention Mapping is typically applied to simple and uni-dimensional behaviors, and can become overwhelming when applied to multi-dimensional behaviors, such as physical activity (McEachan, et al., 2008). Additionally, the comprehensive development involved with integrating IM with CBPR was not funded in this study and may not be a feasible for other fire departments to take on these efforts without university or academic supports. Funding for development and demonstration grants is often limited for this phase of the research process and is typically not given sufficient consideration prior to implementation of an intervention. This may help to explain why many interventions lack the use of planning models and are often not theoretically grounded or evidence based (McEachan, et al., 2008).

The nature of Community Based Participatory Research is also time-consuming and challenging. Examples of these efforts include; identifying and networking with gatekeepers and key informants; building partnerships; developing community capacity; leveraging material and human resources; training of community and academic program planners; and development of a comprehensive iterative evaluation plan. For example, it took over half a year to network with firefighters before a CAP could be formally established, another half year before a needs assessment was conducted, and before the department wide and high-risk interventions were launched and evaluated (2 years of total networking and planning). This time consuming process of community based research does not lend itself to high rates of multiple publication, and on top of not often being a fundable aspect to the research process, often precludes researchers from getting involved who are interested in tenure track faculty positions.

Despite the time-consuming nature of the CBPR and the IM protocol, we believe it allowed us to create a comprehensive intervention package that was tightly focused and theory based. Studies show interventions using planning models that are grounded in health theory to be more efficacious and effective than those that are not. Additionally, health promotion efforts utilizing CBPR are more likely to be sustainable. Furthermore, the comprehensive iterative evaluation of IM provides critical information as to the formative, process, impact, and outcome evaluations of the intervention. Formative and process evaluations can lead to changes that need to take place during the development or implementation of the intervention to improve success. Further, these evaluations can be used to identify the program components that are attributable to the impacts and outcomes of the intervention. These formative and summative evaluation

results are critical to addressing threats to the internal and external validity of the entire research project.

The proposed studies are among the first efforts to describe the participatory process of community-driven health promotion research in firefighters, to validate the current cardiorespiratory fitness assessment used to measure cardiorespiratory fitness of firefighters, and to pilot test the use of theory-driven ecological strategies to reduce CVD risk factors in firefighters. Further research is needed to assess the utility of engaging academics with local firefighters to reduce CVD and promote health in other geographic locations, studying the effectiveness of integrating CBPR with other planning models, and to study community based approaches to health promotion in other diverse firefighter communities, study utility of CBPR for promoting other health issues such as nutrition, stress management behaviors, alcohol, tobacco or other drug behaviors in firefighters.

Table 2-1. Definitions for the principles of community-based participatory research

Principles of CBPR	Description
Respects and recognizes community as a unit of identity	The community is a group of individuals who share some common interests, values, goals, politics, and characteristics
Builds on strengths and resources in the community	Researchers use the resources that are internal to the community when possible
Facilitates collaborative, equitable involvement of all partners in all phases of research	All members of the team will be informed about, and included in, all aspects of the research process
Integrates co-learning of knowledge and intervention for mutual benefit of all members	Information desired by the community will be considered integrated with the community's needs for intervention to create positive change for the community
Balance of research and action via information and learning are shared equally by all members	All parties learn equally from each other as everyone shares their ideas, perspectives and expertise
Involves a cyclical and iterative process	All phases of the research process may be refined as each community adds its insight
Addresses research topics from both positive and ecological perspectives	Addresses the whole system and emphasizes outcomes that are beneficial to the health, happiness, and success of the community
Disseminates findings and knowledge gained to all partners	Research findings are communicated to the academic and research societies and to the communities in ways that are most useful for each
Involves a long-term commitment by all partners	The goals of the project should take the future welfare of all parties into consideration

Table 2-2. The steps of Intervention Mapping

Step	Description of action	End product
1. Needs assessment	Assess the health problem, its related behaviors and environmental conditions, and their associated determinants for the at-risk population	A description of a health problem, its impact on quality of life, and determinants of behavioral and environmental causes
2. Define program objectives	Provides the foundation for the intervention by specifying who and what will change as a result of the intervention	A set of matrices that combines performance objectives at each ecological level with select determinants to produce change objectives
3. Selection of methods and strategies	Seek theory-informed methods and practical strategies to effect changes in the individual behaviors and the environment	Organize and operationalize the intervention methods
4. Program design and production	Pilot testing of program strategies and materials with target audience	Completed program materials and protocols
5. Program adoption, implementation, and sustainability	Matrix development linking adoption and implementation performance objectives to personal and external determinants	A detailed plan for accomplishing program adoption and implementation by influencing behavior of key individuals or groups
6. Process and outcome evaluation	Finalize an evaluation plan	A plan for analyzing the anticipated changes in health outcomes

Table 2-3. Integrating CBPR principles with Intervention Mapping steps

CBPR principles	Steps for Intervention Mapping					
	1	2	3	4	5	6
Builds on strengths and resources of community	X		X	X	X	
Facilitates partnerships in all phases of research	X	X			X	X
Promotes co-learning and capacity building	X	X	X	X		X
Emphasizes local relevance and ecological perspective of multiple determinants of health outcomes		X	X	X		
Involves system development through cyclical and iterative process	X	X		X		X
Involves long term process and commitment					X	

Step 1=Needs assessment
 Step 2= Developing matrices of change objectives
 Step 3= Theory
 Step 4=Development of program
 Step 5= Program adoption and implementation
 Step 6= Program evaluation

CHAPTER 3 VALIDATION OF A CARDIORESPIRATORY FITNESS ASSESSMENT IN FIREFIGHTERS

Background

Cardiovascular disease (CVD) constitutes the leading cause of on-duty death and disability in firefighters, contributing to 45% of on-duty fatalities annually (Duenas-Laita, et al., 2007; National Institute for Occupational Safety and Health, 2001; United States Fire Service & National Fire Data Center, 2002). The majority of fatal and non-fatal CVD events in firefighters occur during prolonged bouts of strenuous exertion including: suppressing a fire (32.1%), physically demanding non-emergency duties (15.4%), responding to an alarm (13.4%), and performing training exercises (12.5%) (Kales, et al., 2007). A high level of physical fitness is essential for firefighters given near-maximal heart rates are achieved and sustained for prolonged periods of time during these on-duty tasks, they are often performed while using heavy equipment, and in extreme temperatures (Geibe, et al., 2008; Holmer & Gavhed, 2007; Rossi, 2003). Therefore, the relationship between physical fitness and CVD during the performance of firefighting duties has received considerable attention among concerned firefighters, public health officials, and researchers (Leiba, et al., 2011; National Institute for Occupational Safety and Health, 2001; Poston, et al., 2011; United States Fire Service & National Fire Data Center, 2002).

Components of physical fitness include cardiorespiratory fitness, body composition, muscular endurance, muscular strength, and flexibility. Among these, cardiorespiratory endurance is proving to be the most important component of physical fitness related to on-duty CVD in firefighters (Harvey, et al., 2008; Leiba, et al., 2011; Rhea, et al., 2004). Cardiorespiratory endurance, also known as 'aerobic capacity' or

'VO₂max', is the maximal capacity of an individual's body to transport and use oxygen during maximal or exhaustive exercise. It reflects the physical fitness of the individual and is measured in milliliters of oxygen used in one minute per kilogram of body weight (mlO₂/min/kg) (Powers & Dodd, 2003). A low VO₂max is a primary risk factor for premature mortality and morbidity due to CVD (Haskell, et al., 2007; Peterson, et al., 2008; Sui, et al., 2006). A longitudinal cohort design study, controlling for BMI, found individuals who could not achieve 85% predicted VO₂max had significantly more fatal and nonfatal myocardial infarctions, unstable angina, and hypertension than those who could achieve 85% predicted VO₂max (P. N. Peterson, et al., 2008; Sui, et al., 2006; Sui, et al., 2007). A recent prospective study of over 25,000 asymptomatic men demonstrated that low VO₂max exercise tests are highly predictive of subsequent cardiac death, and the association increases for each additional CVD risk factor present (Sui, et al., 2006; Sui, et al., 2007).

Research shows VO₂max may be one of the most important biological factors related to CVD in firefighters, and is believed to be an even stronger predictor of fatal and nonfatal CVD in firefighters than obesity (Harvey, et al., 2008; Leiba, et al., 2011; Poston, et al., 2011; Rhea, et al., 2004; D. L. Smith, et al., 2001). Rates of substandard VO₂max are shown to be highly prevalent among the firefighter population as studies find 25% of firefighters fail to achieve the current minimum standard VO₂max of 42.0 mlO₂/kg/min in firefighters (Harvey, et al., 2008; International Association of Firefighters, 2009; Mier & Gibson, 2004). In addition, a substandard VO₂max is significantly associated with the presence of other CVD risk factors in firefighters such as obesity

and hypertension, thus compounding the likelihood of CVD in firefighters (Donovan, et al., 2009; Poston, et al., 2011).

The strong relationship between $VO_2\text{max}$ and CVD has led firefighters and researchers to advocate for the development of a validated cardiorespiratory endurance test to be periodically administered to firefighters in order to identify those who are at risk for CVD (Donovan, et al., 2009; Harvey, et al., 2008; Poston, et al., 2011). In addition, a validated $VO_2\text{max}$ exercise test can help to identify a healthy $VO_2\text{max}$ standard for protecting firefighters against CVD (Geibe, et al., 2008; Mier & Gibson, 2004; Williams-Bell, Villar, Sharratt, & Hughson, 2009). Discrepancy currently exists among researchers and professional firefighters regarding a healthy $VO_2\text{max}$ standard for aerobic fitness of firefighters. Recommended $VO_2\text{max}$ values for firefighters from previous research vary greatly and range from 33.5 to 51.0 $\text{mlO}_2/\text{kg}/\text{min}$ (Harvey, et al., 2008; Holmer & Gavhed, 2007; Mier & Gibson, 2004; Sothmann, et al., 1990; Williams-Bell, et al., 2009). The inconsistency for a recommended $VO_2\text{max}$ standard from previous research is largely due to these studies utilizing various forms of protocols to measure $VO_2\text{max}$ (Bilzon, Scarpello, Smith, Ravenhill, & Rayson, 2001; Harvey, et al., 2008; Henderson, Berry, & Matic, 2007; Mier & Gibson, 2004; Sothmann, Gebhardt, Baker, Castello, & Sheppard, 2004; vonHeimburg, KRasmussen, & Medbo, 2006). For instance, previous methods for determining $VO_2\text{max}$ values in firefighters have evolved over time and included the Gerkin treadmill protocol and Balke treadmill protocol (Mier & Gibson, 2004; Sothmann, et al., 1990).

The gold standard for measuring $VO_2\text{max}$ is by direct measurement of exhaled gases during exercise and involves laboratory-based equipment, such as metabolic

carts and gas exchange analyzers, and incrementally brings the subject up to maximal exertion in a stage-based test. This type of VO_2 max testing is normally not feasible for fire departments to administer because it is costly, generally lacks portability, and is thus unrealistic for administering in the field on a large scale. The governing body for firefighter fitness known as the Fire Service Joint Management, developed the Wellness and Fitness Initiative or WFI (International Association of Firefighters, 2009) which currently uses a sub-maximal treadmill test based on the time to reach 85% of age-predicted maximal heart rate to estimate the true VO_2 max of firefighters. To date, the WFI sub-maximal test has not been validated in the scientific literature.

