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I, Jane Christianson , hereby submit this original work as part of the requirements for the degree of Doctor of Philosophy in Nursing - Doctoral Program.

It is entitled:

"Tai Chi as a Possible Way to Reduce Cardiovascular Risk Factors in Firefighters"

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Tai Chi as a Possible Way to Reduce Cardiovascular Risk Factors in Firefighters

A dissertation submitted to the

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at the College of Nursing

by

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Abstract

Coronary heart disease is the number one killer in the United States, with one in every four deaths related to heart disease (CDC, 2010). In firefighters, 39 out of 100 occupational deaths are attributed to heart disease (Drew-Nord et al., 2009). According to Linville (2009), firefighter's mortality may be prevented with optimal physical conditioning. Improving physical fitness results in reducing the risk of coronary heart disease and obesity, improving physical strength, and delaying the onset of chronic health problems.

Purpose: To test the effectiveness of Tai Chi to reduce cardiac risk factors in firefighters. The specific aims: (a) to determine if Tai Chi is beneficial in reducing cardiac risk factors of heart rate, blood pressure, and body fat within a group of firefighters, and (b) to determine if Tai Chi is beneficial in improving the physiological endurance factors of wall squat, balance, and fatigue.

Methods: Quasi-experimental design (two groups, repeated measures) with 60 participants from urban fire departments in a mid-size city (intervention group = 31, comparison group = 29). The intervention group received Tai Chi instruction for one hour a week for 10 weeks from a Tai Chi Master. Dependent variables were heart rate, blood pressure, body fat, lower body strength, balance, fatigue, and life stress.

Results: In the intervention group, there was a significant decrease in heart rate between initial measures and midpoint of the study (M_{diff} = 4.46 p = 0.15). From initial measurement to the third and final measurement, mean heart rate was reduced (M_{diff} = 3.267, p = 0.55); systolic and diastolic blood pressure reduction was significant (M_{diff} = 9.30, p = 0.003) and (M_{diff} = 4.67, p = 0.011), respectively; and body fat significantly decreased (M_{diff} = -.982, p = 0.012). Time of maintaining a wall squat position significantly increased (M_{diff} = 3.287, p = 0.005); the chronic fatigue score was significantly reduced (M_{diff} = - 5.69, p = 0.007); and the acute fatigue score

increased (M_{diff} = .39288, p = .0690). Inter-shift recovery and balance measures were not significant. In the comparison group, the only significant change was an increase in body fat measures (M_{diff} = -4.38, p = 0.023). Wall squat measures, chronic fatigue, and inter-shift recovery were not significant; and acute fatigue increased (M_{diff} = .39286, p = 0.858). On the Life Stress Event Score, 29 participants in the intervention group (93.5%, M_{diff} = 53.7) and 26 participants in the comparison group (89.7%, M_{diff} = 47.6) were in the low-risk category.

Conclusion: The study found that a 10-week session of Tai Chi reduced the cardiovascular risk factors of elevated heart rate, systolic and diastolic blood pressure, and body fat percentage. Through the use of group sessions with a Tai Chi Master, a video for station or home use, and a fire station champion, participants engaged in an activity that has shown improvement in risks related to coronary heart disease. Although balance did not improve significantly in this study, measurement at longer time points may show a benefit over time.

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Chapter One

Cardiac Risk in Firefighters

According to the United States Fire Association 2009 report, “Firefighting is the Nation’s most dangerous and hazardous job, with heart attacks, high stress levels, sprains and strains all too common” (p. iv.). Coronary heart disease (CHD) accounted for 39% of the occupational fatalities in firefighters (Drew-Nord, Hong, & Froelicher, 2009; Geibe et al., 2008; Lund, Taylor, & Herbold, 2001). Firefighters must maintain high levels of physical fitness in order to protect public safety. Because of the occupational dangers and cardiac implications, the health and safety of this population should be a priority to our nation (Drew-Nord et al., 2009). The prevalence of heart disease in firefighters has been well documented in the literature, however, a successful reduction in the etiology has not followed that documentation.

Coronary heart disease is the number one killer in the United States, with one in every four deaths related to heart disease (CDC, 2010). Mortality for heart disease was even higher in firefighters with thirty-nine out of 100 deaths of firefighters attributed to heart disease. According to Linville (2009), firefighter's mortality may be prevented with optimal physical conditioning. Improving physical fitness results in many health benefits, such as reducing the risk of coronary heart disease and obesity, while improving physical strength and delaying the onset of chronic health problems.

Physical fitness is the ability to carry out daily tasks with vigor and alertness, without undue fatigue, and with ample energy to enjoy leisure-time pursuits and respond to emergencies…and includes a number of components consisting of cardio-respiratory endurance (aerobic power), skeletal muscle endurance, skeletal muscle strength, skeletal muscle power, flexibility, balance, speed of movement, reaction time, and body composition. It is evident that

firefighters must maintain exceptional physical fitness in order to perform the demanding duties and tasks of their job without fatigue and injury related to fatigue.

A Possible Way of Reducing Cardiac Risk Factors in Firefighters

The purpose of this study was to test the effectiveness of using Tai Chi to increase firefighters' physical well being, while reducing cardiovascular risk factors. It was believed that by practicing Tai Chi, the firefighter population would have improved muscle strength, balance, and overall physiological endurance to carry out the demanding and essential functions of their job.

Significance of Reducing Cardiac Risk Factors

The National Institute for Occupational Safety and Health (NIOSH) recommended the development of a comprehensive wellness/fitness program to reduce the cardiovascular risk factors in firefighters; and the National Fire Protection Association (NFPA) Standard 1582 includes a recommendation that mandatory pre-placement and periodic medical evaluations be completed for all firefighters. Nevertheless, due to the associated costs, Standard 1582 has not been implemented in its entirety in any fire departments (NFPA, 2010). According to a spokesman for the Cincinnati chapter of the International Association of Firefighters (IAFF, 2010), enactment of these recommendations would save many of the firemen's lives; however, these recommendations would cause monetary hardships for the fire departments and many firefighters are fearful they would lose their jobs if they could not pass the medical requirements.

A review of literature from 2006 to 2009 provided strong evidence that firefighters' demanding workload, heavy gear, and emergent nature of rescue situations placed the firefighters at an increased risk for cardiac events (Drew-Nord et al., 2009). Additionally, firefighters' experience situations that increase the risk of cardiac events when they must transition from

sleep or inactivity to an immediate state that is physically demanding and stress provoking. As in the general population, there was also evidence of the poor health conditions in this population of workers. Cardiac risk factors such as obesity, physical inactivity, improper diet, smoking, hypertension, diabetes, and hyperlipidemia were all evident in the firefighters (Drew-Nord et al., 2009). Also reported in the previously mentioned study are hypertension and hypercholesteremia, which often go undetected and untreated (Drew-Nord et al., 2009). Standards that promote health through routine physicals, such as NFPA 1582, are not enforceable by law (2010). Firefighters, like many other occupational groups, do not have routine physicals. A longitudinal study of 806 Cincinnati firefighters between 1984 and 1992 reported that the firefighters' cardiac diseases were associated with modifiable risk factors (Glueck et al., 1996). Of the 113 fatal cardiac events that occurred during the study, smoking and hypertension were significant predictors of the on-duty fatalities (Glueck et al., 1996).

A systematic review of Tai Chi, a mind and body exercise, as an adjunctive therapy in cardiac rehabilitation was conducted by Yeh, Wang, Wayne, and Phillips (2009), who concluded that most of the 29 studies reported a decrease in blood pressure and an increase in physical endurance. Because firefighting job activities fluctuate between a physically demanding job and one of immeasurable sedentary time, an intervention such as Tai Chi was beneficial in reducing the modifiable cardiac risk factors of inactivity and hypertension in this population.

A Review of Tai Chi and Cardiac Risk Factors

The ancient Chinese art of Tai Chi is attributed to Taoism, Confucianism, and Buddhism. Tai Chi is a low-impact martial art that has been used to promote health in various populations such as children and adults of all ages. Tai Chi combines physical activities, meditation, and body awareness and is an easily accessible and an economic form of exercise

(Yeh et al., 2009). The Tai Chi movements are modeled from animal and bird movements and are used to improve health, breathing, strength, and endurance without adverse physical effects (Horowitz, 2009).

In one study by Ko, Tsang, and Chan (2006), 22 healthy Chinese women participated in a 10-week program of Tai Chi. The aim of the study was to determine if Tai Chi could be a useful physical activity in healthy populations. The Chinese women practiced Tai Chi for one hour twice a week. Of the 20 Chinese women who completed the program, there was a significant reduction in the women's systolic blood pressure, lipid profiles, and cholesterol levels. The average systolic blood pressure was significantly reduced from 114 mmHg (± 9 mmHg) to 108 mmHg (± 9 mmHg). The average lipid profile was reduced from 4.7 ng/ml (± 8 ng/ml) to 4.4 ng/ml (± 0.5 ng/ml). The average low-density lipoprotein cholesterol level reduced from 2.7 mmol/L (± 0.05) to 2.2 mmol/L (plus or minus 0.05). Ko and Chang (2006) concluded that Tai Chi has the potential to be a useful way to increase health outcomes.

Of the 70 participants initially enrolled in a study by Lan, Chen, and Lai (2008), 53 participants in Taiwan completed a study of Tai Chi to determine if this form of exercise would reduce cardiac risk factors. The intervention group (n = 28) results were significantly improved over the control group (n = 25) results in exercise capacity, lowered systolic blood pressure (SBP), and cholesterol, triglyceride, insulin, and C-reactive protein (CRP) levels in individuals with a high risk for heart disease (Lan et al., 2008). At 12 months, the Tai Chi group (n = 28) had an increase in VO2 peak from 25.2 mL.kg-1.min-1 (± 4.2) to 27.4 mL.kg-1.min-1 (± 4.1) whereas the comparison group had a decrease in VO2 from 25.6 mL.kg-1.min-1 to 24.1 mL.kg-1.min-1. The Tai Chi group results showed a 26.3% decrease in triglyceride levels, a 7.3% decrease in total cholesterol levels, an 11.9% reduction in low-density lipoprotein (LDL-C), an

11% reduction in insulin, and a 29% reduction in CRP levels compared to the comparison group results. At baseline, the Tai Chi group's average SBP was 121.1 mmHg. At the completion of the study, the average systolic blood pressure was 116.4 mmHg, a reduction of 4.7 mmHg. At baseline, the Tai Chi group's average triglyceride levels were 224.5 mg/dl. At the completion of the study, the average triglyceride levels were 165.9 mg/dl, a reduction of 58.6 mg/dl. At baseline, the Tai Chi group's total cholesterol average was 228.0 mg/dl. At the completion of the study, the average total cholesterol was 211.4 mg/dl, a reduction of 16.6 mg/dl. At baseline, the Tai Chi group's average LDL-C was reported as 134.3 mg/dl. At the completion of the study, the average LDL-C was reduced by 16 mg/dl. At baseline, the Tai Chi group's average fasting glucose level was 96.4 mg/dl. At the completion of the study, the average glucose level was 93.0 mg/dl, a reduction of 3.4 mg/dl. At baseline, the Tai Chi group's average CRP was 2.22 mg/L. At the completion of the study, the average CRP was 1.58 mg/L, a reduction of 0.64 mg/L. Lan et al. (2008) concluded that in patients with dyslipidemia, a 12-week program of Tai Chi would significantly improve the patient's aerobic capacity and reduce CHD risk factors.

Tsai et al. (2003) conducted a 12-week Tai Chi study in Taipei, Taiwan with 88 participants diagnosed with borderline hypertension. At the onset of the study, participants were not receiving medications to control their blood pressure and were recruited from either the Taipei Medical University or one of the university's two teaching hospitals. There was a 9% drop out rate, which resulted in 37 subjects in the Tai Chi group and 39 subjects in the comparison group. The Tai Chi group participated in structured Tai Chi exercise training three times a week while the comparison group was not engaged in a regular exercise program. After 12 weeks, the Tai Chi group's results showed significant decreases in their SBP and diastolic blood pressure (DBP), an increase in the high-density lipoprotein cholesterol (HDL), and

decreased anxiety. The Tai Chi group's initial SBP average of 142.4 mmHg was lowered by the completion of the study to 126.8 mmHg, a reduction of 15.6 mmHg. At the onset of the study, the Tai Chi group's average DBP was 87.4 mmHg. At the completion of the study, the average DBP was 78.6 mmHg, a reduction of 8.8 mmHg. According to Tsai et al. (2003), Tai Chi could be used as an alternate treatment modality for those patients with mild hypertension.