The need to accurately assess VO_2 max in firefighters is critical given the high rates of on-duty CVD deaths and disabilities in firefighters. A validated aerobic capacity assessment will help to identify those at greatest risk for an on-duty CVD-related event and provide the opportunity for intervention. Further, it can help to set an accurate healthy VO_2 max standard, and can be used to accurately evaluate health promotion efforts aimed at increasing the VO_2 max of firefighters. Therefore, the purpose of this study is to evaluate the validity of the current WFI sub-maximal treadmill test to predict the true VO_2 max of firefighters obtained from the laboratory-based maximal Bruce Protocol. This study hypothesized that the WFI sub-maximal VO_2 max protocol under-predicts the true VO_2 max in more fit firefighters and over-predicts the true VO_2 max in relatively less fit firefighters. Or, in other words, it compresses the true VO_2 max values into a more narrow range than what actually exists.

Methods

Thirty firefighters from a North-central Florida fire department voluntarily completed both the WFI sub-maximal prediction and true VO_2 max tests on two separate

occasions. The sample was comprised of 86% male and 14% females (department-wide average of 89% male and 11% female), thus the sample population accurately represents the gender make-up of the department tested. Participants first completed the WFI sub-maximal test, followed by the Bruce protocol on the following week. Institutional Review Board approval was obtained for this study and participants completed the informed consent process prior to testing wherein the protocols, risks, and benefits for the study were disclosed. No incentives were provided for participation. All participants completed health screenings prior to aerobic testing including: height, weight, body mass index, percentage body fat, blood pressure, and pre-exercise heart rate. A 3-point skin fold measure was used to measure percentage of body fat. In addition to the health screenings, participants also completed a survey on information including: age, gender, stage of motivation to participate in regular physical activity, and frequency, intensity, and duration of weekly physical activity participation. Table 3-1 compares the sample mean demographic and physical fitness variables of the participants with those from the entire department they were sampled from for this study. Overall, the participants were on average 7 years younger (38.5 vs. 31.9 YO) roughly equivalent in gender (89% vs. 85.2% male), slightly higher body fat percentage (25.96% vs. 22.24% body fat), and slightly higher submaximal predicted VO_2 max (44.58 vs. 42.91 mlO₂/kg/min) than the population from which they were sampled. The participants reported an average of 4.6 days/week of moderate to strenuous physical activity lasting on average 40 minutes per session. There was no attrition or dropout from the sample tested, however, one of the participating firefighter's results was

discarded due to mechanical issues with the equipment that arose during testing giving invalid results, thus the final sample size was 29 participants.

WFI Sub-maximal Test

The WFI sub-maximal test predicts $VO_2\text{max}$ of firefighters based upon the amount of time it takes to reach 85% of estimated maximal heart rate (HR_{max}), during a graded treadmill protocol. The sub-maximal test uses the age predicted estimation of HR_{max} , thus the formula to calculate 85% of $HR_{\text{max}} = (220 - \text{age}) \times 0.85$. The amount of time it takes to achieve 85% of HR_{max} (test time), and BMI is inserted into the following formula to predict true $VO_2\text{max}$: $VO_2\text{max} = 56.981 + (1.242 \times \text{test time}) - (0.805 \times \text{BMI})$ (International Association of Firefighters, 2009). The WFI sub-maximal test begins with a 3 minute warm-up at a speed of 3.0 mph at a 0% grade, followed by 1 minute stages of alternating increases in speed and incline of the treadmill. For example, after the 3 warm-up, treadmill speed is increased to 4.5 mph, at 4 minutes the incline of the treadmill is raised to a 2% grade, at 5 minutes the speed is increased to 5.0 mph, at 6 minutes the treadmill is raised to a 4% grade. Each of the subsequent stages of the WFI protocol last 2 minutes and alternate between a 0.5 mph increase in speed and 2% incline of the treadmill until 85% of HR_{max} is reached and maintained for 15 consecutive seconds. Afterwards, participants complete a cool-down phase consisting of walking for 3 minutes at 3 mph at a 0% grade. Recovery heart rate was recorded during the first minute of the cool-down phase. Appendix B describes the stages for the first 10 minutes of the WFI sub-maximal protocol.

Bruce Protocol (Maximal VO_2 Test)

Prior to administering the Bruce protocol, electrocardiogram (EKG) and metabolic cart gas exchange analyzers were calibrated to proper settings according to

manufacturer instructions. A 12-lead EKG was used to monitor the participant's heart rate prior to testing, throughout the duration of the test, and for 5 minutes following the completion of the test. A standard mouthpiece and nose clip were assembled and secured to the participant's head using a face mask. A spirometer was connected and calibrated to the metabolic cart in order to accurately measure the amount of oxygen consumed and carbon dioxide exhaled by participants. Each participant was hooked up to an electrocardiogram machine and monitored for EKG abnormalities during the assessment. Participants walked for 3 minutes at 2.5 miles prior to administration of the Bruce protocol to familiarize themselves with using the treadmill. Participants were instructed to exercise as long as possible during the Bruce protocol, which involves successive 3-minute stages of increasing speed and incline of the treadmill over time (Appendix C describes the stages of the Bruce protocol). Rate of Perceived Exertion (RPE), according to the Borg scale (Borg, 1982) was recorded twice during each 3-minute stage (once at the start of a stage and once at the end of a stage). Criteria for terminating the test included the participant discontinuing the test at any time due to fatigue or any other reason, a plateau in VO_2 reached, or when two out of the following three criteria are met: 1) reaching maximum heart rate ($HR_{max} = 220 - \text{age}$), 2) achieving a respiratory exchange ratio (RER) greater than 1.15, or 3) reporting a RPE of 20. After completion of the Bruce protocol, participants walked for a recovery period of at least 5 minutes while heart rate and RPE were recorded at the one, three, and five minute time points.

Data Analyses

All statistical analyses were performed using SAS version 9.2 software (SAS Institute Inc., Cary, NC, USA). Mean differences between the department population

and the participants were analyzed with independent samples t-tests to check for equivalence between groups. Pearson correlation coefficients were calculated to examine the relationship between the predicted WFI sub-maximal values to the true VO_2 max values obtained from the Bruce protocol. Additionally, Pearson correlations coefficients were obtained to determine if there was a relationship between demographic and physical fitness variables to the true VO_2 max values obtained from the Bruce protocol ($\alpha = 0.05$). Additionally, participants results were divided into two categories as true VO_2 max being over- vs. under-predicted by the WFI test and the hypothesized predictor variables of exercise frequency/intensity, BMI, and body fat were tested as predictors for classification into either group.

Results

All participants completed both the sub-maximal and maximal VO_2 testing, and each participant achieved the criteria for maximal effort during the Bruce protocol. Mean values and standard deviations from the 2008 WFI sub-maximal and Bruce protocol are presented in Table 3-2. The estimated sample mean values for the sub-maximal VO_2 and true VO_2 max values from the Bruce Protocol were similar (44.58 ± 3.91 mlO₂/kg/min and 45.68 ± 7.22 mlO₂/kg/min respectively, paired t-test p-value = 0.2616). Though the means are similar, the ranges of mean values and standard deviations differed between the predicted and true VO_2 max values (min – max: 35.4 to 50.9 mlO₂/kg/min vs. 28.6 to 58.4 mlO₂/kg/min, and standard deviation of 3.91 vs 7.22 respectively). These results show the prediction formula compresses VO_2 max values into a more narrow range than what is true. Additionally, the 2008 WFI sub-maximal test under-predicted the true VO_2 max in 72.4% of firefighters, and over-predicted in 27.6% of the firefighters tested (Table 3-3). Further analysis showed the group whose VO_2 max was over-predicted by

the WFI sub-maximal test had a higher mean body fat percentage compared to those who were under-predicted ($p=0.0157$).

Pearson correlation analyses between the WFI sub-maximal and Bruce protocol produced a significant and moderate correlation coefficient ($r=0.635$, $p = 0.005$). True VO_2 max values were significantly and moderately correlated with percentage body fat ($r=-0.7353$, $p=0.0001$), diastolic blood pressure ($r=-0.541$, $p =0.0035$), BMI ($r=-0.5445$, $p=0.0033$), one-minute recovery HR ($r=0.537$, $p=0.0038$), and body composition ($r=-0.5178$ $p=0.0080$) (Table 3-4).

Discussion

The purpose of this study was to examine the ability of the WFI sub-maximal VO_2 test to accurately predict the true VO_2 max of individual firefighters. The sub-maximal test was shown to be moderately correlated in its ability to accurately predict the true VO_2 max of firefighters ($r=0.635$, $p = 0.005$). A moderate correlation may be considered low for a physiologically-based prediction test and is potentially unacceptable for clinical applications. Additionally, the range of VO_2 values and standard deviations between the predicted and true VO_2 max values varied greatly (35.4 to 50.9 vs. 28.6 to 58.4 $mlO_2/kg/min$, and standard deviation of 3.91 vs 7.22 respectively). This suggests the prediction formula for the sub-maximal test compresses the VO_2 max values into a more narrow range than what is true. This finding is concerning because a firefighter with a low true VO_2 max is likely to produce a higher predicted VO_2 max on the WFI sub-maximal test than what is actually true, thus limiting the ability of the WFI test to identify firefighters who are at a high-risk for CVD. Given that the purpose of this test is to track firefighter's individual fitness levels and give them feedback to improve their health, a test that can significantly over- or under-predict individual values should be examined

carefully for its applicability and place in a fitness assessment for a population that is especially vulnerable to on-duty CVD events.

Although the sample means for the sub-maximal and Bruce VO_2 max protocols were similar, the sub-maximal VO_2 treadmill test underestimated the true VO_2 max by as much as 21.1% in the majority (72.4%) of the participants, and over-estimated the true VO_2 max by as much 30.6% in our sample. Participants whose VO_2 max values were over-predicted by the WFI test were significantly more likely to have a higher body fat percentage than those who were under-predicted by the test. This finding is concerning given the main purpose for using this test is to identify firefighters at risk for on-duty CVD events. A test that over-predicts the true VO_2 max of firefighters may fail to accurately identify those at greatest risk for on-duty CVD, and thus preclude the opportunity to intervene in these high-risk firefighters. One issue may be that variances in individual body composition and metabolic characteristics may impact the estimated values. Another explanation that may account for the under- and over-estimation of VO_2 max is the use of age estimated HR_{max} used in the WFI sub-maximal formula to predict true VO_2 max. Age-estimated HR_{max} ($HR_{max} = 220 - \text{Age}$) has been shown to vary from true HR_{max} by +/- 10-12 beats per min among individuals (American College of Sports Medicine, 2000).

True VO_2 max values were found to be significantly and strongly correlated with percentage body fat ($r = -0.7353$, $p = 0.0001$), and moderately correlated with other physiological measures: diastolic blood pressure ($r = -0.541$, $p = 0.0035$), BMI ($r = -0.5445$, $p = 0.0033$), one minute recovery HR ($r = 0.537$, $p = 0.0038$), and body composition ($r = -0.5178$, $p = 0.0080$). This finding may be useful for improving the accuracy of the WFI

sub-maximal test in predicting the true VO_2 max of firefighters. Assessing indicators such as percentage body fat, resting diastolic blood pressure, and one minute recovery heart rate in conjunction with the WFI sub-maximal test may help identify less-fit firefighters who are producing overestimated VO_2 max values.

Caution should be used in the interpretation of these results as there are several limitations to this research. First, the sample size in this study was small ($n=29$). In light of this limitation, this is the only VO_2 max validation study to our knowledge using a sample entirely comprised of active duty firefighters. Typically, firefighters only make up a small percentage of the sample in VO_2 max validation studies, wherein all or the majority of the sample is often comprised of non-firefighters (Mier & Gibson, 2004). The sample of female firefighters was also small. However, the sample size of females in our study (15%) is inherent in the actual firefighter profession (national average of 4% female) (U.S. Department of Labor: Bureau of Labor Statistics, 2011). Another limitation of our study is the majority of firefighters who participated had a slightly higher estimated VO_2 max than the average from within the department they were sampled (see Table 3-1). No incentives were offered when recruiting firefighters, so most firefighters who voluntarily participated were generally fitness conscious and more inclined in knowing their level of physical fitness in terms of true VO_2 max. Offering incentives in future studies may help increase recruitment and participation of less fit firefighters. Another demographic limitation is that the average age of the sample was lower than the department average. This was in part due to study exclusion criteria of ages >45 years old due to concerns with the intensity of the true maximal aerobic test potentially triggering a cardiac event during testing. Future research is needed to

validate the WFI sub-maximal VO_2 test with a larger sample size of actual firefighters, especially for female firefighters, and in firefighters of varying fitness levels.

A validated aerobic capacity assessment will help to identify firefighters at greatest risk for CVD, provide opportunity for intervention, it can help to set an accurate healthy VO_2 max standard for firefighters, and can be used to accurately evaluate health promotion efforts aimed at increasing the VO_2 max of firefighters. To our knowledge, this is the first study to validate the current WFI sub-maximal VO_2 protocol in a pure firefighter population. The ease in which the WFI sub-maximal test can be administered and calculated in the field makes it a feasible and attractive assessment for measuring VO_2 max in firefighters. Additionally, the sub-maximal nature of this test makes it less risky than maximal based protocols. However, our results show the accuracy of the WFI sub-maximal test in predicting true VO_2 max in firefighter is questionable and may fail to identify firefighter's who are at an increased risk for on-duty CVD, particularly those with a higher percentage of body fat. Additional improvements to the current WFI protocol should be considered and could include incorporating the assessment of percentage body fat, diastolic blood pressure, and one minute recovery heart rate following the completion of the sub-maximal test. However, at this time and in its current form, a feasible and validated field-based VO_2 max assessment is needed to accurately reflect the true VO_2 max of individual firefighters.

Table 3-1. Descriptive characteristics and health screening information

Variable	VO2 sample mean (std dev)	Department mean (std dev)
Gender (% male)	85.2	89
Age (yrs)	31.93 (6.426)	38.5 (9.6)
BodyfFat (%)	25.96 (6.387)	22.2 (6.523)
BMI	27.204 (3.787)	N/A
Submax VO2	44.580 (3.912)	42.917 (5.402)

Table 3-2. Simple statistics: Bruce protocol vs. WFI Sub-maximal Prediction Tests

Variable	Mean	Std dev	Min value	Max value
Bruce VO2max	45.68	7.22	28.6	58.4
Submax VO2	44.58	3.91	35.4	50.9

Table 3-3. WFI Sub-maximal Prediction Test compared to Bruce VO₂max protocol

Direction	N	Mean	Std dev	Min	Max
Under-predicted	21	-3.887	3.13	-0.3	-11.1
Over-predicted	8	5.878	4.97	0.5	13.75

Table 3-4. Correlation of predictor variables with Bruce VO₂max value

Variable	Pearson correlation coefficient	p-value
WFI sub-max prediction test*	0.6348	0.005
Age	-0.2639	0.1834
Body fat**	-0.7353	<0.0001
BMI*	-0.5445	0.0033
Body composition*	-0.5178	0.0080
Resting HR	-0.1303	0.5182
Recovery HR 1 min*	0.5373	0.0038
Recovery HR 3 min	0.3662	0.0603
Recovery HR 5 min	0.2403	0.2473
Resting systolic blood pressure	-0.2015	0.3158
Resting diastolic blood pressure*	-0.5412	0.0035
Exercise days / week (mod-strenuous)	0.2652	0.2104
Exercise duration (mod-strenuous)	0.1628	0.4473
Strenuous days	0.0972	0.6514
Strenuous duration	0.1879	0.3793
Moderate days	0.2688	0.1939
Moderate duration	0.0004	0.9985

*- significant at p<0.05 level; **- significant at p<0.001 level

CHAPTER 4 EFFICACY OF A CARDIOVASCULAR DISEASE INTERVENTION FOR HIGH-RISK FIREFIGHTERS: A PILOT STUDY

Background

Cardiovascular disease (CVD) is the leading cause of on-duty death and disability among firefighter populations, accounting for 46% of all fatalities and injuries annually (Duenas-Laita, et al., 2007; National Institute for Occupational Safety and Health, 2001; United States Fire Service & National Fire Data Center, 2002). In contrast, CVD is responsible for 22% of fatalities in police, 10% in emergency medical service workers, and 11% of all deaths in the general work force (Maguire, et al., 2002). The disproportionately high rates of death and disability due to CVD among firefighters have produced urgent calls from concerned firefighters and public health officials to address this issue (National Institute for Occupational Safety and Health, 2001; Rosenstock & Olsen, 2007; United States Fire Service & National Fire Data Center, 2002). Recent research has identified several specific risk factors for CVD events in firefighters (Leiba, et al., 2011; Poston, et al., 2011; Soteriades, et al., 2008), and is providing critical insight towards the development, implementation, and evaluation of health programs aimed at reducing these risk factors in firefighters (Bjerk, 2011; Elliot, et al., 2007).

The majority of CVD deaths and disabilities in firefighters occur during strenuous bouts of physical exertion (Kales, et al., 2007); suppressing a fire (36%), performing physically demanding non-emergency duties (15%), responding to an alarm (13%), and engaging in physical training (12%). During these conditions, firefighters often work at near maximal heart rates for prolonged periods of time, under the stress of heavy equipment, and in the presence of high temperatures (Glendhill & Jamnik, 1992; Holmer & Gavhed, 2007; Rossi, 2003). Therefore, the relationship between physical fitness and

risk of CVD events during the performance of firefighting duties has received considerable attention from researchers (Leiba, et al., 2011; National Institute for Occupational Safety and Health, 2001; Poston, et al., 2011; United States Fire Service & National Fire Data Center, 2002).

Several physical fitness risk factors are shown to be related to CVD events in firefighters and include poor cardiorespiratory endurance (also referred to as VO₂max or aerobic capacity), having a high percentage of total body fat, having an overweight or obese Body Mass Index classification (BMI), having poor musculoskeletal fitness profiles, hypertension and dyslipidemia (Baris, et al., 2001; Glendhill & Jamnik, 1992; Haas, et al., 2003; Holmer & Gavhed, 2007; Kales, et al., 2007; Kales, et al., 2003; Leiba, et al., 2011; Poston, et al., 2011; Rosenstock & Olsen, 2007; Soteriades, et al., 2008). Studies show 25% of all firefighters fail to meet the minimum recommended cardiorespiratory endurance (VO₂max) standard of 42.0 ml/kg/min thought necessary to safely perform firefighter duties (Harvey, et al., 2008). Research finds 90% of all CVD fatalities occurred in firefighters who were classified as being either overweight or obese (National Institute for Occupational Safety and Health, 2001; United States Fire Service & National Fire Data Center, 2002). This is concerning since several studies show 53% of all firefighters are overweight, 35% are obese, 2.5% are extremely obese, and only 12% of firefighters have a healthy body fat percentage or BMI (Clark, et al., 2002; Fahs, et al., 2009; Yoo & Franke, 2009). A high prevalence of having more than one of these CVD risk factors exists in firefighter populations (Mier & Gibson, 2004; Rhea, et al., 2004). Many incumbent firefighters and even new firefighter recruits are commonly found to be overweight and have low-to-normal aerobic capacities (Clark, et al., 2002;

Kales, et al., 2007; Poston, et al., 2011) needed to safely perform physically demanding on-duty tasks (Donovan, et al., 2009; Leiba, et al., 2011; Poston, et al., 2011).

A large body of evidence shows regular aerobic Physical Activity (PA), is a protective factor against developing CVD as it increases VO₂max, is a critical component in reducing body fat, increasing musculoskeletal fitness, and is shown to both prevent and manage hypertension and cholesterol levels (Haskell, et al., 2007; Kesaniemi, et al., 2001; Sui, et al., 2006; Sui, et al., 2007). Regular PA is also necessary to develop the physical fitness required to safely meet the strenuous demands on-duty tasks most commonly linked to CVD events in firefighters (Harvey, et al., 2008; Poston, et al., 2011; D. L. Smith, et al., 2001). Therefore, researchers, public health officials, and concerned firefighters are advocating for programs promoting regular PA and physical fitness to reduce CVD risk in firefighters (Kales, et al., 2007; MacKinnon, et al., 2010; National Institute for Occupational Safety and Health, 2001). However, most fire departments do not require firefighters to exercise regularly (Kales, et al., 2007; Kales, et al., 2003). Approximately 70% of fire departments lack programs promoting PA or cardiovascular health, do not require firefighters to exercise on-duty, do not require incumbent firefighters to maintain physical fitness standards, and do not require routine physical fitness examinations to screen for CVD risk factors (Geibe, et al., 2008). Additionally, little evidence-based research exists regarding the evaluation of PA health promotion programs as a means to increase physical fitness or to reduce CVD risk factors in firefighters (Elliot, et al., 2007; Geibe, et al., 2008; Kales, et al., 2003; MacKinnon, et al., 2010; Poston, et al., 2011). The lack of programs and studies promoting PA in firefighters underscores the need for researchers and firefighter

communities to collaborate on best practice and evidence-based efforts to improve physical fitness and reduce CVD in firefighters.