Patients who had experienced CHD (n = 30) participated in a study by Li, Li, and Shnider (2010) and were equally divided into either the Tai Chi group or the comparison group. All of the 30 participants completed the randomized 12-week study, which consisted of a pre-test, intervention phase, and post-test design. The pre-test and post-test measures included leg strength, leg flexibility, stationary balance, agility, and aerobic endurance. The Tai Chi participants attended two 1-hour sessions of Tai Chi per week. The comparison group was required to attend weekly discussion seminars related to their cardiac and health conditions. Both groups were encouraged to continue their prescribed cardiac rehabilitation activities and routine care. The analysis of the groups' results concluded that the Tai Chi group had significantly better performance on the physical function tests than the comparison group. The Tai Chi group's results of the leg strength performance test were on average 3.38 times higher than the comparison group. The Tai Chi group demonstrated that the balance test was on average 2.68 seconds longer, the 2-minute step test was 34.8 steps longer, and the flexibility test score was on average 1.79 inches longer than the comparison group. The researchers concluded that Tai Chi training enhances physical function in those patients who have CHD and that this form of exercise enhances cardiac rehabilitation (Li, Li, & Shnider, 2010).

These studies provide evidence that Tai Chi has the potential to improve cardiac risk factors in individuals who are healthy and at high risk for cardiac disorders. Tai Chi had not been

implemented as an alternate form of exercise in the firefighter population; however, this form of mind-body exercise may have the potential to prevent or reduce cardiac risks factors in firefighters as well.

Theoretical Framework

The culture of a fire station was representative of a team-based structure; therefore, to bring about changes in health, a health intervention, such as Tai Chi that can be practiced as a group, would be an appropriate choice of a health promotion activity to implement in the firefighter population in order to reduce cardiac risk factors and improve physiological endurance. The theoretical framework for this study was Bandura's Social Learning Theory (SLT) (1977), which reflects learning within a cohesive group. Bandura identified four conditions necessary for adaptation of health promotion principles: *attention*, *retention*, *motor reproduction*, and *motivation*. These four conditions will be applied to a fitness program designed for the firefighter population

For effective adaptation of Tai Chi mastery, the participants paid attention to instructions and directions from the Tai Chi master because individuals learn through observing and modeling the behaviors of other people who are admired and respected within their environment. Retention of Tai Chi movements was facilitated through practice of the basic movements as they watched the supplemental 30-minute video and practiced Tai Chi within a group. A firefighter from each station served as a group leader to encourage Tai Chi practice. The firefighters were also encouraged to practice Tai Chi a minimum of two hours a week while away from the fire station. Motor reproduction occurred when the firefighters were comfortable performing the basic Tai Chi movements. Motivation was facilitated through group sessions. As a group, it was expected that there would be competition, encouragement, and a focus to improve performance

of the movements. The Tai Chi Master modeled the sessions to ensure the firemen were able to replicate the movements. Bandura's four conditions were considered adapted when the firefighters mastered the Tai Chi movements and incorporated the movements into their fitness routine. The Tai Chi classes were given one hour a week over a 10-week period.

Since 2007, the NIH funded project "Promoting Healthy Lifestyles Alternate Models' Effect" (PHLAME) has analyzed long term effects of the firefighters' health promotion interventions that use SLT structure (MacKinnon et al., 2010). The project's analysis found that the majority of worksite programs have had a positive lasting effect on improving and changing health promotion (MacKinnon et al., 2010). Through the use of the SLT structure, it was anticipated that Tai Chi would have a lasting effect on improving and reducing cardiac risk factors and physiological fatigue of the Cincinnati firefighters participating in this study.

Statement of the Problem

The goal of the study was to evaluate Tai Chi as an adjunctive intervention for reducing cardiovascular risk factors. The specific aims were:

1. To determine if Tai Chi is beneficial in reducing cardiac risk factors of heart rate, diastolic and systolic blood pressure, and body fat within the firefighter population of Cincinnati.
2. To determine if Tai Chi is beneficial in improving the physiological endurance factors of wall squat, balance, and fatigue.

Hypotheses

The following hypotheses were tested:

1. Individuals who receive Tai Chi will reduce cardiac risk factors of heart rate, diastolic and systolic pressure, and body fat.

2. Individuals who receive Tai Chi will improve their overall physiological endurance of wall squat, balance, and fatigue.

Operational Definitions

The following conceptual and operational definitions were used for the study:

Adipose tissue – connective tissue consisting chiefly of fat cells surrounded by reticular fibers and arranged in lobular groups or along the course of one of the smaller blood vessels. The operational definition is percent body fat.

Blood pressure – a measurement of the force applied to the walls of the arteries as the heart pumps blood through the body. The pressure is determined by the force and amount of blood pumped and the size and flexibility of the arteries. The operational definition consists of two measurements associated with blood pressure: systolic and diastolic. The average adult blood pressure is around 120/80 mmHg, as measured by a sphygmomanometer with a blood pressure cuff around the upper arm while sitting. The classification of blood pressures:
normal = less than 120/80 mmHg, pre-hypertensive = 120-130/80-89 mmHg, Stage 1 hypertension = 140-159/90-99 mmHg, and Stage 2 hypertension = >160/$\geq$100 mmHg.

Hypertension – a sustained increase of blood pressure. The operational definition is a sustained diastolic pressure >90 mmHg and a sustained systolic pressure >140 mmHg.

Fatigue – extreme tiredness or weariness resulting from physical or mental activity. The operational definition is the inability to function normally because of excessive stimulation or prolonged exertion.

Lower body strength – muscle strength in the lower body, thigh, and calf muscles are especially important for performance of the activities of daily living for those who sit a great deal of the

time. The operational definition is the ability of the lower body muscles to function normally with excessive stimulation or prolonged exertion.

Physical fitness – the ability to carry out daily tasks with vigor and alertness without undue fatigue, with ample energy to enjoy leisure-time pursuits, and the ability to respond to emergencies climbing up and down ladders while wearing safety apparatus. The operational definition is the having the ability and stamina to perform specific aspects of the job.

Physiological endurance – the functioning of a living system related to the ability to sustain a rate of energy output for extended periods of time. The operational definition is functioning at a level that allows one to endure both the mental and physical requirements of the job.

Postural balance - the optimally distributed body mass relative to the force of gravity.

Assumptions

The following assumptions were made:

1. Because participation is voluntary, those firemen who joined the Tai Chi class will be motivated to increase their physical activity level.
2. No other physical activities will be implemented at the fire stations during the course of the study.

Limitations

The limitations of the study were:

1. The firefighters were homogenous and the generalizability of the findings may not be possible beyond the study population.
2. Compliance with the Tai Chi regiment was not assured.

Chapter Two

Review of Literature

In Chapter Two, a background regarding the cause of on-duty death in firefighters, as well as the identification of cardiac risk factors that are found within the firefighter population, is presented. The importance of reducing fatigue, maintaining balance, and improving muscle strength in firefighters is also discussed. The origin and benefits of Tai Chi, how this method was hypothesized to reduce cardiac risk factors, improve balance, and muscle strength within the firefighter population is explored as well. Furthermore, current literature selections describing how the martial art of Tai Chi has been used as an adjunctive intervention to reduce cardiac risk factors, improve balance, and muscle strength in the general public will be examined. Finally, Chapter Two contains a description of the firefighters' culture, the need for establishing cultural acceptance, and the implementation of Tai Chi to positively impact the health of the firefighter population.

Background

Sudden cardiac death is the major cause of on-duty death in firefighters (Drew-Nord et al., 2009; Geibe et al., 2008; Lund, Taylor, & Herbold, 2001). The prevalence of heart disease in firefighters is well documented in the literature; however, a reduction in the rate has not followed that documentation. The focus of the research was the reduction of preventable cardiovascular risk factors and measures to improve the firefighters' general health status.

The National Institute for Occupational Safety and Health (NIOSH), the National Fire Protection Association (NFPA), and the United States Fire Administration (USFA) health authorities have developed specific goals and standards aimed to improve the health of firefighters, reduce heart disease, cholesterol levels, blood pressure, diabetes, and increase

regular physical activity. NIOSH guidelines for firefighters include periodic medical screenings and the adoption of risk reduction measures during firefighting operations. Furthermore, the guidelines from these institutions include the development of a comprehensive wellness and fitness program to reduce the cardiovascular risk factors in firefighters.

Cardiac Risk Factors in Firefighters

Since 1995, the leading cause of mortality among on-duty firefighters is cardiac arrest (Drew-Nord et al., 2009; Geibe et al., 2008; Fahy, 2005; Lund et al., 2001). The firefighters' cardiac risk factors are those which are present in the general population. The risk factors include but are not limited to: elevated blood cholesterol, obesity, increased body fat, hypertension, stress, smoking, and sedentary lifestyle (Davis, Jankovitz, & Rein, 2002). In a study by Davis et al. (2002), the researchers examined the results of 71 male firefighters in California compared to males in the general population and found increase hypercholesterolemia, body fat, hypertension, and reduced physical fitness across the career life span of firefighters. Firefighters must be ready at any given time to respond to emergencies. Often they are relaxing, eating, or sleeping when they must suddenly respond to varying types of tense situations and must quickly shift from a relatively calm state to a potentially dangerous situation that is extremely stressful on the cardiovascular system (USFA, 2009).

Since 1977, USFA, NFPA, and NIOSH (2008) have tracked firefighter's fatalities. These associations' statistics document that firefighters are more likely to die on duty than any other American worker. Statistics from these institutions provide evidence that the line-of-duty deaths (LODD) have been attributable to previous cardiac risk factors, stress, and overexertion from being physically unfit (NFPA, 2010; USFA, 2010; NIOSH, 2010). Each of these LODDs is associated with heart disease. Furthermore, the USFA and NFPA (2008) have established

specific goals to improve the health of firefighters that include reducing heart disease, cholesterol levels, blood pressure, diabetes, and increase regular physical activity The NFPA developed a standard on health-related fitness programs for firefighters (NFPA 1583, 2010). This standard stipulates that “fire departments establish and provide a health-related fitness program that enables members to develop and maintain a level of health and fitness to safely perform their assigned functions” (NFPA 2010, p.1). Improvement of cardiac status can be obtained by reducing cardiac risk factors (NFPA, 2010). One of the best ways to reduce cardiac risks factors is through physical activity (Linville, 2009; NFPA, 2010; USFA, 2010). Tai Chi, a martial art form used for physical fitness, has been shown to reduce cardiac risk factors in multiple research studies (Drew-Nord et al., 2009; Geibe et al., 2008; Fahy, 2005; Lund et al., 2001). Therefore, Tai Chi was a way to improve the fitness of firefighters and reduce their cardiac risk factors.

Definition of Tai Chi

According to the Medical Dictionary (2010), “Tai Chi is a Chinese exercise system that uses slow and smooth body movements to achieve a state of relaxation of both body and mind.” Tai Chi, a Chinese martial art and exercise, has an origin intended to combine nature and harmony for overall wellness and combines moderate movements with deep breathing. No expensive equipment is necessary and it can be performed in groups or individually, making this form of exercise suitable to practice in any setting (Cheng, 2007). Tai Chi movements are circular, not forced. The muscles are relaxed, not tensed. Tai Chi movements strengthen muscles, increase flexibility and balance, and help to improve heart function (Harvard, 2009). The gentle controlled movements of Tai Chi are believed to promote inner power that strengthens the mind and the body by developing upper and lower muscle groups, improving balance and health, and developing a union between the body and the mind (Lam, 2010). This union allows the body,

breath, mind, and the inner nature to become one entity (Lam, 2010). The blend of physical movement and deep breathing bring about a state of relaxation that is helpful in reducing stress and improving inner peace (Rogers, Larkey, & Keller, 2010).

Chang San Feng is recognized as the founder of Tai Chi. Feng lived during the Yuan Dynasty in China (1279-1368). According to Chinese mythology, Feng witnessed a bird attacking a snake and was inspired by the snake's defensive tactics. The snake remained still and alert during the attack and ultimately lunged and killed the attacker (Verstappen, 2010). The same principal applies to dealing with stressful situations that occur today. Those who practice Tai Chi can return to their learned state of relaxation to reduce the stress of the situation of which they are faced. Through Tai Chi training, one can remain calm and stay alert in order to handle difficult challenges. The basic training in Tai Chi consists of conditioning exercises that include stretching, meditation, breathing, and stances or steps. Tai Chi is indicative of the ancient Chinese wisdom of an ideal conditioning exercise and is considered to be the “perfect exercise” for individuals with chronic heart disease as well as healthy individuals (Cheng, 2007). A perfect exercise is one that can be incorporated into all age groups, is inexpensive, and results in multiple health benefits.