Incorporating principles of Community Based Participatory Research (CBPR) may be an efficacious orientation for guiding firefighter community involvement in the application of IM in the development, delivery, and evaluation of health programming since studies show worksite health promotion efforts involving the target community in the research process has been successful for increasing physical activity (Israel, et al., 2005; Pazoki & Nabipour, 2007). CBPR is recognized as a critical orientation in efforts to effectively reduce health disparities in underserved communities (Pazoki & Nabipour, 2007), and is defined as “a collaborative partnership approach to research that equitably involves community members, organizational representatives, and researchers in all aspects of the research process” (Wallerstein & Duran, 2006). Both CBPR and IM are founded upon the ecological model, wherein as it has evolved in the behavioral sciences and in public health, the ecological model focuses on influential factors at the individual, interpersonal, community, environmental, and policy levels of health. Incorporating CBPR and IM in promoting health of firefighters may be an effective strategy due to the unique characteristics inherent in the firefighter profession. Compared to most other professions, firefighter have distinct personality traits, rely more heavily upon the social dynamics of team work, have unique cultural norms, are present in the work environments for longer periods of time (24-hour shifts), and are governed by paramilitary-style institutional policies of job performance, conduct, and behavior (Elliot, et al., 2007). Therefore, the orientation of CBPR and Intervention Mapping may have practical applications for guiding health promotion efforts to reduce

CVD in firefighters. Theory-based health promotion efforts are more likely to succeed when delivered through a well-designed health planning model (Green & Kreuter, 2005). Decades of research examining the determinants of PA behaviors and the effectiveness of interventions promoting PA provides meaningful insight towards identifying the appropriate theoretical understandings and health planning models needed for increasing physical fitness via PA in firefighters (Biddle & Nigg, 2000; Farag, et al., 2010; Greaves, et al., 2011; Kahn, et al., 2002; Sallis, et al., 2000). Social Cognitive Theory (SCT) and Intervention Mapping (IM), have both emerged as an efficacious health theory and planning model respectively for increasing PA (Antikainen & Ellis, 2011; Booth, et al., 2000; Foster, et al., 2005; Kok, et al., 2004; Michie, et al., 2009). IM is a protocol specifically designed for systematically applying theoretical strategies when developing, implementing, and evaluating health promotion programs (Bartholomew, et al., 2006). The synergistic influence of individual characteristics, interpersonal interactions, and environment factors (reciprocal determinism), as postulated by SCT (Bandura, 1986), is well-matched for translation into the work structure found in the firefighter profession (Elliot, et al., 2007; Murphy, et al., 2002). Reciprocal determinism can be applied since firefighters are characterized by unique individual traits inherent to their profession, rely heavily upon the social dynamics of team work, are present in the work environments for longer periods of time (24-hour shifts), and are governed by paramilitary style institutional policies for job performance, conduct, and behavior (Elliot, et al., 2007; Melius, 2001).

The purpose of our study is to evaluate the ability of a peer mentor-based worksite health promotion program based on SCT and IM to significantly increase

cardiorespiratory fitness ($VO_2\text{max}$), reduce body fat percentage, and increase musculoskeletal fitness in high-risk firefighters. Our working hypothesis is that unhealthy firefighters who participate in a three month Peer Fitness Intervention (PFI) will significantly increase $VO_2\text{max}$, maintain body fat percentage (no significant increase in body fat composition), and increase musculoskeletal fitness compared to firefighters in controlled conditions.

Methods

Participants

Firefighters from a North Central Florida Fire department ($n=144$), completed a battery of physical fitness health measures to identify firefighters considered to be at an increased risk for CVD. The criteria for classifying firefighters as high-risk for CVD was based on possessing both a $VO_2\text{max}$ score below 40 ml/kg/min and possessing a percentage of body fat considered to be overweight (>23% male, >33% female) (Gallagher et al., 2000). These $VO_2\text{max}$ values and body fat percentages were used as the discriminating risk factors because they are strongly associated with CVD risk (The Emerging Risk Factors Collaboration, 2011). Firefighters identified as high-risk ($n=24$) were then recruited into the study and randomly assigned into either treatment (full intervention) or comparison (environmental and policy change only) groups. Both groups (and the entire fire department) were exposed to various environmental and policy-level changes targeting increased physical activity levels. The treatment group was exposed to the full ecological intervention which included an individualized three month intervention in addition to the changes that occurred department-wide. The individual intervention was delivered by peer mentor firefighters and based on Social Cognitive Theory. Institutional Review Board approval was obtained in all 24 of the

firefighters who voluntarily consented to participating in the study prior to baseline testing and the intervention.

Health Measures

Each participant completed baseline, three month, and one-year-follow-ups on a variety of physical fitness health measures including: sub-maximal aerobic capacity (VO₂max) assessment, body fat percentage, BMI, hand grip strength, arm and leg strength, push-ups, abdominal static plank, and a flexibility (sit-and-reach) test. These health measures were selected from the physical fitness standards created from the firefighter National Wellness & Fitness Initiative that was set forth by the International Association of Firefighters and the Fire Chiefs Association (International Association of Firefighters, 2009). These health measures were obtained by a trained team of firefighters who were all able participate in baseline and post-testing data collections to ensure consistency in measurements. Aerobic capacity (also known as VO₂max), is the maximal volume of oxygen that can be utilized during maximal or exhaustive exercise, and is measured in milliliters of oxygen used in one minute per kilogram of body weight (ml/min/kg) (Powers & Dodd, 2003). Predicted aerobic capacity was measured using the firefighter Wellness Fitness Initiative (WFI) sub-maximal graded exercise treadmill test and is widely used among fire departments across the nation to assess VO₂max. In the WFI sub-maximal test, participants complete a standard protocol of increasing intensity over time until the participant reaches 85% of their age-predicted maximum heart rate $[(220 - \text{age}) \times 0.85]$. The amount of time taken to reach 85% of their age-predicted maximum heart rate during the WFI sub-maximal test (test time), and the BMI of participants is inserted into an equation $[56.981 + (1.242 \times \text{test time}) - (0.805 \times \text{BMI})]$, to predict their true VO₂max. This sub-maximal test was developed by a fire department

physician in Arizona, and has been shown to be significantly and moderately correlated ($r=0.6348$, $p\text{-value}=0.05$) in predicting trueVO₂max by the authors of this present study (Delisle et al., 2010).

A variety of physical fitness measurements were performed in accordance with WFI fitness assessment protocols (International Association of Firefighters, 2009). Body fat percentage was estimated using a three-point skin-fold body composition. In males, triceps, subscapular, and pectoral measurements were used, and females were measured at the triceps, abdominal, and superiliac sites. Hand grip, arm, and leg strength was measured as a static contraction and was measured with a dynamometer reported in kilograms. Push-ups were measured by the total number of continuous biomechanically sound repetitions completed without stopping. The abdominal static plank was measured by timing the total number of seconds a participant was able to maintain a biomechanically sound body position. Flexibility was measured by using a sit-and-reach box test, and reported in inches.

Peer Mentor Intervention

Using a CBPR approach, researchers teamed with peer mentor firefighters to develop, deliver, and evaluate the intervention. Peer mentor firefighters were selected based on criteria that included: firefighters who possessed a strong working knowledge and commitment to physical fitness, those who were well-respected among their peers, and those who have a sincere desire to enhance the physical fitness of their co-workers. Ten fire fighters meeting these criteria were identified and recruited, with a total of eight agreeing to participate in peer mentor training and programming. Once formally recruited, the eight firefighters received 40 hours of training based on the American Council on Exercise “Peer Fitness Trainer” program, and from health behavior

theory-based curriculum developed by the investigators of this study. The American Council on Exercise training program focused on teaching education-based information regarding the components and principles of physical fitness. The peer mentors received additional training provided by the researchers of this investigation on behavioral change strategies consistent with Social Cognitive Theory and included the modeling of health behaviors (observational learning), goal setting (expectancies), skill building techniques (behavioral capability), motivational reinforcement, and methods for building confidence (self-efficacy). Training from researchers also included strategies based on the ecological model the peer mentors used to create positive social normative attitudes towards aerobic fitness, ideas for modifying environmental factors for promoting physical activity, and methods to advocate for policies in promoting PA in the treatment group. One-on-one meetings between the peer mentors and participants in the treatment group were administered weekly during the intervention and consisted of custom-tailored exercise plans based on individualized fitness levels, preferences for PA, role-modeling experiences, and motivational reinforcements to be physically active. Weekly personal goals were developed for each participant with supportive activities designed to be build skills, be interactive, enjoyable, and consistent with principles of adult education; emphasizing relevance and active learning in the application of the new skills. These skill-building activities involved the use of several key theoretical constructs belying SCT including role-modeling (observational learning), addressing belief structures (expectations, expectancies), enhancing skills related to PA behavior (behavioral capability), and confidence-building experiences (self-efficacy). The weekly

meeting were supplemented by following up with participants over the phone throughout the week to monitor progress on their individual goals.

Statistical Analysis

To examine the ability of a peer mentor-based worksite health promotion program to significantly improve physical fitness in high-risk firefighters, we tested mean differences of cardiorespiratory fitness ($VO_2\text{max}$), body fat percentage, and musculoskeletal fitness between and within treatment and control groups. All analyses were performed using SAS version 9.2 (SAS Institute Inc., Cary, NC, USA). Distributions were first tested for normality and then a repeated measures Analysis of Variance test (ANOVA), was conducted to examine mean differences between treatment and control groups. Multivariate Analysis of Variance was conducted to examine within group changes since the assumption of a common spherical covariance matrix had not been met. When within group significance was detected from MANOVA testing, multiple paired sample t-tests were performed at baseline, 3-month and one-year follow-up. Formative evaluation was conducted to assess the quality of intervention development and training; process evaluations were conducted to assess the quality of implementation of the intervention including the fidelity and adherence of participation by peer mentors and participants in the treatment group.

Results

All 144 firefighters in the department completed baseline physical fitness assessments to identify high-risk firefighters and 24 were identified as high-risk. Table 4-1 describes sample and department-wide baseline health measures and shows that the sample recruited for the study were older, had a lower average $VO_2\text{max}$, and higher body fat composition than the department as a whole. Baseline equivalence was tested

prior to intervention with independent samples t-tests on all health factors assessed between the treatment and control groups and revealed both groups were similar (not significantly different at the $p=0.05$ level), and is described in Table 4-2.

Table 4-3 describes the sample means for each of the assessments of the intervention group and the control group both at baseline and 3 month post-test. Statistical analyses using the independent and paired samples t-tests (Table 4-4) examined if health measures significantly changed from baseline to post-testing both within and between groups. Sub-maximal aerobic capacity significantly increased from a baseline of 37.38 mlO₂/min/kg to 39.98 mlO₂/min/kg at 3-month post-testing for the intervention group ($p < 0.001$). The control group significantly increased body fat percentages of 28.71% at baseline to 29.53% at post testing ($p = 0.044$), while the intervention group maintained body fat percentages from 30.48% at baseline to 30.20% at post-testing ($p=0.384$). No significant increases or decreases were detected in any of the musculoskeletal health measures in either treatment or control group from baseline to post-testing.