Researchers have reported that Tai Chi improves and prevents chronic conditions such as arthritis, heart disease, diabetes (Lan, Su, Chen, & Lai, 2008), improves balance and immunity, and reduces stress, blood pressure, fall risks, depression, and anxiety (Hong, Xian, & Robinson, 2000; Park et al., 2009; Rogers, Larkey, & Keller, 2010; Wang, Collet, & Lau, 2004; Yeh, Wang, Wayne, & Phillips, 2009). Use of Tai Chi to reduce cardiac risk factors in the firefighter population has not been reported; however, there are reports of potential benefits with regards to heart disease and other chronic conditions. These studies are described below.

Tai Chi and Cardiac Risk Factors

Yeh, et al. (2009) conducted a systematic review of Tai Chi literature using Chinese and English databases through 2007. Eighty five percent of the 29 studies reported that patients with cardiovascular diseases participating in Tai Chi exercise had improved physical capacity and a decrease in blood pressure. Most of the 29 studies had fewer than 100 subjects (range 5-207) and all of the study populations were 50 years old or older. The participants' medical diagnoses included CHD and heart failure, and the largest group had combined diagnosis of hypertension, dyslipidemia, and impaired glucose metabolism. The most significant improvements were in blood pressure reduction. These improvements ranged from 3 to 32 mmHg in systolic pressure and from 2 to 18 mmHg in diastolic pressure. According to Neal, Mac Mahon, and Chapman (2000), even modest reductions in blood pressure can result in a 35-40% reduction in strokes and a 20-25% reduction in CHD. The 29 studies included randomized controlled trials, prospective non-randomized controlled trials, non-controlled studies, and observational controlled and non-controlled trials. The analysis also reported that no adverse effects were reported in any of the studies and noted that the exercise intensity of Tai Chi can be easily modified to the appropriated level for the participants.

Tai Chi, along with nutrition, can also be added to a health promotion program. Park et al. (2009), conducted a quasi-experimental study with a non-equivalent comparison group. The study's population included 85 individuals with an average age of 66 years. Measurements on three groups were taken at the study onset and again at the completion of the six-month study. The three groups consisted of: Tai Chi with nutrition education (n = 33), Tai Chi only (n = 19), and comparison (n = 33). The study reported that both Tai Chi groups had clinically significant lower systolic blood pressure than the comparison group. Although the age reported in the study

population is older than that within firefighter populations, similar blood pressure reduction could potentially be realized in a younger population with established cardiac factors.

The benefits of Tai Chi in reducing additional cardiac risk factors were reported in a 12-month Tai Chi study conducted in Taiwan (Lan, Su, Chen, & Lai, 2008). Tai Chi intervention groups' showed significant improvements in lipid profile, peak oxygen uptake, blood pressure, insulin resistance, and inflammatory makers. The Tai Chi treatment group (n = 28) had an average of age of 52.8 years. The comparison group (n = 25) had an average age of 50.1 years. The 53 participants of the study were previously treated with lipid-lowering medication and diet therapy, and had reported living a sedentary lifestyle.

Another study was conducted in Taiwan with 61 subjects diagnosed with CHD who reported living a sedentary lifestyle (Chang et al., 2008). These subjects had undergone either a percutaneous intervention or coronary bypass grafting at least one month prior to participation in the Tai Chi versus normal activity study. The premise of the study was to evaluate the effectiveness of Tai Chi on heart rate variability (HRV). Low HRV is associated with a higher risk of mortality for individuals who experience a heart attack (myocardial infarction). Exercise has been shown to improve HRV. The treatment group (n = 22) received weekly Tai Chi sessions for nine months and the comparison group (n = 39) continued with the normal activities of daily living. After the completion of the nine-month study, vagal and sympathetic modulation (both of which improve cardiac function) were improved in the patients who received the Tai Chi intervention. Therefore, the assumption is made that a once-a-week program of Tai Chi combined with repeated Tai Chi video exposure can have a positive impact on the physical well-being within the firefighter population.

Tai Chi has also improved general physical functions. A cross-sectional comparison study examined adults who practice Tai Chi (n = 140) with adults of the same age and gender (n = 560) from the general population (Horowitz, 2009). Those who practiced Tai Chi had significantly higher scores in performing age-appropriate normal activities of daily living, general health, vitality, and social interaction than that of the comparison group.

Tai Chi has replaced many upper limb weight exercises in cardiac rehabilitation programs (McCleary, 2009). According to McCleary, the upper limb weight exercises are detrimental to high-risk patients and lead to sternal instability (2009). This study also found that Tai Chi is effective in reducing many of the problems cardiac patients concurrently have in that it reduces stress and the incidence of falls and improves balance and flexibility. McCleary's (2009) study findings have implications for firefighters related to the improvement of balance. Balance is crucial to firefighters due to climbing ladders in dangerous circumstances with the added weight of essential equipment.

Measurement Rationale for Blood Pressure

Blood pressure readings show the results of two elements, systolic and diastolic pressures. The diastolic and systolic pressures represent the pressure on the walls of the arteries at different points in the pumping cycle of the heart (Sechrest, 2005). The systolic pressure is measured when the heart is contracting and the diastolic pressure is measured when the heart is at rest. The sphygmomanometer is considered to be the gold standard for non-invasive measurement of blood pressure if used by a properly trained person (Pickering et al., 2005; Sechrest, 2005). The classification of blood pressures: normal = <120/80, pre-hypertensive = 120-130/80-89, Stage 1 hypertension = 140-159/90-99, Stage 2 hypertension = >160/>100.

Measurement Rationale for Percent of Body Fat

Upper body and abdominal fat distribution increase the risk of hypertension, diabetes, hyperlipidemia, and heart disease (Allison, Fontaine, Manson, Stevens, & VanItallie, 1999). Fat distribution, especially found in the abdomen, is the best predictor of metabolic complications (Mundi et al., 2009). Metabolic complications are considered to be cardiovascular disease, elevated cholesterol, elevated triglycerides, diabetes, insulin resistance, hyperlipidemia, and myocardial infarction (Mundi et al., 2009). Measuring percent of body fat will help to identify firefighters who are at higher risk of developing metabolic complications. The amount and distribution of fat is the best measure of obesity and the inherent risks of morbidity (Burkhauser & Cawley, 2008).

Balance in Firefighters

Postural stability and balance is vital to performing the job tasks of firefighting, while neuro-muscular fitness is essential for static and dynamic balance. Carrying heavy gear for prolonged periods can result in fatigued postural muscles, resulting in injury. Firefighters must wear and carry heavy personal protective equipment (PPE), including breathing apparatus, various head protection, and layers of clothing. The firefighting tools they must carry include hoses, ladders, and hatchets. Firefighters work in adverse conditions that challenge their mobility and stability, and PPE, heavy tools, and adverse work conditions can impinge their ability to maintain their postural balance. Visual cues, important in maintaining balance, are hampered due to reduced visibility at fire sites. Firefighters face numerous problems that reduce their ability to maintain good static (postural) as well as dynamic (gait) balance.

Firefighters often work on the roof or inside of burning structures. These hazardous working conditions may result in slip, trip, and fall accidents, which are increased when fatigue

is involved. Signs of reduced balance during exercise and or on-site job are indications that the firefighter's neuro-muscular system is not optimally functioning. Tai Chi may be beneficial to help the firefighters improve postural balance, gait, and maintain a healthy body weight – essential to performing their physically demanding job.

Tai Chi's Effect on Balance

A cross sectional study (Hong, Xian, & Robinson, 2000) compared a group of males (n = 28) with a mean age of 67.5 years who were long term Tai Chi practitioners (average 13.2 years) to a group of sedentary males (n = 30) with a mean age of 66.2 years to determine the long-term effect of regular Tai Chi on balance, flexibility, and cardiovascular fitness. The long-term Tai Chi practice group performed better than the sedentary group in the tests of balance, flexibility, and cardiovascular function. Hong et al. concluded that long-term regular Tai Chi exercise had a positive effect on balance control, flexibility, and cardiovascular health and has that Tai Chi has the potential to decrease the rate of physical decline due to aging.

A randomized controlled trial (Lelard, Doutrellot, David, & Ahmaidi, 2010) was conducted with older adults to determine the effects of two balance training programs: a Tai Chi program and a balance training program on postural control and walking. The Tai Chi intervention group (n = 14) had a mean age of 76 and the balance-training intervention group (n = 14) had a mean age of 77. There were no significant differences in postural control or walking ability after a 12-week period; however, Tai Chi training was helpful to maintain balance in poorly lit environments or in total darkness. These results are valuable for firefighters who often work in similar conditions.

Gyllensten, Hui-chan, and Tsang (2010) compared two healthy groups of elderly citizens in Hong Kong who were living in a senior citizen dwelling, were independent, and did not have

cognitive or physical impairments. The participants were divided into two groups. The intervention group (n = 24) had an average age of 68 years and practiced Tai Chi three times a week for at least three years. The comparison group (n = 20) had an average age of 71 and maintained normal activities of daily living without the addition of Tai Chi. At the end of the study, the Tai Chi group had significantly better stability, increased ability to perform single-leg jumps, stability upon landing, and increased body awareness.

Song, Lee, Lam and Bae (2003) used a randomized controlled trial using Tai Chi to study Korean women in who suffer with osteoarthritis. The Tai Chi group (n = 22) and comparison group (n = 21*)* were made up of women at least 55 years old and had no significant group differences in demographic or pre-test measures. The intervention group received two weeks of supervised or videotaped Tai Chi instruction three times a week. For the next 10 weeks, the Tai Chi participants received one hour of supervised instruction and practiced on their own for 20 minutes at home three times a week. Pain was measured using the Korean version of the Western Ontario-McMaster Universities OA index. Study findings indicated less pain in the Tai Chi group and significant improvements in balance and muscle strength, flexibility, cardiovascular functioning, BMI, knee muscle strength, and endurance.

A pilot study conducted by Hackney and Earhart (2008) examined the benefits of Tai Chi on balance and mobility in a population that experienced Parkinson disease. The Tai Chi (n = 17) and the comparison group (n = 16) participants were at least 30 years old and could stand for 30 minutes and walk 3 meters with or without the use of assistive devices. The Tai Chi group attended sessions lasting one hour twice a week. The comparison group received no intervention. Those who receive Tai Chi had significant improvements in balance, a six-minute walk, and the ability to get up and move independently.

Measurement Rationale for Balance

Obesity and the varied occupational tasks significantly impact firefighters' postural balance (Davis et al., 2009). Firefighters wear 40 pounds or more of protective equipment including breathing apparatus, head protection and protective clothing, and must carry firefighting tools, and work in adverse conditions that challenge their mobility and stability.

Lower Body Strength in Firefighters

Firefighters must perform physically demanding tasks in unpredictable working conditions associated with their job. Carrying apparatus and victims, pulling hoses, and climbing stairs and ladders are physical demanding activities. Often these tasks result in occupational injuries due to fatigued muscles and overexertion (USFA, 2009). Overexertion, according to Webster, "occurs when the physical efforts of a worker who lifts, pulls, pushes, holds, carries, wields, or throws an object results in an injury" (2006). Muscular strains and sprains account for 18% of the firefighters' injuries (USFA, 2009). From 1992 to 1999, the cost due to overexertion injuries in firefighters was an average $545,000.00 per year (Watson, Conrad, Furner, & Samo, 2003). Regular physical fitness activities strengthen the upper and lower muscles, decrease the risk of muscular strains, and improve cardiovascular health (USFA, 2009). Physical fitness can also decrease the loss of stamina, strength, flexibility, bone density, and metabolic rate – all of which affect the firefighters' ability to fight fires (USFA, 2009). Firefighters are not required to follow an exercise training program even though there is a NPFA Standard 1583 (2010) for health-related fitness programs. The scope of Standard 1583 is to establish minimum requirements associated with the development, implementation, and management of health-related fitness firefighter programs (NPFA, 2010). Tai Chi may be beneficial in improving

muscle strength and improving muscle mass in order to perform the physically strenuous tasks associated with the job.

Tai Chi's Effect on Lower Body Strength

Wang, Collet, and Lau's (2004) analysis of 40 studies found Tai Chi promoted muscular strength, balance, strength, cardiovascular and respiratory function, and flexibility, as well as psychosocial benefits. Song, Lee, Lam, and Bae (2003) also reported improvements in balance and muscle strength, flexibility, cardiovascular functioning, BMI, knee muscle strength, and endurance. Lan, Lai, Chen, and Wong (1998) evaluated the effectiveness of Tai Chi on health fitness in older individuals. The Tai Chi group had a 16% increase in flexibility, an 18% increase in muscle strength of the knee extensor, and a 15% increase in muscle strength of the knee flexor. According to a pilot study by Wu (2008), Tai Chi practitioners had significant improvement in knee and hip flexion and lower leg strength. The potential benefits of Tai Chi training to improve balance, muscle strength, flexibility, cardiovascular functioning, and endurance could potentially reduce the risk of on the job muscle strains and sprains in the firefighter population.

Measurement Rationale for Lower Body Strength

Upper body strength is important in performing activities that require the firefighters to lift and carry objects. Firefighters are subjected to muscular stress performing the duties of their job. Carrying heavy gear for a prolonged period of time fatigues the upper body muscles. In addition, firefighters rely on lower body strength while carrying apparatus and victims, pulling hoses, and climbing stairs and ladders. The tasks associated with firefighting are physically demanding, therefore, upper and lower body strength is of optimal importance.

Tai Chi's Effect on Fatigue/Well-Being

Jin (1992) recruited two groups of individuals who practiced Tai Chi: beginners (n = 33) and experienced practitioners (n = 33). The participants completed the Profile of Mood States (POMS) and the Trait Anxiety Inventory along with the measurement of heart rate, noradrenalin excretion, and cortisol concentrations. The groups were divided into three groups according to experience, time of day, and when the measurements were taken (before, during, or after Tai Chi). The results indicated heart rate elevations were greater in the beginner group, cortisol levels were lower after Tai Chi, mood improved significantly during Tai Chi and remained positive one hour after Tai Chi, and the participants reported less tension, anger, fatigue, depression, confusion, more vigorous, and less anxiety after Tai Chi. Jin also stated that Tai Chi may serve as a distraction from individuals' problems and anxiety.

College students were recruited to examine the effects of Pilates and Tai Chi on self-efficacy, sleep quality, mood, and physical performance (Caldwell, Harrison, Adams, & Triplett, 2009). The students were already enrolled in 15 weeks of physical education classes: Pilates (n = 51), Tai Chi (n = 35), and special recreation (n = 28). The students completed the Harrison and McGuire self-regulatory efficacy instrument, either the Pilates self-efficacy or the Taiji Quan Self-Regulatory Efficacy Scale, the Pittsburgh Sleep Quality Index, and the Four Dimensional Mood Scale. Strength and balance were also measured within each group. Results from the study demonstrated no difference in strength and balance among the groups. However, the researchers did report improved self-efficacy, self-regulator, positive mood, and sleep quality in the Pilates and Tai Chi groups.

A pilot study conducted by Toda, Den, Hasegawa-Ohira, and Morimoto (2011) examined the influence of Tai Chi on 22 healthy females (mean age 68.9 years) over a 20-minute time

frame. The women were recruited in Osaka, Japan. They completed a 30-item Profile of Mood States questionnaire, the Tokai University Type A Pattern Scale, and the Health Practice Index. Results showed that even a brief period Tai Chi was mentally beneficial to the type A behavior pattern group, especially because this group is often associated with higher cardiovascular factors.

Measurement Rationale for Fatigue

Firefighters are on duty for 24 hours and must be prepared to handle any emergency that happens on their shift. Firefighters experience fatigue due to shift scheduling, lack of uninterrupted sleep and psycho-physiological events they encounter in the line of duty (Takeyama et al., 2005).

Firefighter Culture

According to Thurnell-Read and Parker (2008), the occupation of firefighting has been primarily dominated by males and characterized by values such as bravery, danger, and courage. In order to be accepted into the firefighter culture, one must understand the dynamics of culture in the organization (Meyer, 2005). Getting to know co-workers and others associated with the organization is the first step. Meyer (2005) further describes this process as information seeking. One must gain knowledge about the organizational structure, how the firefighters perform their duties, and the norms of the environment. According to Arnault (2009), culture impacts the various aspects of health and illness and the behavioral options of health promotion.

Summary

The cardiovascular, postural balance, and muscular strengthening benefits of Tai Chi are well documented in the published literature. The evidence of cardiovascular morbidity and mortality in firefighters without concomitant interventions to address this risk points to the

necessity to design programs to reduce cardiac risk factors and increase physical fitness. NFPA Standard 1583 was developed as a guideline to increase physical activity within a local context. Additionally, NIOSH health authorities recommend that fire departments and firefighters follow established medical screening guidelines. According to Linville (2009), fitness programs should address various types of physical activity that promotes mental and physical well being and can be incorporated into the firefighters work schedule. Tai Chi may address these issues by improving mental and physical well being and reducing the firefighters' cardiac risk factors. Tai Chi can be incorporated into a group routine without additional equipment or trainers once the skill is achieved.

The reviewed Tai Chi literature appears to recommend further research studies to determine if Tai Chi is beneficial for cardiovascular and postural balance issues in population groups other than older adults. Because there is no evidence that Tai Chi has been studied in firefighters as a way to reduce cardiac risk factors or to improve postural balance and muscle strength, the proposed research study was warranted. The challenge for this researcher was to generate a competitive atmosphere around this form of martial arts that matches the firefighter culture.

Chapter Three
Methods

Because of the nature of the job, firefighting is one of the more dangerous careers. Firefighters work in situations that can cause bodily harm or death. They are asked to work between periods of time that are highly stressful and physically demanding and periods of time that are sedentary and inactive. This work pace places additional stress on their cardiovascular system and can cause them harm. In fact, the combination of stressful/demanding and sedentary/inactive situations may increase the prevalence of death due to cardiovascular disease, which is higher in firefighters than the prevalence of death due to cardiovascular disease in the general public. In the general American population, one in four deaths is attributable to cardiovascular disease (CDC, 2010), while for firefighters, approximately two in five deaths are attributable to cardiovascular disease. Perhaps not coincidentally, life expectancy for firefighters is five to nine years below the national average (CDC, 2010; Drew-Nord et al., 2009; Hilyer, Brown, Sirles, & Peoples, 1990).

Firefighters are subjected to adverse work conditions that can result in decreased postural stability, increased physical and mental fatigue, and an increased potential for injury. The work of firefighting may impinge the firefighters' ability to maintain postural and dynamic balance. They often work on wet surfaces while wearing 40 pounds of PPEs, which often results in injury. Muscle strength and physical conditioning is critical to decrease the muscular skeletal sprains and sprain injuries in firefighters (USFA, 2009). The Health and Wellness Guide published by the USFA (2009) reported 18% of all injuries were muscle injuries that were attributed to overexertion and strain. Steenland's (2000) analysis of the firefighter working conditions concluded that working 24-hour shifts are stressful, fatiguing, and are associated with an increase in the risk of heart disease.

These statistics are alarming and have resulted in the establishment of specific goals to reduce the firefighters' cardiovascular and injury risk factors (NFPA, 2010, NIOSH, 2010; USFA, 2010). Reducing cardiac risk factors, such as elevated blood pressure, heart rate, and body fat, along with improving the firefighters' physiological endurance were the goals of this research study. Tai Chi is a health-related fitness program that may facilitate compliance with NFPA Standards 1582 and 1583 and NIOSH and USFA recommendations to reduce cardiac risk factors. Tai Chi may be beneficial to firefighters as a way to maintain an optimal level of cardiac health, as well as to safely perform their assigned job functions with improved balance along with increased upper and lower body strength. Two specific aims are proposed to determine if Tai Chi has accomplished the study's objectives of reducing health and safety risk factors for firefighters. The specific aims were:

1. To determine if Tai Chi is beneficial in reducing cardiac risk factors of heart rate, diastolic and systolic blood pressure, and body fat within the firefighter population of Cincinnati.
2. To determine if Tai Chi is beneficial in improving physiological endurance of wall squat, balance, and fatigue.

In this third chapter, the research culture, design, participants, setting, procedures, instrumentation, and data analysis will be described.

Firefighter Culture

Acceptance by upper management that the research has the potential to improve the health of the firefighters was a vital part to gain access to population. The PI met with 28 district fire chiefs in order to convey the importance of the Tai Chi study. Additionally, meetings at several fire stations facilitated the PI's understanding of the norms, values, and work schedule of the population. Further support was accomplished when the firefighters viewed and discussed

with the PI the various flyers, poster, and handouts distributed to the fire stations prior to participation consent. The importance of confidentiality was emphasized and the significance of the research to improve health and safety was conveyed within each of the participating firehouses.

The typical work schedule for full time firefighters was to work the entire twenty-four hours in the day, every three days. They are given an additional day off at scheduled intervals, as well as holiday, personal time, and vacation time. This work scheduling complicates study recruitment, thus it took several weeks to obtain the required number of participants for the Tai Chi treatment group.

Design

The original research plan included a one group, repeated measure design aimed to identify the effects of Tai Chi on cardiac risk factors (blood pressure, heart rate, and percent body fat), balance, strength, and fatigue of firefighters in Cincinnati, Ohio. Firefighters participated in Tai Chi sessions lasting one hour, conducted with a Tai Chi Master, once a week over a 10-week period. The intervention was supplemented by access to a Tai Chi video for voluntary additional sessions. According to Stevenson (2002), repeated measures designs are powerful because the variability in individual differences is removed; therefore, there is reduced error term. The participants were measured at the onset of the study, again at week five, and once more at week 10. Comparing the measurements taken at the onset, midpoint, and the end of the intervention helped to determine if the Tai Chi intervention had brought about reduction of the cardiac risk factors, improvement in lower body strength and balance and a reduction in overall fatigue. The intervention was Tai Chi. The independent variable was time and the dependent

variables are percent of body fat, resting heart rate, blood pressure, lower body strength, balance, and fatigue.

Procedure

Participants received a one-hour Tai Chi session once a week for 10 weeks by a Master Instructor who has been teaching Tai Chi for over 20 years. Additionally, the Tai Chi Master Instructor has a background in Occupational Therapy and a degree in Holistic Studies/Wellness Management and is a regular presenter at local and state conferences. The Master Instructor has studied Qi Gong and Tai Chi since 1990, and has taught since 1997. He has studied with Jiwu Wang, Tianyou Hao, Dr. I'chih, and Dr. Paul Lam (in the USA and Australia).

If the firefighters were out of the station transporting individuals with medical emergencies or extinguishing fires, they may not have received the full benefit from the Master's instructions, thus the fire stations were given a video of Tai Chi movements to use if they were called away. This video was also used for additional sessions throughout the week. The individuals also received a workbook depicting basic Tai Chi movements to facilitate practicing at home or during free time at work.

As highlighted in Chapter One, Bandura's (1977) Social Learning Theory (SLT) identified four conditions necessary for adaptation of health promotion principles: *attention, retention, motor reproduction,* and *motivation*. The Tai Chi master required the firefighters' attention to ensure the firefighters learned the Tai Chi movements and stances in order to master Tai Chi and receive the full benefit of the intervention. Retention of the Tai Chi movements was achieved as the firefighters practiced together at the fire station facilitated by the fire station champion and the station's 30-minute Tai Chi video. Retention was also achieved if the firefighters practiced Tai Chi movements and stances at home two additional times per week.

They were provided with a Tai Chi workbook to keep at home that depicted the basic movements and stances. Retention was also facilitated through the tracking of practice sessions on a self-reporting sign-in sheet. By completing the sign-in sheets, the firefighters could visualize the number of times per week they practiced. With this accountability, they were aware of how many times they practiced. Motor reproduction was achieved when the firefighters mastered the movements and stances associated with Tai Chi. Through the anticipated practice routine of meeting with the Tai Chi master, practicing as a group at the fire station, encouragement from the firehouse champion, and practicing two additional times while away from the station, motor reproduction could be achieved. The firehouse champion encouraged practicing together and was vested in everyone's mastery of the movements and stances. The firefighters had increased motivation to improve their health with Tai Chi as they participated as a group and were encouraged by the firehouse champion and the Tai Chi Master.

Participants

Six fire stations within a 40-mile radius of Greater Cincinnati were invited to join the Tai Chi intervention group. Stations were recruited until 60 subjects consented to join the study. The recruitment of 60 participants allowed for a 20% attrition of participants.

Firehouse employees with the job title "firefighter" in the Greater Cincinnati, Ohio area comprised the population for the study. This population included firefighters, EMT, and firefighter administrative personnel. The population included males and females and people of different cultures and ethnicities. If a female firefighter was pregnant, she was excluded from the study due to the normal changes of pregnancy. However, the pregnant females were able to take part in the exercise training after approval from their physician, but measurements were not

taken for research purposes. Protection of human rights was approved through the Institutional Review Board (IRB) at the University of Cincinnati.