Assessment of the long-term impacts of the intervention was conducted through collection and analysis of 12-month follow-up (9 months post-intervention) aerobic capacity data in both groups (Table 4-5). Paired sample t-tests evaluated whether the improvements in VO₂max were sustained in the intervention group (Table 4-6) and independent samples t-tests analyzed if the long-term changes seen differed significantly between the two groups (Table 4-7). The results of the tests showed that the intervention group not only sustained, but showed a non-significant trend of continued improvement of mean VO₂max from the end of the study (3-month follow-up)

until the 12 month follow-up (mean change 0.7383, p-value 0.1045). The intervention group showed an overall strong trend of significant improvement from baseline to 1-year follow-up (mean change of 2.998, p-value 0.0004) significant at the $p < 0.005$ level. The comparison group showed a small improvement in mean $VO_2\text{max}$ from 3 month post-intervention to follow-up (0.310 mean change, p-value 0.4126), yet from baseline to 1-year follow-up, they still showed a non-significant overall decline (mean change -0.4146, p-value 0.3926).

Discussion

The hypothesis that high-risk firefighters participating in a three-month peer mentor intervention will significantly improve aerobic capacity and musculoskeletal health measures, while decreasing body fat percentage compared to those in control conditions was partially met. The intervention group significantly increased $VO_2\text{max}$ while the control group did not. The control group significantly increased percentage of body fat while the intervention group did not. Further, the intervention group showed a trend of continued improvement in $VO_2\text{max}$ after the conclusion of the peer mentor portion of the program. Aside from a significant decrease in right hand grip strength from baseline to post testing in the intervention group, no other significant increase or decrease was observed for any of the musculoskeletal health measures for either the treatment or control group. Therefore our results indicate that firefighters exposed to a peer mentor-based intervention can increase aerobic capacity and maintain body fat percentages over firefighters who do not receive such an intervention. Further, it shows that impacts on $VO_2\text{max}$ are sustained at least 9 months after the conclusion of the intervention.

The significant increase in aerobic capacity of firefighters that was sustained post-intervention in the treatment group is encouraging since there is a strong relationship between VO₂max and risk of CVD. A low VO₂max is a primary risk factor for premature mortality and morbidity due to CVD (Haskell, et al., 2007; P. N. Peterson, et al., 2008; Sui, et al., 2006), and increasing one's aerobic capacity markedly reduces risk of CVD events (Peterson et al. 2008). A longitudinal cohort design study, controlling for BMI, found individuals who could not achieve 85% predicted VO₂max had significantly more fatal and nonfatal myocardial infarctions, unstable angina, and hypertension than those who could achieve 85% predicted VO₂max (Peterson, et al., 2008; Sui, et al., 2006; Sui, et al., 2007). A recent prospective study of over 25,000 asymptomatic men demonstrated that low VO₂max exercise tests are highly predictive of subsequent cardiac death, and the association increases for each additional CVD risk factor present (Sui, et al., 2006; Sui, et al., 2007). In fact research shows VO₂max may be one of the most important health measures related to CVD and is now believed to be an even stronger predictor of fatal and nonfatal CVD in firefighters than obesity (Harvey, et al., 2008; Leiba, et al., 2011; Poston, et al., 2011; Rhea, et al., 2004; Smith, et al., 2001).

The strong relationship between low aerobic capacity and CVD is concerning since studies find 25% of firefighters fail to achieve the current minimum firefighter standard VO₂max for of 42.0 ml/kg/min (Harvey, et al., 2008; International Association of Firefighters, 2009; Mier & Gibson, 2004). Our sample represents these firefighters since both the intervention and control groups had average VO₂max values well below the current minimum standard (37.4 and 38.9 mlO₂/min/kg respectively). The intervention group significantly increased VO₂max by 3.0 mlO₂/min/kg from a baseline

of 37.4 mlO₂/min/kg to a one year follow up of a 40.4 mlO₂/min/kg. This increase has important real world implications for efforts to address substandard VO₂max in firefighters since the intervention group began 4.5 mlO₂/min/kg below the minimum standard of 42.0 mlO₂/min/kg at baseline, and was only 1.5 mlO₂/min/kg below this standard at one year follow up. In comparison, the control group began at 3.1mlO₂/min/kg below the minimum firefighter standard at baseline, and 3.5 mlO₂/min/kg below this standard at one year follow up. Therefore our findings of a significant increase in aerobic capacity due to intervention are clinically meaningful for firefighters with low cardiorespiratory fitness since all participants in our sample had a VO₂max well below 42.0 ml/kg/min.

As with the sample we examined, a substandard VO₂max is significantly associated with the presence of other CVD risk factors in firefighters such as obesity, thus increasing the likelihood of developing CVD (Donovan, et al., 2009; Poston, et al., 2011). The control group demonstrated they were compounding this dual risk for CVD since they significantly increase percentage of body fat and did not improve their VO₂max. Improvements in CVD risk factors were seen in the intervention group as they maintained their body fat percentage while significantly increasing their VO₂max. No significant changes in body fat percentages in the treatment group indicates it was maintained during the intervention, which is often deemed a success in weight management research since body fat percentages tend to increase over time with age and without intervention (Lee, et al., 1999). Although insignificant, body fat percentages were declining in the treatment group and further research is needed to better understand the long term trajectories of this change.

Positive non-significant changes in the other physical fitness measures in the intervention group, such as leg strength, static plank, and sit-and-reach flexibility tests are also important to note. Increasing performance in auxiliary exercises and overall physical fitness can also reduce the risk of CVD events (Harvey, et al., 2008). Although significance was not detected in aforementioned health measures, the trajectories were trending towards improved health and could potentially lead to a significant change over time. The large decrease seen in grip strength in follow-up testing of the intervention group may be related to a mechanical malfunction of the hand dynamometer that was used on the day of post-testing. This device was later discovered to not be properly calibrated and had to be sent off to the manufacturer for repair.

The results of this pilot study demonstrate efficacy of worksite health interventions using peer-based efforts for firefighter populations to improve critical health indicators related to CVD such as increasing aerobic capacity and maintaining body fat percentages. The sustainability of the changes after the program concluded were supported as continued improvements were seen in the intervention group at one-year follow-up. These findings have important implications due to the limited success of worksite health interventions for improving physical fitness indicators via promoting physical activity (Dishman, et al., 1998) and the overall lack of successful CVD interventions in the firefighter population. Many researchers believe the ineffectiveness of worksite health promotion efforts to improve physical fitness is largely due to a lack of effective planning and theory-driven approaches to intervention design (Conn, Hafdahl, Cooper, Brown, & Lusk, 2009; Dishman, et al., 1998). The strength of the current study is that it involved the systematic planning from the use of a Community Based

Participatory Research (CBPR), approach that incorporated Intervention Mapping. Both researchers and firefighters agreed involving firefighters in the planning, implementation, and evaluation of the intervention was a key component in obtaining a 100% participation rate from all 144 firefighters in baseline assessments, from high-risk firefighters to participate in either treatment or control conditions, and from the firefighters serving as peer mentors. Another strength was the application of several Social Cognitive Theory constructs such as role-modeling of physical activity behaviors through vicarious learning, developing behavioral capability via skill building activities, and increasing self-efficacy to perform physical activity. The use of CBPR helped to identify SCT as the health behavior theory to use during the planning phase, and was integral in implementing peer mentor efforts to promote physical activity in high-risk firefighters, and was critical for empowering firefighters to take the lead on evaluating physical fitness since their professional skill set predisposes them to be competent in measuring health indicators. Involvement of firefighters in the participatory process of development, delivery, and evaluation of the program may have contributed to the high rate of program fidelity, dose-delivered and received of the physical intervention as reported from the formative and process program evaluations.

Results of this study should be interpreted in lieu of several limitations. First, the findings of the study may be limited due to the small sample size of both treatment and control groups. A small sample size limited the ability to conduct a within-group ANOVA since the assumption of a common spherical covariance matrix had not been met. A larger sample size would increase the likelihood of meeting the assumption of a common spherical covariance matrix, and would also allow for more statistically robust

analysis such as regression modeling to plot the slopes of change over time. Additional studies of firefighters involving larger samples drawn from urban, rural, and suburban settings, along with more diverse demographic populations, would improve external validity. Although the sample was small, it did over-represent female firefighters since 20.8% of the participants in our sample were female, compared to the 13% of female firefighters who make up the fire department's work force and 4% nationwide. A small sample size in our study may account for the lack of statistical significance detected for musculoskeletal fitness outcomes due to reduction of statistical power. The fact statistical significance was detected in a small sample demonstrates a peer mentor intervention can produce a large effect size exists for increasing aerobic capacity, and that a large effect size may exist for increasing body fat percentage in high-risk firefighters when no intervention is present. Future research is also needed to identify efficacious strategies for increasing musculoskeletal fitness, such as incorporating intervention components targeting significant health influences in firefighters that are outside of the work environment.

The firefighting profession requires a high level of physical fitness to perform on-duty tasks and to protect against CVD. Few fire departments have health programs that promote physical activity, require on-duty physical activity or to maintain minimum standards for physical fitness. Additionally, little research exists regarding the effectiveness of health programs to promote physical activity and fitness in firefighters. Our pilot study demonstrated efficacy for peer mentor-based efforts to increase aerobic capacity and maintain body fat percentage in firefighters. In addition to the favorable impact physical activity has on the task specific and physical fitness risk factors related

to CVD events in firefighters, it is a low-cost, feasible, safe therapy with minimal risk of adverse side-effects (Elliot, et al., 2007; MacKinnon, et al., 2010). Therefore, future research should examine the effectiveness to promote physical fitness in firefighters via peer-driven physical activity worksite health promotion efforts in larger samples of diverse firefighters,

Table 4-1. Baseline descriptive measures for department-wide, intervention group and comparison group

Variable	Department-wide mean(95%CI)	Comparison group mean (95% CI)	Intervention group mean (95% CI)
N	144	12	12
Age	38.9 (37.3, 40.5)	45.8 (39.2, 52.4)	44.3 (39.5, 49.1)
Gender (% male)	87.1	83.9	75.8
VO2max	43.2 (42.6, 43.9)	38.0 (36.7, 39.3)	37.4 (35.5, 39.3)
Body fat %	22.2 (21.1, 23.3)	28.9 (25.9, 32.0)	30.3 (27.5, 33.0)

Table 4-2. Baseline equivalence of control and intervention group

Variable (mean/ std dev)	Comparison group	Intervention group	Paired samples T-test p-value
Age (yrs)	45.73	44.33	0.688
VO2max (ml O2/kg/min)	38.9 (2.68)	37.4 (2.99)	0.179
Body fat (%)	28.7 (3.7)	30.5 (4.47)	0.329
Left hand max (kg)	52.5 (7.52)	57.7 (13.41)	0.216
Leg max (kg)	139.4 (21.37)	132.7 (34.32)	0.537
Arm max (kg)	41.2 (10.01)	42.6 (15.48)	0.782
Push-ups (reps)	23.5 (8.55)	23.7 (7.18)	0.949
Static plank (min)	1.53 (0.83)	1.83 (0.97)	0.390
Sit and reach (in)	15.4 (3.54)	16.2 (3.00)	0.434

Table 4-3. Baseline and 3-month post-test

Variable Mean (std dev)	Comparison Group (n=12)		Intervention Group (n=12)	
	Pre-test	Post-test	Pre-test	Post-test
VO2 max (mlO2/kg/min)	38.9 (2.68)	38.1 (1.63)	37.4 (2.99)	39.6 (2.78)
Right hand max (kg)	52.9 (8.43)	54.8 (6.34)	60.9 (11.42)	56.8 (11.32)
Left hand max (kg)	52.5 (7.52)	52.8 (6.55)	57.7 (13.41)	53.6 (13.73)
Leg max (kg)	139.4 (21.37)	142.3 (19.48)	132.7 (34.32)	133.2(25.96)
Arm max (kg)	41.2 (10.01)	45.0 (13.09)	42.6 (15.48)	41.4 (9.97)
Push-ups (reps)	23.5 (8.55)	21.3 (8.68)	23.7 (7.18)	23.7 (5.19)
Static plank (min)	1.53 (0.83)	1.42 (0.67)	1.83 (0.97)	1.58 (0.52)
Sit and reach (in)	15.4 (3.54)	15.1 (2.54)	16.2 (3.00)	16.5 (2.46)
Body fat (%)	28.7 (3.7)	29.5 (3.71)	30.5 (4.47)	30.2 (4.46)

Table 4-4. Baseline to 3 month follow-up changes in outcome measures: Paired samples t-test

Variables	Intervention group		Comparison group	
	Mean (Std dev)	P-value	Mean (Std dev)	P-value
VO2max*	2.259 (1.646)	0.0006*	0.145 (0.501)	0.3838
Body fat	-0.330 (0.808)	0.2289	0.675 (0.778)	0.0438
Left hand strength	-4.008 (7.513)	0.0864	0.000 (1.4142)	1.000
Right hand strength*	-4.083 (6.244)	0.0447*	-0.400 (1.837)	0.5086
Leg strength	0.550 (17.026)	0.9129	-2.770 (4.785)	0.1004
Arm strength	-1.208 (11.787)	0.7292	2.280 (10.465)	0.5082
Push-ups	0.083 (9.249)	0.9757	-0.700 (2.111)	0.3217
Static plank	-0.250 (0.933)	0.3730	-0.101 (0.404)	0.4698
Flexibility	0.270 (1.539)	0.5545	-0.281 (0.784)	0.3442

Table 4-5. Baseline, 3-month, and 1-year follow-up mean aerobic capacity values

VO2max (mlO2/kg/min) Timeline	Intervention group n=12 Mean (std dev)	Comparison group n=12 Mean (std dev)
Baseline	37.4 (2.99)	38.9 (2.68)
3 month	39.6 (2.78)	38.1 (1.63)
1 year follow-up	40.4 (2.20)	38.5 (3.74)

Table 4-6. Long-term changes in VO2max in intervention and comparison groups

Time period measured	Intervention group		Comparison group	
	Mean change (std dev)	p-value	Mean change (std dev)	p-value
Baseline to 3-month	2.259 (1.646)	0.0006*	0.145 (0.501)	0.3838
3-month to 1-yr follow-up	0.738 (1.45)	0.1045	-1.104 (2.17)	0.1926
Baseline to 1-yr follow-up*	2.998 (2.10)	0.0004*	-0.514 (2.09)	0.3926

Table 4-7. Between-group differences in 1-year mean changes in VO2max (Intervention vs. Comparison Groups)

	Mean (std dev)	p-value
Baseline to 1-yr follow-up	-3.512 (2.10)	0.0004

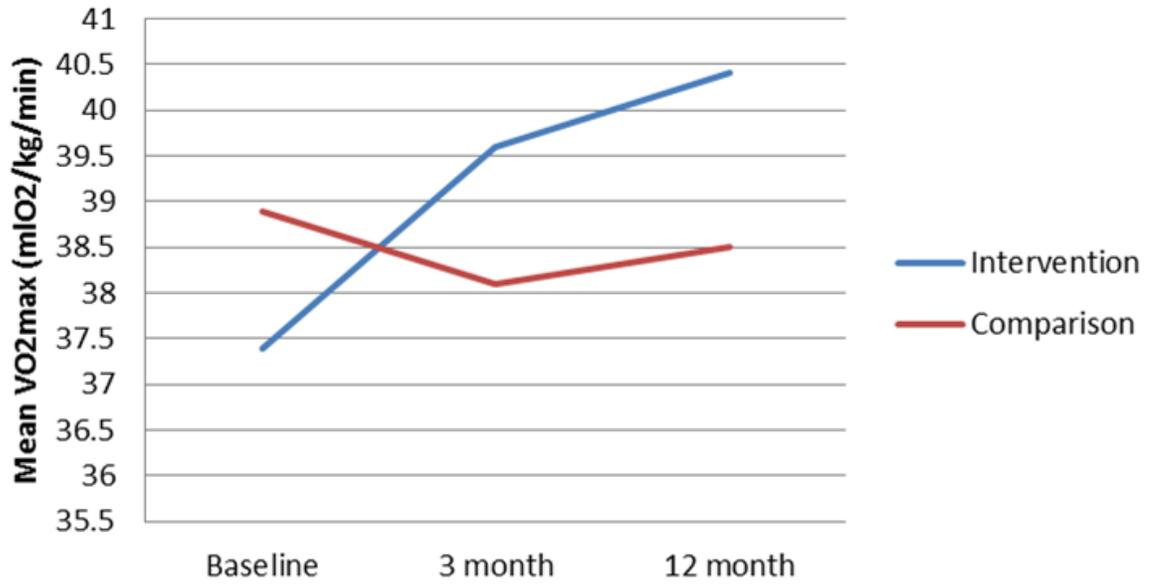


Figure 4-1. Measured Aerobic Capacity in Intervention and Comparison Groups
Note: A VO2max of 42.0 ml/Kg/min is minimum safe standard for firefighters

CHAPTER 5 SUMMARY, CONCLUSIONS, RECOMMENDATIONS, AND IMPLICATIONS

Summary

The present research focused on cardiovascular disease prevention in firefighters. Specifically, this research primarily focused on three integrated studies. The purposes for each of the studies were: 1) to describe the methods used to engage firefighters in the participatory processes of planning, implementing, and evaluating a CVD prevention program utilizing Intervention Mapping (IM). 2) to evaluate the validity of the current WFI sub-maximal VO_2 protocol used to predict the true VO_{2max} of firefighters. 3) to examine the use of a peer-driven firefighter worksite health promotion intervention on increasing physical activity, improving cardiorespiratory fitness, body composition, and other physical fitness indicators in unhealthy firefighters failing to meet “fit-for-duty” requirements.

The study in Chapter 2 examined the participatory processes a Community Academic Partnership (CAP) used to integrate the principles of Community Based Participatory Research (CBPR) with the methods of Intervention Mapping (IM) to develop, deliver, and evaluate a worksite health promotion program targeting cardiovascular disease (CVD) risk factors in firefighters. Two fire departments, representatives from a local public health department, and three health-oriented university academic departments comprised the CAP. The results of the study found facilitating partnerships in all phases of the research process building upon the strengths of the community, and capacity building and co-learning were the most frequently utilized CBPR principles integrated into the steps of IM. Key elements of the health program developed from the process of integrating principles of CBPR with IM

included: establishing department wide annual physical fitness and CVD screenings; training of firefighters to serve as Peer Fitness Trainers (PFT); validation of instrumentation evaluating cardiorespiratory fitness of firefighters; identification of firefighters at highest risk of CVD; PFT-driven development and delivery of individually-tailored fitness interventions; improved access to workout equipment; and policy changes to mandate on-duty physical activity. The CAP ultimately created and delivered a one-year CVD prevention program resulting in an 8% increase in cardiorespiratory fitness ($p=0.001$) in high-risk firefighters, while capitalizing on the community capacity, thus, requiring minimal financial resources.

The study in Chapter 3 examined the validity of the current sub-maximal VO_2 test used to measure aerobic capacity of firefighters to predict their true VO_{2max} ascertained from the Bruce VO_{2max} Protocol. Thirty healthy firefighters completed both the sub-maximal and Bruce protocols. The estimated sample mean values for the sub-maximal and true VO_{2max} were similar; 44.58 ± 3.91 $mLO_2/kg/min$ and 45.68 ± 7.22 $mLO_2/kg/min$ respectively. Although the means are similar, the ranges of values and standard deviations differed between the predicted and true VO_{2max} values (min – max: 35.4 to 50.9 vs. 28.6 to 58.4 $mLO_2/kg/min$, and standard deviation of 3.91 vs 7.22 respectively). This suggests the prediction formula compresses VO_{2max} values into a more narrow range than what is true. Additionally, the sub-maximal test under-predicted the true VO_{2max} in 72.4% of firefighters, and over-predicted in 27.6% of the firefighters tested. The estimated and true VO_{2max} values were moderately correlated ($r = 0.6348$, $p = 0.005$). True VO_{2max} values were also significantly and moderately correlated with

one minute recovery heart rate ($r=0.537$, $p=0.0038$), percentage of body fat ($r=0.5178$, $p=0.0080$), and resting blood pressure ($r= -0.541$, $p\text{-value}=0.0035$).

Chapter 4 describes a study in which firefighters from a North Florida Fire department ($n=144$) completed a battery of physical fitness and CVD risk factor assessments to identify firefighters at increased risk for CVD. Firefighters identified as high-risk ($n=24$) based on these measures (primarily a $VO_2\text{max}$ score < 40 and higher body fat composition) were recruited into the study and randomly assigned into either treatment or control groups. The intervention group was exposed to a one-year Peer Fitness Intervention (PFI) based on Social Cognitive Theory, which was delivered by firefighters trained to be peer fitness mentors. Both intervention and control groups completed baseline and one-year post-testing across a broad range of health outcome measures. The baseline equivalence of the two groups was tested with a paired samples t-test on all factors assessed and indicated there were no significant differences between the two groups at baseline. Statistical analyses using the independent and paired samples t-tests showed which key health measures significantly changed from baseline to post-testing both within and between groups. Sub-maximal aerobic capacity significantly increased from a baseline of 37.38 ml/min/kg to 39.98 ml/min/kg at post-testing for the intervention group ($p < 0.001$). The control group significantly increased body fat percentages of 28.71% at baseline to 29.53% at post testing ($p = 0.044$), while the intervention group maintained body fat percentages from 30.48% at baseline to 30.20% at post-testing ($p=0.384$). Though not statistically significant, the intervention group also showed a decrease in body fat percentage, arm

strength, pushups, and hand grip strength, and an increase in leg strength, abdominal static plank, and sit-and-reach.

Conclusion

These investigations represent the first efforts to examine the participatory process of engaging firefighter and academic partners in the planning, implementation, and evaluation of CVD health program for firefighters; to validate the current sub-maximal cardiorespiratory fitness test used for assessing aerobic fitness of firefighters; and to assess the effects of a peer driven intervention for improving physical fitness of high-risk firefighters. Findings from this research suggest integrating principles of CBPR into health planning models such as IM, is an efficacious process for involving firefighters and academics in all phases of the research process, designing key elements for a health program relevant to the culture of firefighters, for building community capacity of firefighters to deliver and assess a health program, and to ensure long term commitments of firefighters and academic partners for the sustainability of health programming. The inherent culture of firefighters may predispose this population towards the participatory process involved in health promotion. These cultural characteristics include a work structure emphasizing team work, paramilitary style policies governing behavior and conduct, norms emphasizing the importance of a high level of physical fitness, and expertise for assessing health indicators. Additionally, the overlapping core concepts between IM and CBPR may account for the success of fostering and sustaining a CAP with firefighters for the purposes of health promotion. Both IM and CBPR are guided by similar conceptual frameworks concerning health promotion efforts including: involving the participation of the target community in all phases of research, utilizing the ecological approach towards understanding and

intervening upon health outcomes, developing capacity via capitalizing on assets within the community, and in using an iterative process in program development, implementation and evaluation. The congruency of these concepts complemented the efforts of integrating the systematic and well-structured methods of IM with the orientation of CBPR.