The power equations given in Diggle, Hegerty, Liang, and Zeger (2002) were used to estimate sample size for the proposed study, with typical assumptions such as alpha = .05 and power = .80. Effect size and the average autocorrelation for the dependent measures were allowed to vary. The effect size was allowed to vary from 0.25 to 0.50, and the average autocorrelation was allowed to vary from 0.2 to 0.8. A sample size of approximately 50 to 60 individuals per group was found to be sufficient for the present study, allowing an effect size of 0.25 to be detected at levels of an average autocorrelation of 0.5 or less, and as high as 0.8 for larger effect sizes.

Recruitment

The recruitment of the participants began in March 2011 and ended in April 2011. The recruitment of participants ended when 60 participants were consented. The PI met with the Hamilton County fire chiefs to receive their support and secure the addresses and phone numbers for each of the fire stations. The PI and assistant called on the larger stations to recruit the firefighters into the study. The first assistant to the PI is a Bachelor prepared nurse in the Occupational Health and Safety Master's Degree program in the College of Nursing at the University of Cincinnati. The second assistant is a doctoral student in the Occupational Health and Safety Engineering program in the Department of Environmental Health at the University of Cincinnati. The two assistants were CITI program certified and were thoroughly trained by the PI regarding measurement issues before the study began. The PI and assistants first distributed flyers and posters to the largest fire stations within Greater Cincinnati. The PI recruited participants as the flyers and posters were distributed. The firefighters signed the consent form

and a sign-in sheet at the time of recruitment. The PI and assistants also took the baseline measurements after the firefighters signed the consent form. See Appendix A for a copy of the consent form and sign-in sheet. Because there were three fire companies within the larger stations, the recruitment phase was repeated three times to each of the fire stations within the 24 hours the firefighters worked during their shift. This process was repeated three days later to ensure all firefighters had been approached. This process required 80 hours to recruit 60 firefighters.

Retention and Attrition

The recruitment of 60 participants allowed for a 20% attrition rate. The district fire chiefs suggested that allowing the firefighters to volunteer to participate in the study was vital to retention and attrition. Retention was also facilitated through a volunteer firefighter who acted as a champion for the group. A firefighter who has demonstrated strong leadership and a vested interest in the health promotion and safety of fellow firefighters was selected as the champion (either self-identified or fellow worker selection). The champion encouraged the practice of Tai Chi as a group with the Tai Chi Master and with the supplied supplemental Tai Chi video for two additional times during the week, either at the station or during time away from the station. Champion leaders have been shown to accelerate behavioral change, act as gatekeepers for health promotion activities, and increase levels of engagement in health promotion (Carter et al., 2009; Valente & Pumpuang, 2007). The firefighters were given a Tai Chi workbook for practicing the Tai Chi movements at home. There was also a sign-in activity sheet (Appendix B) for the purpose of self-reporting of individual Tai Chi practice. The sign-in activity sheet was kept in a secure place within each fire stations agreed upon by the participants in the study.

Demographic Data

An investigator-developed questionnaire (Appendix C) was used to collect demographic data from each participant in the study. The demographic data included the participant's age, race, gender, smoking status, alcoholic consumption, marital status, current exercise practice, and number of years as a firefighter. Descriptive statistics were used to identify the participants' demographic characteristics.

Instruments

Several instruments were used to measure various components of the study and to address the specific aims. The first aim of the study was to determine if Tai Chi is beneficial in reducing cardiac risk factors in Cincinnati firefighters, to be determined by improvements in blood pressure measures, resting heart rate, and reduced percent of body fat. The second aim of the study was to determine if Tai Chi is beneficial in improving physiological endurance as demonstrated by improvements wall squat, balance, and fatigue. Study assistants helped the principle investigator (PI) collect these measures. The assistants were trained and then supervised through the watchful eye of the PI to ensure the accuracy of measurements. It took approximately one hour to collect these measures per participant at each of the measurement periods using the data collection form (Appendix D). The PI recognized the participant burden for data collection; therefore the initial measures were collected over a two-week period. The first set of measurements included the blood pressure, wall squat, body fat, balance, and fatigue scale. The second set of measures was collected over a three-week period at the midpoint of the study. The second set of measures included the measures of blood pressure, heart rate, and body fat. The third set of measures was collected over a three-week period after the completion of the

study, which included the heart rate, blood pressure, wall squat, body fat, balance, fatigue, and the Holmes-Rahe Life Stress Inventory.

Blood Pressure

The sphygmomanometer is considered the gold standard for measuring blood pressure if used by a properly trained person (Pickering, et al., 2005; Sechrest, 2005). The PI has been certified by the University of Cincinnati to perform these measures. Blood pressure was measured while the person was seated using the same sphygmomanometer and appropriately sized blood pressure cuff depending on the participant's upper arm girth. The sphygmomanometer was secured from the College of Nursing at the University of Cincinnati. The PI used a manual sphygmomanometer that did not require calibration.

Percent of Body Fat

The FUTREX-6100/XL Body Composition Analyzer was used to determine the participants' percent of body fat and muscle mass. This analyzer is a near infrared interactance (NIR) device that determines the body's essential, reserve, and excess body fat (Futrex, 2010). Essential body fat provides thermal and bruise protection, reserve body fat is stored for fuel, and excess body fat is not necessary. The FUTREX-6100/XL directly measures the percent of body fat by transmitting a light beam into the biceps of the dominant arm. Body fat absorbs the light, lean muscle mass reflects the light, and this light absorption is measured by the analyzer (Futrex, 2010). The body composition information obtained includes the individual's percent of body fat, total body fat, total lean mass, basal metabolic rate, total body water, and body mass index. Davis and Paynter (2010) determined that the FUTREX-6100 XL had excellent reliability and good validity when used to assess body composition. The determination of Davis and Paynter (2010) was based on a 0.94 intra-class correlation, a reliability coefficient of 0.98, and the

validation to hydrostatic weighing yield of $r = 0.83$. Additionally, Dotson (1996) determined that the FUTREX-6100 XL is a valid predictor of body fat and comparable to within 99% to hydrostatic weighing based upon the validation correlation of $r = 0.87$ and the resulting correlation of r = 0.828. The NIR method used for body fat assessment has 95.3% reliability, good repeatability, and has low intra- and inter-observer variability when administered with well-trained testers (Fornetti, Pivarnik, Foley, & Fiechtner, 1999; Schreiner, Pitkaniemi, Pekkanen, & Salomaa, 1995).

OFER Scale

The Occupational Fatigue Exhaustion/Recovery (OFER) scale developed by Winwood, Winefield, Dawson, and Lushington (2005) was used to measure firefighter's fatigue. The OFER Fatigue scale (Appendix E) has been used to measure the fatigue of female nurses in Japan and the United States, Australia in quarry workers, and in 314 men and women who work in various other occupations (Winwood et al., 2005; Winwood & Lushington, 2006). This scale identifies the three dimensions of fatigue related to firefighters' work – acute fatigue, chronic fatigue, and inter-shift recovery. Each of the three dimensions has five items that are scored on a 7-point Likert scale (0 = strongly disagree to 6 = strongly agree). The higher the score indicates more of the subscale construct. Winwood, Baker, and Winefield (2007) implemented the OFER scale in a sample of 314 workers of diverse occupations. The study concluded that inter-shift recovery played a significant effect on the effects of work strain. Cronbach's alpha coefficients for acute, chronic, and inter-shift recovery were reported at 0.84, 0.86, and 0.84, respectively.

Holmes-Rahe Life Stress Inventory

The Holmes-Rahe Life Stress Inventory (HRLSI) was developed in 1967 by psychiatrists Dr. Thomas Holmes and Dr. Richard Rahe. Holmes and Rahe (1967) believed the higher the

score on the HRLSI, the more likely the individual would develop an illness. The scale consists of 43 life events with a numeric value for each event over the previous year. According to Holmes and Rahe (1967), those individuals with total scores over 300 points are more likely to become ill. The HRLSI was administered to the firefighters during the third data collection to determine their magnitude of stressful events over the last year (see Appendix F).

Lower Body Strength

The wall squat is one of the most commonly used measures to accurately assess strength of the quadricep muscles (see Appendix G). If the intervention is effective, muscle strength will improve (Liebenson, 2003).

Force Plate

According to Kincl, Bhattacharya, Succop, and Scott (2002), "postural balance is an indirect measure of the effect of both physiological and biomechanical stress on a worker to perform job tasks efficiently and safely" (p. 257). A force plate is an instrument that measures ground reaction forces of standing objects that can be used to quantify an individual's balance (Chung, Lobb, Nutt, McNames, & Horak, 2010). The force plate measures forces and torques in three orthogonal directions. The Department of Environmental Health at the University of Cincinnati uses custom made software to quantify the movement patterns of a person's body center of pressure (CP) (Bhattacharya, 2011). The movement pattern of CP in the X-Y direction in the horizontal plane is used to develop a stabilogram, which is further analyzed by custom software to extract variables of postural balance (A. Bhattacharya, personal communication, February 7, 2011). Postural balance was collected with a hall-effect type force plate, Model ACS-110 manufactured by Advanced Mechanical Technology, Incorporated. Kincl et al. (2002) reported that the movement patterns of CP have been used repeatedly to quantify postural

stability (Benda, Riley, & Krebs, 1994; Corlett et. al, 1980; Pippenger, 1993; Seliga et al, 1991; Wickstrom, Bhattacharya, & Shukla, 1988). Chung et al. (2010) found the force place to be a reliable instrument to measure levodopa-induced dyskinesia in patients who were diagnosed with Parkinson's disease.

Data Analysis

Repeated measures data require specialized statistical techniques because the data are clustered, or nested, with the individuals over time. This clustering effect results in the standard errors for the statistical tests being underestimated (Huber, 1981). This yields *p*-values that are underestimated as well. Therefore, modern applied statistical methods, which include techniques such as latent growth curve modeling and others, have been developed to control for this clustering effect. These methods have largely replaced outdated general linear modeling techniques such as repeated measures ANOVA and MANOVA, which have extremely restrictive assumptions to be met (Huber, 1981). One modern technique for analyzing repeated measures data uses a fitting algorithm known as generalized estimating equations or GEE (e.g., Diggle et al., 2002). GEE is readily available, implemented in software such as SPSS/PASW. One of the attractive features of GEE is that the setup and output for GEE looks much like that for repeated measures ANOVA and MANOVA. Another advantage of this analytic method is that the dependent measures can be non-normal or even categorical such as those in the current study. The standard errors provided by the sandwich estimator (Huber, 1981) in GEE are considered robust to clustering effects. The independent variable is participation over time in the intervention of Tai Chi. The dependent variables will be the measure of percent of body fat, resting heart rate, blood pressure, wall squat, balance, and fatigue. The Holmes-Rahe Life Stress

Inventory was administered at the end of the study to determine if the participants have experience major life stressor over the last year.

Chapter Four

Presentation, Analysis, and Interpretation of Data

The findings from the study are reported in this chapter. Additionally, the statistical methods to test each of the two hypotheses of the study are identified. Lastly, the results of the study are summarized and interpreted. The study was designed as an interventional study with 60 firefighter participants who would receive training from the Tai Chi Master. However, 29 of the 60 participants were not able to receive Tai Chi training and agreed to serve as the study as the comparison group. There were many reasons why the firefighters were unable to participate in the Tai Chi training sessions. Firefighters do not have a typical work schedule. A full-time firefighter's workday is twenty-four hours long, repeated every three days. Furthermore, the firefighters have a day off after six scheduled days, termed "Kelly Day," as well as accumulating holiday, personal holiday, and vacation time. During the time of the study, eight firehouses were shut down each day, termed "brown out," to save money for their employer, the City of Cincinnati. The firefighters do not receive their daily work schedule until they arrive at work. Often they were transferred to another station termed "detailed out," or asked to use a personal holiday to receive payment for the furlough day. This uncertainty led some firefighters to participate in the comparison group instead of the intervention group.

Table 1 presents the population demographics and exercise frequency prior to Tai Chi. There were 58 males and 2 females, although both females served in the comparison group. The majority of firefighters were male, married, Caucasian, and between 20-49 years. Of those who participated in the study (intervention group n = 31), 100% were male, 87% married, 80.6% Caucasian, 67.7% were between the ages 20-49. For those in the control group (n = 29), 93.1% were male, 79% married, 93% Caucasian, and 82.8% were between 20-49 years old. The average

participant worked sixteen and one half years as a firefighter. Prior to participating in the study, 35.5% of the firefighters in the intervention group reported they exercised less than one time per week compared with 34.5% of the firefighters in the comparison group reporting exercising more than three times a week. The participants in the comparison group were encouraged to continue with their current exercise regimen. On average, the intervention participants took part in 5.90 of the 10 Tai Chi lessons and practiced Tai Chi 9.90 times over the course of the 10-week study. The effect size for the firefighters who practiced Tai Chi was $r = 0.84$.