With regards to the cardiorespiratory validation study, the sample means for the sub-maximal prediction and Bruce VO_2 max protocols were similar, the sub-maximal VO_2 treadmill test underestimated the true VO_2 max in the majority of healthy firefighters, and overestimated the VO_2 max in less-healthy firefighters. This finding is concerning given the main purpose for using this test is to identify firefighters at risk for on-duty CVD events. A test that over predicts the true VO_2 max of unfit firefighters will not identify those at greatest risk for on-duty CVD, nor provide the opportunity to help intervene to improve the cardiorespiratory fitness of these high-risk firefighters. The sub-maximal test was shown to be moderately correlated ($r = 0.6348$, $p = 0.005$), in its ability to accurately predict the true VO_2 max of firefighters. A moderate correlation may be considered low for a physiologically-based prediction test, and is potentially unacceptable for clinical applications. Additionally the ranges of values differed between the predicted and true VO_2 max values (min – max: 35.4 to 50.9 vs. 28.6 to 58.4 $mlO_2/kg/min$, and standard deviation of 3.91 vs. 7.22 respectively). This suggests that the prediction formula for the sub-maximal test compresses the VO_2 max values into a more narrow range than what is true. A potential danger in this is that a firefighter with low true VO_2 max is likely to have a higher predicted VO_2 max, thus limiting the tests ability to identify a high-risk firefighter. Resting Heart Rate, resting blood pressure, and

three point skin-fold body composition measures were determined to be significant and moderately correlated to true VO_2max . Therefore, assessing recovery heart rate, blood pressure, and body composition in conjunction with the sub-maximal test may improve the precision of this test, and perhaps eliminate the issues this current assessment has in over- or under-estimating the aerobic fitness levels of firefighters.

The hypothesis that high-risk firefighters participating in a one year PFT intervention will significantly improve aerobic capacity and muscular conditioning, while decreasing body fat percentage compared to those in control conditions was partially met. The intervention group significantly increased aerobic capacity, did not significantly increase muscular conditioning assessments or significantly reduce body fat percentage. Although significance was not detected these measures, the trajectories for body fat percentages were decreasing and several muscular conditioning assessments were increasing. These non-significant findings are important because these measures were trending towards improved health and could potentially lead to a decreased risk of CVD-related events in firefighters. The trajectory of decreasing body fat percentage is particularly encouraging since the body fat percentages significantly increased in the control group. No significant changes suggest that body fat percentages were maintained during the intervention, which is often deemed a success in weight management research since body fat percentages tend to increase with age and without intervention (The Emerging Risk Factors Collaboration, 2011). Therefore our results indicate that firefighters exposed to a peer mentor based-intervention can increase aerobic capacity and maintain body fat percentages over firefighters who do not receive such an intervention. Increased aerobic capacity and maintenance of body

fat percentage of firefighters in the treatment group is very encouraging given these health indicators are shown to have significant and strong relationships with the likelihood of developing CVD in firefighters (Yoo & Franke, 2009).

Recommendations for Future Research

The findings from this study suggest the following actions:

The use of community based orientations, health program planning models, and social behavioral theories in the development, implementation, and evaluation of CVD prevention programs for firefighter populations

To investigate the use of peer driven interventions to promote cardiovascular health and physical fitness in firefighter populations with a larger sample size than was investigated in the present study (n=24). Additional studies of firefighters involving larger samples drawn from urban, rural, and suburban settings, along with more diverse demographic populations, would improve external validity.

To conduct longitudinal studies examining the effectiveness of interventions on promoting cardiovascular health of firefighters for a longer period of time than was examined in the present investigation.

To investigate how social culture normative beliefs of firefighters influence the practice of health behaviors related to cardiovascular disease. Anecdotally, our study revealed firefighters assigned gender roles to the practice of physical activity and nutrition behaviors often leading them to choose strength-building over aerobic activities and a heavy animal-based diet over a plant-based diet. Understanding how members of male-dominated professions, such as firefighting, assign and act upon perceived gender roles of different health behaviors, may lead to social marketing efforts to alter these perceptions and encourage the practice of CVD-protective health behaviors.

To examine the effectiveness of promoting healthy nutrition behaviors for the prevention of CVD in firefighters.

To examine the effects of interventions targeting social networks of firefighters outside of the fire department, such as their family members, for promoting physical activity and healthy nutrition in firefighters.

To validate the WFI sub-maximal VO_2 test with a greater sample size of firefighters, especially for female firefighters, and in firefighters of varying fitness levels, particularly unfit firefighters.

To investigate whether the precision of the current WFI sub-maximal VO_2 test to predict true VO_2 max can be improved by incorporating health indicators significantly correlated to true VO_2 max (such as blood pressure, recovery heart rate, and percentage body fat), into the WFI sub-maximal prediction formula.

Implications

Despite the need for future research, this study provides important implications for the prevention of CVD events in firefighters. First, this study is the first of its kind to demonstrate efficacy in applying the principles of Community Based Participatory Research towards the process of fostering and guiding a Community Academic Partnership for addressing CVD in firefighters. This finding implies the unique dynamics of the firefighter profession make it readily accessible to the orientation and application of CBPR, thus CBPR is likely to be a useful approach for future health promotion efforts in firefighters. Second, this is the first study to validate the current WFI sub-maximal VO_2 test used in firefighters in its ability to accurately predict cardiorespiratory fitness of individual firefighters. Though this test is useful for measuring mean aerobic capacity levels of groups of firefighters, our findings suggest this test is not sufficient in its

precision to accurately measure the true aerobic capacity of firefighters. This is likely due to high variability in true maximum heart rate, body composition, and metabolic characteristics between individuals. However, for the purposes of tracking changes of VO_2 max within individuals, the test appears to be reliable due to individual factors that impact the accuracy of the results are unlikely to vary within the individual. The WFI sub-maximal VO_2 test was shown to either under-predict or over-predict the true VO_2 max by greater than 10% in a majority of firefighters tested. The implication for this finding is that high-risk firefighters may not be identified, and that a new test is needed in order to accurately identify firefighters who are at risk for on-duty CVD events. Third, results of this study provide support for efficacy of worksite health interventions using peer-based efforts for firefighter populations to improve critical health indicators related to CVD such as aerobic capacity and body composition, in high-risk firefighters. These findings have important implications due to limited success of worksite health interventions for improving physical fitness indicators via promoting physical activity (Dishman, et al., 1998). In addition to the favorable impact PA has on the task specific and biological risk factors for CVD in firefighters, these intervention efforts are likely to be translatable and disseminated to other firefighter communities as these efforts to increase PA is a low-cost, feasible, and a safe therapy with minimal adverse side-effects (Elliot, et al., 2007; MacKinnon, et al., 2010).

Therefore the implications of this study suggest firefighters, academic partners, and public health officials should: use community-based orientations, health program planning models, and social behavioral theories in the development, implementation, and evaluation of CVD prevention programs for firefighter populations; utilize a more

accurate cardiorespiratory fitness assessment for assessing aerobic capacity of firefighters than what is currently being used; and to use peer mentoring strategies such as role-modeling of physical activity behaviors through vicarious learning, developing behavioral capability via skill building activities, and developing self-efficacy to perform aerobic physical activity for improve cardiorespiratory fitness and maintenance of body composition in firefighters who are high-risk for CVD.

APPENDIX A
PARTICIPANT INFORMATION

Validation of VO₂Max Data Forms

Name of Fitness Assessor: _____

Date _____

Informed Consent Form Signed? ___ YES ___ NO

General Information

Subject ID Number: _____

Have you exercised today? YES NO

(If yes, how much exercise?)

Have you had any caffeine (coffee, soda) today? YES NO

Are you on any medications that affect your heart rate? YES NO

Age _____ Gender _____ Height (in) _____

Weight (lbs) _____

Resting Heart Rate _____ (bpm)

Resting Blood Pressure _____ / _____

BODY COMPOSITION: BIA Scale

Bioelectrical Impedance (BIA scale)

Weight (lbs) _____ Body Fat% _____

Body Muscle% _____ BMI _____

Waist-Hip Ratio

Waist (upper abdominal): _____ (in) Hip (gluteal): _____ (in)

Waist/Hip ratio: _____

Body Fat %: 3 Point Skin-Folds

	Trial #1	Trial #2	Trial #3
Average			
Men:			
Triceps	_____	_____	_____
Chest	_____	_____	_____
Subscapular	_____	_____	_____
			Sum of Skinfolds _____

Women:			
Triceps	_____	_____	_____
Abdomen	_____	_____	_____
Suprailiac	_____	_____	_____
			Sum of Skinfolds _____

APPENDIX B
WFI SUBMAXIMAL AEROBIC CAPACITY ASSESSMENT

CARDIOVASCULAR FITNESS: WFI 85% Sub maximal Treadmill Test

Resting Heart Rate _____ bpm Resting Blood Pressure ____/____

Age Predicted Max Heart Rate (220 – age) _____ bpm 85% HR max _____ bpm

WFI 85% Sub maximal Treadmill Test Protocol

Stage	Time (mi n)	Speed (mph)	Incline	Heart Rate	Blood Press	RPE
Rest	- -	- -	- -			
1	0:00 – 3:00	3.0	0 %			
2	3:01 – 4:00	4.5	0 %			
3	4:01 – 5:00	4.5	2 %			
4	5:01 – 6:00	5.0	2 %			
5	6:01 – 7:00	5.0	4 %			
6	7:01 – 8:00	5.5	4 %			
7	8:01 – 9:00	5.5	6 %			
8	9:01 – 10:00	6.0	6 %			
9	10:01 – 11:00	6.0	8 %			
10	11:01 – 12:00	6.5	8 %			
11	12:01 – 13:00	6.5	10 %			
12	13:01 – 14:00	7.0	10 %			
13	14:01 – 15:00	7.0	12%			
14	15:01 – 16:00	8.0	12%			
15	16:01 – 17:00	8.0	14%			

Recovery 1	0:00 – 1:00					
Recovery 2	1:01 – 2:00					
Recovery 3	2:01 – 3:00					
Recovery 4	3:01 - 4:00					

Total Time (min: sec) _____:_____ TT Decimal (min) _____

Predicted VO₂max = 56.981 + (1.242 x TT) – (0.085 x BMI) = _____ ml/kg/min

Predicted VO₂ MAX _____ ml/kg/min

APPENDIX C
BRUCE VO₂MAX ASSESSMENT

CARDIOVASCULAR FITNESS: Bruce VO₂ Max Protocol

Ht. _____(in) _____(cm) Wt. _____(lbs.) _____(kg) BMI _____(kg/m²)