Table 1

Summary of Demographics for the Intervention and Comparison Groups

Demographic	Intervention Group	Comparison Group
Gender		
Male	31	27
Female	0	2
Marital Status		
Single	2	2
Married	26	25
Separated	2	2
Divorced	1	0
Age		
20-29	3	1
30-39	6	9
40-49	15	15
50-59	7	3
60-69	0	1
Ethnicity		
African American	6	2

Caucasian	25	27
Hispanic	0	0
Other	0	0
Exercise Pattern		
Less than once a week	11	1
Once a week	4	2
Twice a week	4	8
Three times a week	9	8
More than three times week	3	10
Years as a firefighter		
0-5 years	0	0
6-10 years	3	3
11-15 years	5	12
16-20 years	6	5
21-25 years	11	4
More than 25 years	6	5

The Holmes-Rahe Life Stress Inventory (HRLSI) was administered to the firefighters during the third data collection point to determine the magnitude of stressful events over the last year. The scale consists of 43 stressful life events with a numeric value for each event. Holmes and Rahe (1967) believed that if an individual scored 150 points or less on the HRLSI, they experienced a relatively low amount of life change in the past year and also had a low susceptibility to stress-induced health breakdown. Individuals whose scores were between 150 and 300 points had a 50% chance of a major health breakdown over the next two years. Those whose scores were 300 or greater had an 80% increased likelihood of developing an illness. Of the 31 firefighters in the intervention group, 29 (93.5%) were in the low-risk category. Of the 29 firefighters in the control group, 26 (89.7%) were in the low-risk category. The control and

intervention groups are homogenous as neither group reported an excessive amount of stressful life events in the past year. These two groups are not likely to develop stress induced illness in the near future. The HRLSI is presented in Table 2.

Table 2

Group Mean Scores on the Holmes-Rahe Life Stress Inventory

Self-reported scores	Intervention Group	Comparison Group
0-150	29	26
151-300	1	2
300 and greater	1	1

Analysis of the Generalized Estimating Equation (GEE) parameter estimations determined that the data had an overall statistically significant effect. The hypothesis test for the combined groups was combined in the initial analysis. Table 3 represents the parameter estimates for the dependent data. The advantage of this analysis method is that the dependent measures may be a non-normal distribution or even categorical, such as those in the current study. With GEE, independent observations are based upon Quasilikelihood under the Independence Model Criterion (QIC) theory. The QIC is used for determining the working correlation structure selection and the Independence Model Criterion (QICC) is used for determining the variable selection. Together these processes compare the model's goodness-of-fit to determine the best-working correlation structure (Cui, 2007; IBM, 2012; Pan, 2001). The baseline for the QIC and QICC were 328.10 and 328.35, respectively. The full model QIC and QICC were 322.02 and 329.42, respectively. In the full model, the QICC does not yield the smallest number. However, the QICC is an approximation to the QIC with the primary function of identifying variables that

may not fit the model (Cui, 2007). For the current study, all of the dependent variables were substantive in determining cardiac modifiable factors and should not be eliminated in an attempt to lower the QICC score.

Table 3

Parameter Estimates for Full Model of Variables using GEE Quasilikelihood under the Independence Model Criterion – Intervention and Comparison Groups Over Time

Parameter Estimates							
			95% Wald Confidence Interval		Hypothesis Test		
Parameter	**B**	**Std. Error**	**Lower**	**Upper**	**Wald Chi-Square**	**df**	**Sig.**
(Intercept)	2.264	1.8020	-1.268	5.796	1.579	1	.209
Heart rate	-.012	.0183	-.048	.023	.462	1	.497
Systolic BP	-.010	.0072	-.024	.004	1.875	1	.171
Diastolic BP	.003	.0150	-.027	.032	.034	1	.854
Wall squat	-.137	.0897	-.312	.039	2.322	1	.128
Body fat	.050	.0203	.010	.089	5.994	1	.014
Chronic fatigue	-.017	.0229	-.062	.028	.529	1	.467
Acute fatigue	-.002	.0366	-.073	.070	.002	1	.966
Inter-shift recovery	-.011	.0403	-.090	.068	.075	1	.784
Life stress scale	6.290	.0017	-.003	.003	.001	1	.970
(Scale)	3.866						

Dependent Variable: Tai Chi instruct
Model: Full, HR, SBP, DBP, WS, BF, CF, AF, IR, Life stress scale

Hypothesis One

The first hypothesis was that the individuals who receive Tai Chi would have reduced cardiac risk factors. The cardiac risk factors measured in this study were heart rate, systolic blood pressure, diastolic blood pressure, and percent of body fat. A paired sample *t*-test estimated via bootstrapping (Efron, 2010) was performed through SPSS 19 to compare the mean scores of the cardiac risk factors of the firefighters. The bootstrap method was used to analyze the data for both the intervention and comparison groups. According to Efron (1981), "the

bootstrap estimate is simply the standard deviation of the quantity of interest" (p. 591). Additionally, bootstrapping was used to test the first hypothesis (IBM, 2010). Table 4 presents the bootstrapped analysis of heart rate, systolic and diastolic blood pressures, and body fat measures of those who participated in Tai Chi. Paired *t*-tests were run independently for the comparison and intervention groups. These tests helped to identify the group differences in cardiac measurements taken during the study.

There were significant improvements on several of the measured cardiac parameters. These measures were taken at three time points: prior to participating in Tai Chi, after five weeks of training, and at the completion of the study after ten weeks of Tai Chi training. There was a significant difference in the heart rate between the initial measures at the beginning and midpoint of the study (M_{diff} = 4.46 p = 0.15). Overall, the mean heart rate was reduced (M_{diff} = 3.267, p = 0.55). Systolic blood pressure was significantly reduced between the initial and second measure (M_{diff} = 13.89, p = 0.000), the initial and third measure (M_{diff} = 9.30, p = 0.003), and improved between the second and final measures (M_{diff} = -4.00, p = 0.119). Diastolic blood pressure was significantly improved at each point of measurement: initial diastolic measure to the second measure (M_{diff} = 10.77, p = .000), second to the third measure (M_{diff} = -5.69, p = 0.007), and initial measure to the final measure (M_{diff} = 4.67, p = 0.011). The firefighters' body fat significantly decreased from the first measure taken before the study began to the measure taken after the study ended (M_{diff} = -982, p = 0.012). The measures taken between the first and second measure and the second to the third measures were not significant.

Table 4

Paired Samples t-Test – Interventions Group

	Paired Differences						
			95% Confidence Interval of the Difference				
	Mean	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Heart rate 1 - Heart rate 2	4.462	1.705	.949	7.974	2.616	25	.015
Heart rate 1 - Heart rate 3	3.267	1.632	-.072	6.605	2.001	29	.055
Heart rate 2 - Heart rate 3	-.462	1.072	-2.669	1.746	-.431	25	.670
Systolic BP 1 - Systolic BP 2	13.885	3.027	7.650	20.119	4.587	25	.000
Systolic BP 1 - Systolic BP 3	9.300	2.815	3.543	15.057	3.304	29	.003
Systolic BP 2 - Systolic BP 3	-4.000	2.475	-9.098	1.098	-1.616	25	.119
Diastolic BP 1 - Diastolic BP 2	10.769	2.134	6.374	15.165	5.046	25	.000
Diastolic BP 1 - Diastolic BP 3	4.667	1.719	1.151	8.182	2.715	29	.011
Diastolic BP 2 - Diastolic BP 3	-5.692	1.933	-9.674	-1.711	-2.944	25	.007
Body fat 1 - Body fat 2	-8.25440	8.19900	-25.17631	8.66751	-1.007	24	.324
Body fat 1 - Body fat 3	-.98174	.36020	-1.72874	-.23474	-2.726	22	.012
Body fat 2 - Body fat 3	-.64444	.52725	-1.75684	.46795	-1.222	17	.238

The 29 individuals who did not receive Tai Chi did not show any significant changes over time for heart rate and systolic and diastolic blood pressures, using a bootstrapped, paired sample *t*-test (see Table 5). The differences in body fat percent over time are presented in Table 5. Significant differences occurred in body fat measures over time (M_{diff} = -4.38, p = 0.023).

Table 5
Paired Samples t-Tests – Comparison Group

	Paired Differences Comparison Group						
			95% Confidence Interval of the Difference				
	Mean	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Heart rate 1 - Heart rate 2	1.800	2.308	-3.422	7.022	.780	9	.456
Heart rate 1 - Heart rate 3	1.591	1.769	-2.087	5.269	.899	21	.379
Heart rate 2 - Heart rate 3	.200	2.195	-4.765	5.165	.091	9	.929
Systolic BP 3 - Systolic BP 2	2.600	3.416	-5.128	10.328	.761	9	.466
Systolic BP 3 - Systolic BP 3	-4.409	4.642	-14.062	5.244	-.950	21	.353
Systolic BP 2 - Systolic BP 3	.400	3.367	-7.217	8.017	.119	9	.908
Diastolic BP 1 - Diastolic BP 2	-1.600	3.052	-8.504	5.304	-.524	9	.613
Diastolic BP 1 - Diastolic BP 3	2.455	2.217	-2.157	7.066	1.107	21	.281
Diastolic BP 2 - Diastolic BP 3	1.800	3.521	-6.164	9.764	.511	9	.621
Body fat 1 - Body fat 2	1.88750	.91465	-.27530	4.05030	2.064	7	.078
Body fat 1 - Body fat 3	-.87143	.37202	-1.67513	-.06773	-2.342	13	.036
Body fat 2 - Body fat 3	-4.38000	1.21795	-7.76157	-.99843	-3.596	4	.023

Hypothesis Two

The second hypothesis was that the individuals who receive Tai Chi will improve their overall physiological endurance these measurements were wall squat, fatigue, and balance. Fatigue was measured by the Occupational Fatigue Exhaustion/Recovery (OFER) scale (Winwood et al., 2005). As previously identified, a bootstrapped, sample *t*-test was performed through SPSS 19 to compare the mean physiological endurance scores of the firefighters. Table 6 presents the analysis of the wall squat and fatigue measures for the firefighters who received Tai Chi. The overall time that the firefighters were able to maintain the wall squat position significantly improved from the initial to final measure (M_{diff} = -1.021, p = 0.005). The time from the initial measure to the midpoint of the study (M_{diff} = -.430, p = 0.022) and from the midpoint to the end of the study (M_{diff} = p = 0.34) showed notable improvement.

The 15-question fatigue scale monitored acute and chronic fatigue as well as inter-shift recovery. One of the benefits of the OFER scale is that the scale is based upon theory and focuses on occupational stressors. The fatigue scale results are also presented in Table 6. The fatigue scale was distributed to the firefighters prior to implementing the Tai Chi study and after the completion of the study. Chronic fatigue was statistically significantly reduced ($M_{diff} = 4.30$, $p = 0.007$). In contrast, acute fatigue increased ($M_{diff} = 0.39$, $p = 0.690$). Inter-shift recovery was not statistically significant, indicating work stress was not alleviated while away from work. An increased acute fatigue score equates to an intensification of the construct. The reduced chronic fatigue score equates to a decrease of the construct. To explain the increase in acute fatigue, decrease in chronic fatigue, and an increased retention of work stress, one must look at what was going on at the work site. As previously stated, there were many potential contributing factors during the time of the study, such as closing eight firehouses each day. Another work influence was State Bill 5 (SB-5). The SB-5 limited the bargaining power of unions. Firefighters are State of Ohio employees represented by an organized union. The firefighters feared future layoffs, early retirements with reduced benefits, and no future bargaining rights for equipment, benefits, and pay.

Table 6

Paired Samples t-Test of Wall Squat, Chronic and Acute Fatigue, and Inter-shift Recovery – Intervention Group

	Paired Differences				t	df	Sig. (2-tailed)
			95% Confidence Interval of the Difference				
	Mean	Std. Error Mean	Lower	Upper			
Wall squat 1 - Wall squat 2	-.429920	.174946	-.790992	-.068848	-2.457	24	.022
Wall squat 1 - Wall squat 3	-1.021393	.338159	-1.715239	-.327547	-3.020	27	.005
Wall squat 2 - Wall squat 3	-.576320	.256074	-1.104830	-.047810	-2.251	24	.034
Chronic 1 - Chronic Fatigue 2	4.29643	1.45798	1.30490	7.28795	2.947	27	.007
Acute Fatigue 1 – Acute Fatigue 2	.39286	.97365	-1.60490	2.39061	.403	27	.690
Inter-shift Recovery1 – Inter-shift Recovery 2	.92857	.96215	-1.04560	2.90274	.965	27	.343

Balance was measured with the hall-effect type force plate, Model ACS-110, manufactured by Advanced Mechanical Technology, Incorporated. The force plate measures subjects total sway length. The sway length represents the length of the movement intersected by the sway pattern measured in centimeters (Kincl, Bhattacharya, Sucoop, & Scott, 2002). According to Kincl et al. (2002), “an increased sway length implies increased muscular activity to maintain balance” (p. 256). Therefore, if a firefighter has an increased sway length, he is struggling to control his balance and must use lower leg muscles to keep from falling.