Medications _____

Clinical History _____

RESTING DATA

Supine BP = _____/_____mmHg Sitting/Standing BP = _____/_____mmHg

Supine HR = _____b/min Sitting/Standing HR = _____b/min

Resting EKG Interpretation _____

TABLE 2a: BRUCE PROTOCOL

Stage	Time (min)	Speed (mph)	Grade (%)	Heart Rate (bpm)	Blood Press (mmHg)	RPE	Comments (symptoms, EKG, etc.)
1*	3:00	1.7	10		/		
2	3:00	2.5	12		/		
3	3:00	3.4	14		/		
4	3:00	4.2	16		/		
5	3:00	5.0	18		/		
6	3:00	5.5	20		/		
7	3:00	6.0	22		/		

VO₂ Max: _____L/min _____ml/kg/min RER (RQ): _____

Recovery Data

Time (min)	Speed (mph)	Grade (%)	Heart Rate (bpm)	Blood Pressure (mmHg)	RPE (6 – 20)	Comments (symptoms, EKG, standing or supine, etc.)
				/		
				/		
				/		
				/		

Reason Terminating the Test:

2 criteria required:

VO2 Max Plateau

Maximal Heart Rate RER > 1.15 RPE of 20

1 criterion required:

Fatigue

Dyspnea

Leg Fatigue

Chest Pain

Other: _____

APPENDIX D
BRUCE PROTOCOL CHECKLIST

Before the subject arrives, the following must be done

- Check to see if the treadmill is working
- Check to see if there EKG display is working
 - Make sure there are enough electrodes
 - Cables are not tangled
- Check to see if the computer program is running
- Warm up the machine for 30 minutes
- Assemble Clean mouthpiece
 - Mouth pieces should be cleaned with a 1:10 bleach to water solution
 - Parts
 - Saliva tube
 - Snorkel-like mouth piece
 - 2 one way valves
 - White air tube
 - Clear air tube
 - Nose clip
 - Head gear
- Assemble spirometer tubing to computer
- Adjust placement of the computer and the EKG screens so subject will not be distracted by them. They should be in plain view of the test administrator.
- Place RPE scale in plain sight of subject and researcher

Calibrating the Machine:

- Open the Program True Max
- Open “gas calibration”
- Set the room temperature, barometric pressure, relative humidity, etc.
- Follow prompt to Turn the Oxygen tank counter clockwise 90 degrees
 - Press ok
- Let the machine calibrate
 - Press ok
 - If it’s not calibrating, a possible problem is that the oxygen tank is empty
- Turn the oxygen tank back to where it needs to go
- Check the gas calibration parameters to make sure they are correct.
- Pull up Flow meter calibration
- Press Sample Baseline
- Hook up the 3 Liter Syringe to the spirometer tube
- Steadily pump the 3 L syringe 9 times.
 - 3 strokes to remove old air
 - then 5 more

- As long as the % error is under two percent you are ok
- Close out Flow Meter Calibration by clicking “save”
- Enter VO2 Metabolic Testing

Participant Prep:

- Provide participant with parking pass and escort them to lab
- First obtain PAR-Q
- Then obtain informed consent and give the participant a copy
- Obtain LTQ questionnaire
- Use self-reported age
- Use self-reported gender
- Measure height on the wall. DO NOT USE SELF-REPORTED HEIGHT
- Use BIA scale to measure weight, BMI, % body fat
- Measure Resting Heart Rate and Blood Pressure
 - Blood Pressure with a diastolic pressure of above 100 will not be qualified to participate
- Continuously communicate to the patient what you are doing as you are doing it
- Decide on a non verbal stop signal for subject to stop the test
- Place electrodes on chest
 - Place electrodes with lead hook facing in such a way that the leads will face towards the ground
 - 4 arm and leg
 - 6 ventricle
 - V1 + V2 are placed in the 4th intercostal space between the ribs
 - V4 is placed directly under the nipple/pectoral muscle
 - V3 is placed in between V2 and V4
 - V6 is placed straight down from the arm pit
 - V5 is placed in between V4 and V6 in a curved line
 - Shave chest if needed
 - Hook electrodes to leads
 - Keep leads as organized as possible. Avoid tangling the leads
 - Attach leads to the top of the treadmill so they do not hang or tug on the electrodes
 - Put shirt back on
- Have subject put in mouth piece
 - Instruct the subject to breath normally to check if the valves have been inserted correctly
 - Instruct the subject to hold the mouth piece in a comfortable position
 - Tighten the cap in a position that comfortably secures the mouthpiece in place

- Have subject stand on either side of the tread mill belt
- Assemble spirometer tubing to mouth piece output valve and to the computer
- Adjust for comfort

Computer and Participant Prep

- Enter subject information and press ok
 - Height, weight, name, age, gender
- Enter Maximal Test
 - Treadmill

Test Administration:

- Get the subject's consent to start the test
- Have spotter stand behind the subject throughout the test to catch them if they trip
- Continuously communicate with the subject throughout the test what is being done as it is being done
- Continuously monitor the subject's physical appearance and symptoms
 - Ask RPE at each stage 2 minutes and 2:45 into the stage.
- First two minutes are a warm up at 2 or 3 miles an hour. No grade.
- Start the Tread mill at 1.7 mph at 10% grade
 - Stages are 3 minutes each as follows:
 - Stage 1 = 1.7 mph at 10% Grade
 - Stage 2 = 2.5 mph at 12% Grade
 - Stage 3 = 3.4 mph at 14% Grade
 - Stage 4 = 4.2 mph at 16% Grade
 - Stage 5 = 5.0 mph at 18% Grade
 - Stage 6 = 5.5 mph at 20% Grade
 - Stage 7 = 6.0 mph at 22% Grade
 - Stage 8 = 6.5 mph at 24% Grade
 - Stage 9 = 7.0 mph at 26% Grade
- Adequately move through the stages at the proper times
- Inform the subject at the end of each stage that there will be a change
 - Tell them what speed and grade they will increase to
 - Ask them if they are fit to continue
- Let the subject cool down at 2mph and 0% grade
 - During recovery continue to measure post-exercise HR, BP, RPE for about 5 minutes
 - Continue to monitor the subject

Indications to Stop the Test

- Systolic Blood Pressure drops 20 mmHg or fails to rise with increasing workloads
- Systolic Blood Pressure > 260 mmHg
- Diastolic Blood Pressure >115 mmHg
- 3+ on the Angina scale
- >2 mm ST depression or signs of ST elevation related to ischemia
- Lightheadedness, ataxia, pallor, nausea, cyanosis
- Failure of testing or EKG monitoring equipment
- SUBJECT REQUESTS TO STOP

Criteria for obtaining a VO2 Max:

- Plateau in VO2 (<150 ml/min) with an increase in work rate
- Heart rate of +/- 10% of age-predicted max and/or failure of HR to increase with increasing work rate.
- RER > or = 1.15
- RPE > or = to 20
 - The 1st Criteria is the *definitive* test
 - If #1 is not met, but at least 2 of the other 3 are, the test can be considered valid.
 - If the criteria are not met, the highest VO2 value is recorded as "VO2 peak"

Clean Up

- Turn Off all equipment
- Wash mouth pieces in 1:10 bleach to water solution for 10 minutes
- Hang mouth pieces to dry.

Equations for Estimating VO2 max without a computer program

- For Men $VO_2 \text{ max} = 14.8 - (1.379 \times T) + (0.451 \times T^2) - (0.012 \times T^3)$
- For Women $VO_2 \text{ max} = 4.38 \times T - 3.9$
- T = Total time on the treadmill measured as a fraction of a minute (i.e.: A test time of 9 minutes 30 seconds would be written as T=9.5).

APPENDIX E
PHYSICAL ACTIVITY RECALL SURVEY

Firefighter ID: _____ Date: _____

Goodwin Leisure-Time Exercise Questionnaire

*Regular Exercise is any **planned** physical activity (e.g., aerobic activities such as jogging, bicycling, swimming, rowing, or muscular conditioning exercises such as lifting weights.) performed to increase physical fitness. Such activity should be performed.*

Question: Do you exercise 5 times *per week* for 30-60 minutes *per session*?

Circle one:

- 1) Yes, I have been for MORE than 6 months.
- 2) Yes, I have been for LESS than 6 months.
- 3) No, but I intend to in the next 30 days.
- 4) No, but I intend to in the next 6 months.
- 5) No, and I do NOT intend to in the next 6 months.

*During a typical **7-day period** (weekly average), how many days on the average and for how long do you do the following kinds of exercises (write the average number days and average time spent in minutes).*

Strenuous Aerobic Exercise (Hearts Beats Rapidly)(e.g. running, jogging, soccer, basketball, swimming, long distance bicycling, roller skating)

Number of days Per Week: _____

Average time in minutes exercising per day _____

Moderate Aerobic Exercise (Heart beats steadily-Not Exhausting)

(e.g. fast walking, baseball, tennis, easy bicycling, volleyball, badminton, easy swimming, popular and folk dancing)

Number of days Per Week: _____

Average time in minutes exercising per day _____

Mild Exercise (Minimal Effort)

(e.g. easy walking, meditative yoga, archery, fishing from river bank, bowling, horseshoes, golf,)

Number of days Per Week: _____

Average time in minutes exercising per day

Muscular conditioning exercises (to the point where your heart beats rapidly)

(e.g. Weight lifting, functional training, calisthenics, power yoga)

Number of days Per Week: _____

Average time spent exercising per day _____

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BIOGRAPHICAL SKETCH

Tony was born in 1969 and raised in Ormond Beach, Florida. He graduated from Father Lopez High School in 1987, graduated with his undergraduate degree in exercise and sport sciences from the University of Florida in 1992, and earned his Master of Exercise and Sport Sciences degree in December 1995 with major in exercise and sport sciences. Prior to entering the doctoral program in health education and behavior, Tony gained twelve years of professional experience working with children, youth, and young adults in various settings including public schools, Department of Child and Family Services, and as a manger for a non-profit agency. His professional experience includes seven years of K-12 instruction in public schools (physical education, health education, and special education), over four years of counseling wayward youth and adolescents remanded into state custody, and five years of experience as a program manager for an innovative nonprofit agency serving high-risk adolescents and young adults.

Tony returned to UF in 2005 and earned his Master of Science degree in May 2008 with major in health education and behavior. On returning, he gained six years of experience teaching health-based courses to undergraduate and graduate students including Medical Terminology, Personal and Family Health, and Foundations and Principles of Health Promotion. Tony was awarded the 2011 UF Graduate Student Teacher of the Year. As a doctoral student, he became the research director for a community academic partnership examining the health effects of outreach programs on young adults with an intellectual disability. This program involved over 100 university-based volunteers in delivering comprehensive peer mentor activities to promote physical, cognitive, and social health based outcomes for students with intellectual

disabilities. Tony has three scientific manuscripts accepted in peer reviewed journals, eleven national conference poster presentations, and one oral presentation at the American Public Health Association 2011 conference.