For each of the balance tests, the participants stood in the same position and were measured on four different test conditions. These conditions were: eyes open on the force plate, eyes closed on the force plate, eyes open standing on four inches of foam on top of the force plate, and eyes closed standing on four inches of foam on top of the force plate. The four test conditions were repeated at each encounter. Sway area was also calculated for each participant. The sway area is the area where one moves from side to side while standing in an erect position. Often this is with a swinging motion. The sway area can increase as individuals have decreased balance due the aging process, injury, alcohol consumption, or fatigue.

A mean was calculated for each subject for the four test conditions. The data were first transformed with a natural log transformation and then analyzed with a paired *t*-test. There was no statistical significance between the pre- and post-measures. Table 7 presents the paired *t*-test results. Figure 1 presents the non-standardized *t*-distribution for the balance data. From the output represented in Figure 1, it appears that there is no correlation between the balance measures. The sway length with eyes open mean scores vary considerably (M = 0.1422 to M = .00791). This variance is due to the individual's positioning on the force plate on paper as opposed to four inches of foam. Similar variances are identified in all of the sway length and sway area mean scores. As previously stated, there are no significant findings between the pre- and post-sway length and sway area results. Perhaps the lack of significance is due length of the study, which was only 10 weeks in duration.

Table 7

Paired t-Tests Balance Data Sway Length and Sway Area, Pretest and Posttest – Intervention Group

	Paired Differences			
	Mean	t	df	**Sig (2-tailed)**
Pre Sway Length eyes open Post Sway Length eyes open	0.1422	.483	22	.634
Pre Sway Area eyes open Post Sway Area eyes open	-.06608	-.958	22	.349
Pre Sway Length eyes closed Post Sway Length eyes closed	.00687	.214	22	.832
Pre Sway Area eyes closed Post Sway Area eyes closed	-.04102	-.481	22	.635
Pre Sway Length eyes open on foam Post Sway Length eyes open on foam	.00791	.212	22	.834
Pre Sway Area eyes open on foam Post Sway Area eyes open on foam	-.04369	-.469	22	.643
Pre Sway Length eyes closed on foam Post Sway Length eyes closed on foam	-.03263	-.860	22	.399
Pre Sway Area eyes closed on foam Post Sway Area eyes open on foam	-.13811	-1.448	22	.162

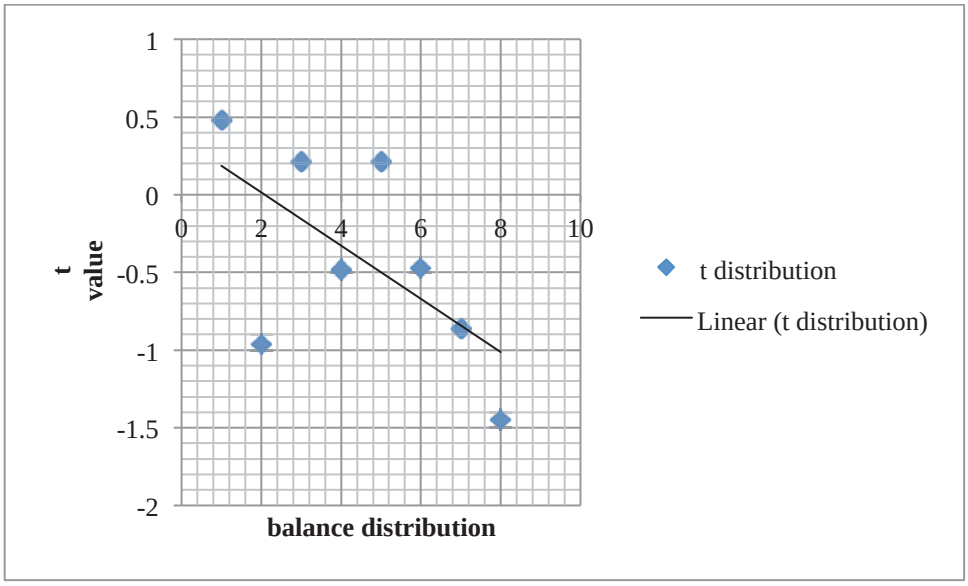

Figure 1. Scatterplot distribution for intervention group balance data.

Table 8 presents the analysis of the wall squat for the firefighters who did not received Tai Chi. The overall the time that the firefighters were able to maintain the wall squat position was not significant and did not show improvement from the initial measurement to the midpoint measurement or with the measures taken at the end of the study. The fatigue scale results are also presented in Table 8. The 15-item fatigue scale was distributed to the firefighters prior to implementing the Tai Chi study and after the completion of the study. Chronic fatigue was not statistically significant. However, acute fatigue increased (M_{diff} = .136, p = 0.858). Inter-shift recovery was not significantly changed, which would indicate work stress was retained while away from work. These results are also indicative of what was going on at the work site as previously stated.

Table 8

Paired Samples t-Test of Wall Squat, Chronic and Acute Fatigue, and Inter-shift Recovery – Comparison Group

	Paired Differences						
			95% Confidence Interval of the Difference				
	Mean	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Wall squat 1 - Wall squat 2	-.067444	.253440	-.651879	.516990	-.266	8	.797
Wall squat 1 - Wall squat 3	-.201700	.140091	-.494913	.091513	-1.440	19	.166
Wall squat 2 - Wall squat 3	-.336300	.253813	-.910466	.237866	-1.325	9	.218
Chronic Fatigue 1 – Chronic Fatigue 2	1.86364	1.63868	-1.54418	5.27145	1.137	21	.268
Acute Fatigue 1 – Acute Fatigue 2	.13636	.75103	-1.42549	1.69822	.182	21	.858
Inter-shift Recovery 1 – Inter-shift Recovery 2	.68182	.49406	-.34564	1.70928	1.380	21	.182

Balance in the comparison group was measured identically as in the intervention group. The four different test conditions were performed at each encounter and an average was calculated for each subject. The data were transformed with natural long transformation and then analyzed using a paired *t*-test. There were no statistical differences between the pretest and posttest measures (see Table 9).

Table 9

Paired t-Test Balance Data Sway Length and Sway Area, Pretest and Posttest – Comparison Group

	Paired Differences			
	Mean	t	df	**Sig (2-tailed)**
Pre Sway Length eyes open Post Sway Length eyes open	-.09892	-.508	13	.620
Pre Sway Area eyes open Post Sway Area eyes open	.20047	2.034	13	.063
Pre Sway Length eyes closed Post Sway Length eyes closed	.09635	1.540	12	.149
Pre Sway Area eyes closed Post Sway Area eyes closed	.06686	.788	12	.446
Pre Sway Length eyes open on foam Post Sway Length eyes open on foam	.05706	1.233	12	.241
Pre Sway Area eyes open on foam Post Sway Area eyes open on foam	.01043	.138	12	.893
Pre Sway Length eyes closed on foam Post Sway Length eyes closed on foam	.06332	.787	13	.445
Pre Sway Area eyes closed on foam Post Sway Area eyes open on foam	.09478	.578	13	.574

Table 10 represents the mean and standard deviations for each of the dependent variables for the participants in the intervention group. Table 11 represents the mean and standard deviations for each of the dependent variables for the participants in the intervention group.

Table 10

Dependent Variables Means and Standard Deviations (SD) – Intervention Group

	Initial	Midpoint	End of study
Heart Rate			
Mean	66.35	62.69	63.55
SD	7.47	5.37	4.15
Systolic Blood Pressure			
Mean	125.7	111.9	116.2
SD	16.5	9.9	12.1
Diastolic Blood Pressure			
Mean	75.1	64.2	69.6
SD	8.7	6.0	7.7
Wall Squat			
Mean	0.89	1.34	1.83
SD	0.6	0.94	1.8
Chronic Fatigue			
Mean	24.6	32.88	26.3
SD	5.7	41.2	6.6
Acute Fatigue			
Mean	12.9	9.6	11.23
SD	7.4	6.0	4.6
Inter-shift Recovery			
Mean	11.3	8.03	6.9
SD	3.9	4.6	2.0

Table 11

Dependent Variables Means and Standard Deviations (SD) – Comparison Group

	Initial	Midpoint	End of study
Heart Rate			
Mean	64.3	63.17	67.3
SD	6.36	5.16	6.15
Systolic Blood Pressure			
Mean	117.9	112.06	121.96
SD	17.7	10.47	24.45
Diastolic Blood Pressure			
Mean	71.0	66.8	69.6
SD	9.8	7.45	7.7
Wall Squat			
Mean	1.05	1.34	1.3
SD	0.65	0.65	.70
Chronic Fatigue			
Mean	23.5	24.39	24.75
SD	5.5	5.6	4.7
Acute Fatigue			
Mean	17.55	10.59	12.38
SD	12.51	8.7	10.61
Inter-shift Recovery			
Mean	9.4	8.21	7.14
SD	4.18	2.06	2.7

Summary of Findings

Hypothesis One

The first hypothesis was that the individuals who received Tai Chi would have reduced cardiac risk factors. In this study, the cardiac risk factors that were measured were heart rate, systolic and diastolic blood pressures, and percent of body fat. The between-subject comparison of firefighters in the Tai Chi intervention group had many statistically significant findings. The significant changes in mean scores from the initial to final measures are as follows: systolic blood pressure ($M_{diff} = 9.3$, $p = 0.003$), diastolic blood pressure ($M_{diff} = 4.667$, $p = 0.011$), and body fat ($M_{diff} = -.9817$, $p = 0.012$). Additionally, the firefighters' overall heart rate was greatly reduced ($M_{diff} = 3.267$, $p = 0.55$). The between-subjects comparison for the control group had only one statistically significant finding. The comparison group had a statistically significant increase in body fat ($M_{diff} = -4.38$, $p = 0.023$) from the second to the final measure. There is sufficient evidence from the study's results to accept the null hypothesis: The firefighters who participated in Tai Chi would not have improved overall physiological endurance.

A comparison of the mean scores for heat rate, systolic and diastolic blood pressure, and body fat measures for the comparison and intervention groups are graphically presented in Figure 2 through Figure 5. This represents a between-group comparison of participants in the comparison and intervention group at the three time measures.

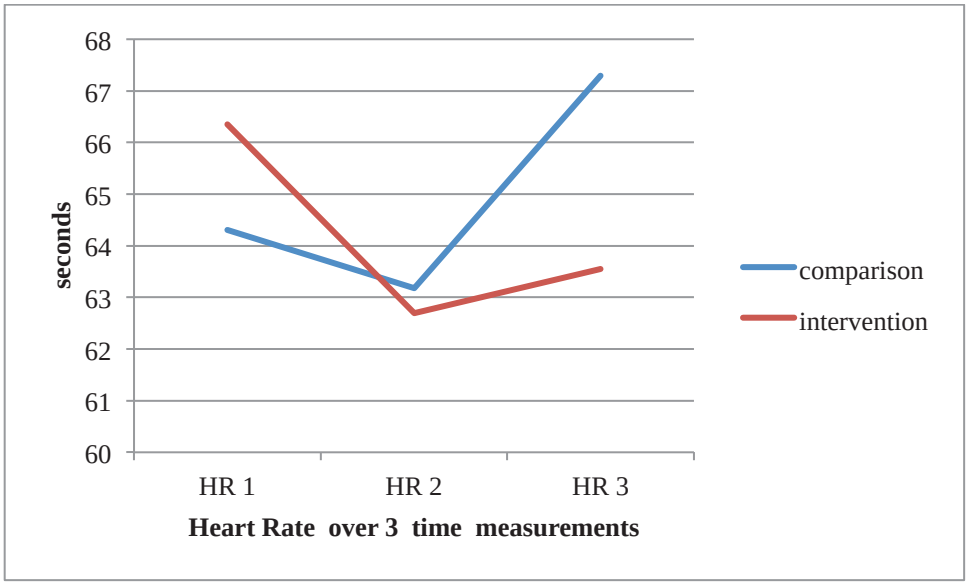

Figure 2. Comparison of heart rate means scores for the intervention and comparison groups.

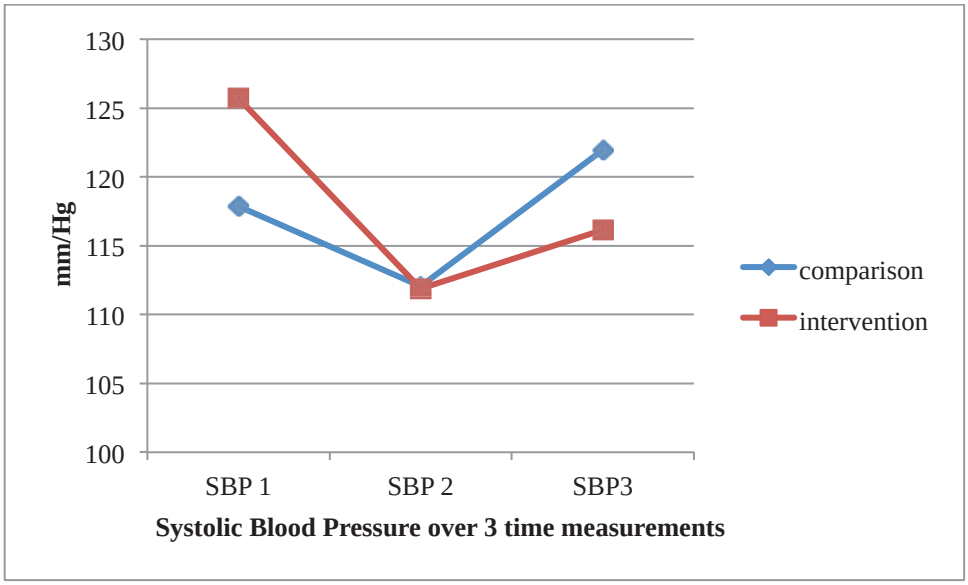

Figure 3. Comparison of systolic blood pressure mean scores for the intervention and comparison groups.

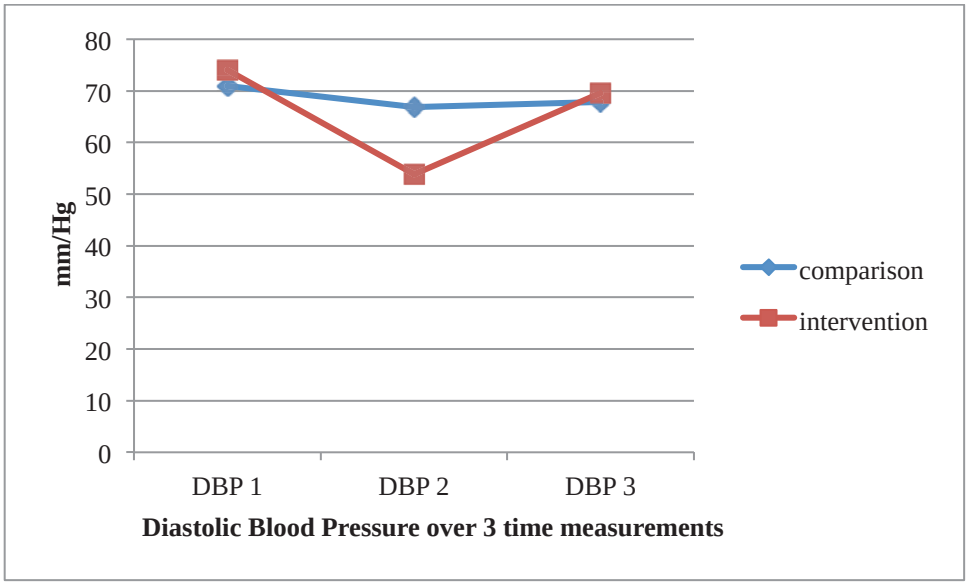

Figure 4. Comparison of diastolic blood pressure mean scores for the intervention and comparison groups.

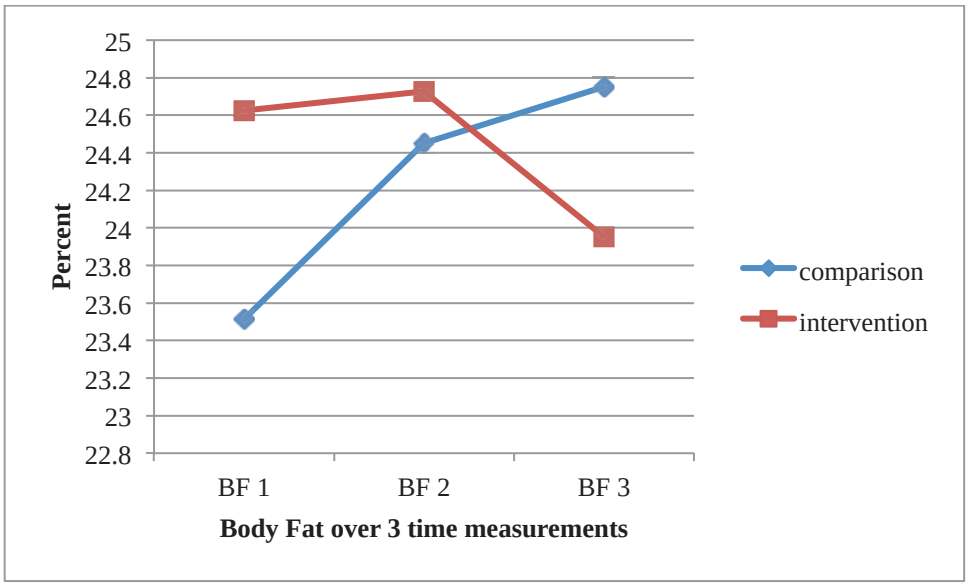

Figure 5. Comparison of body fat mean scores for the intervention and comparison groups.

Hypothesis Two

The second hypothesis was that the individuals who receive Tai Chi will improve their overall physiological endurance. These measurements were wall squat, fatigue, and balance. The between-subject comparison of firefighters in the Tai Chi intervention group had a few statistically significant findings. The total time that the firefighters were able to maintain the time wall squat position from the initial to the final measure was a statistically significant improvement ($M_{diff} = 3.287$, $p = 0.005$). There were many noteworthy changes in the fatigue scale results. The chronic fatigue score was significantly reduced ($p = 0.007$) and the acute fatigue was greatly increased ($M_{diff} = .39288$, $p = .0690$). However, the inter-shift recovery was not significant. The balance measures were not statistically significant. Of the 31 firefighters in the intervention group, 29 (93.5%, $M_{diff} = 53.7$) were in the low-risk category on the Holmes-Rahe Life Stress Inventory. The between-subject comparison for the control group was not statistically significant. The wall squat measures from the initial to the final measure were not significant. There was a noteworthy change in the acute fatigue measure. Chronic fatigue was not statistically significant, yet acute fatigue greatly increased ($M_{diff} = .39286$, $p = 0.858$) and the inter-shift recovery was not statistically significantly changed. The balance measures were not statistically significant. A comparison of the mean scores for wall squat, chronic and acute fatigue, and inter-shift recovery for the comparison and intervention groups are graphically presented in Figure 6 through Figure 9. This represents a between-group comparison of participants in the comparison and intervention group at the three time measures.

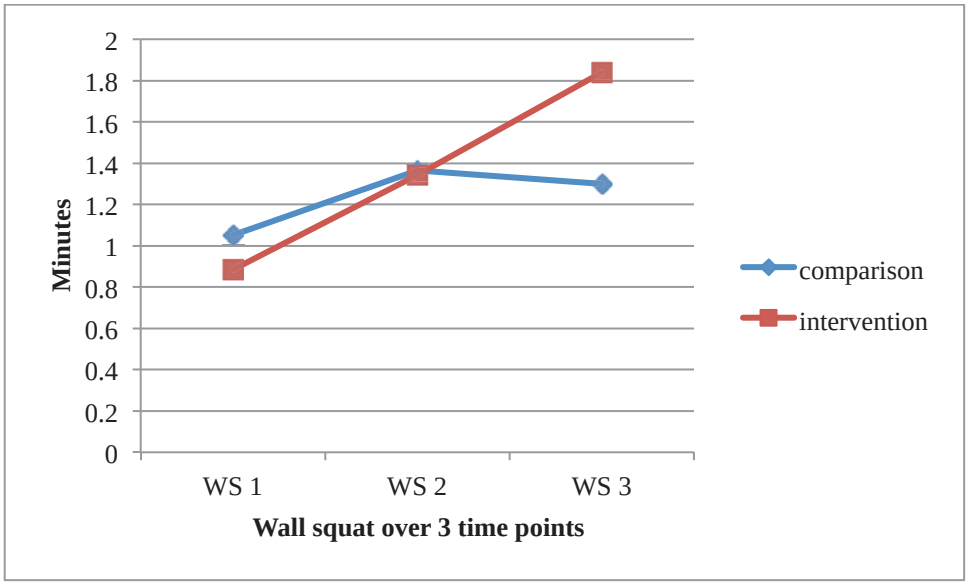

Figure 6. Comparisons of wall squat mean scores for the intervention and comparison groups.

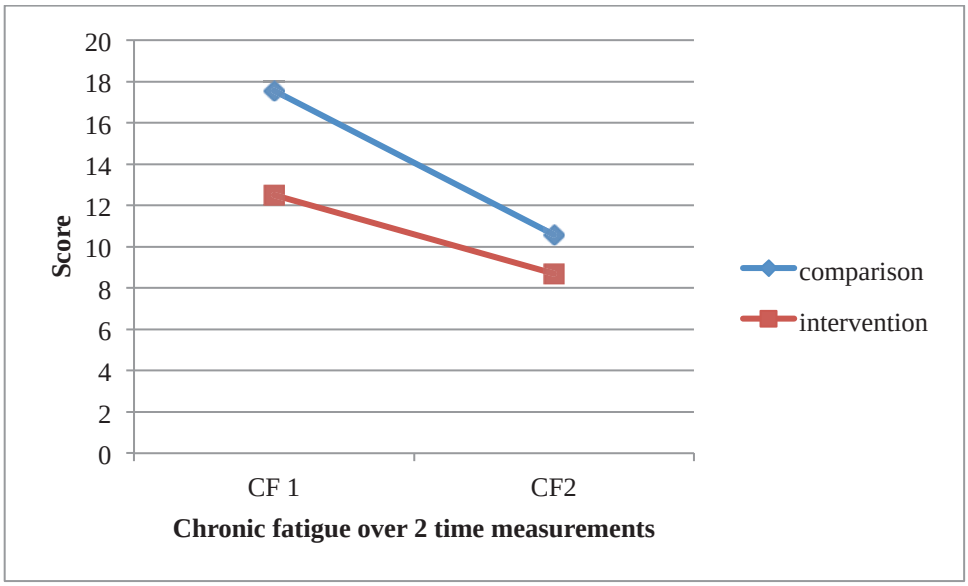

Figure 7. Comparison of chronic fatigue mean scores for the intervention and comparison groups.

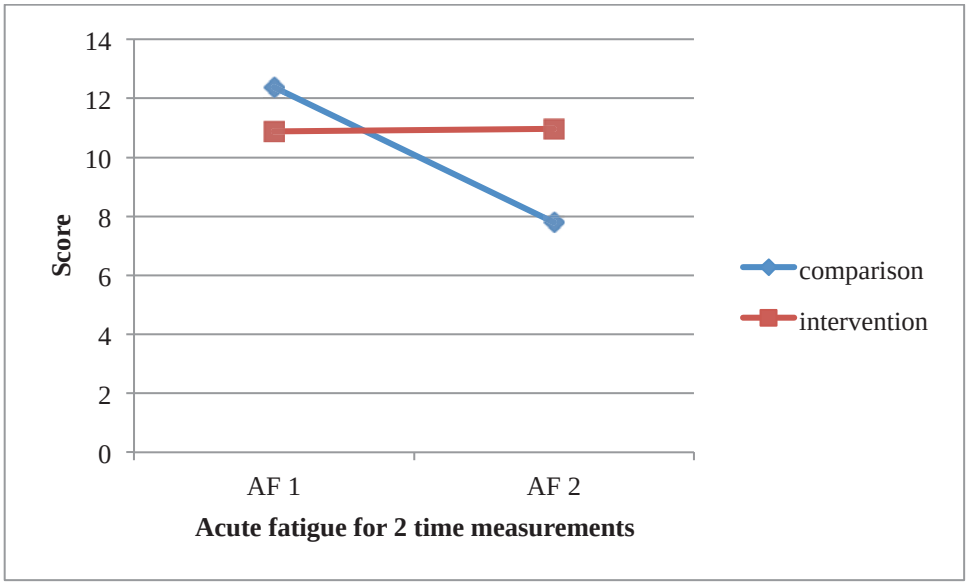

Figure 8. Comparison of acute fatigue mean scores for the intervention and comparison groups.

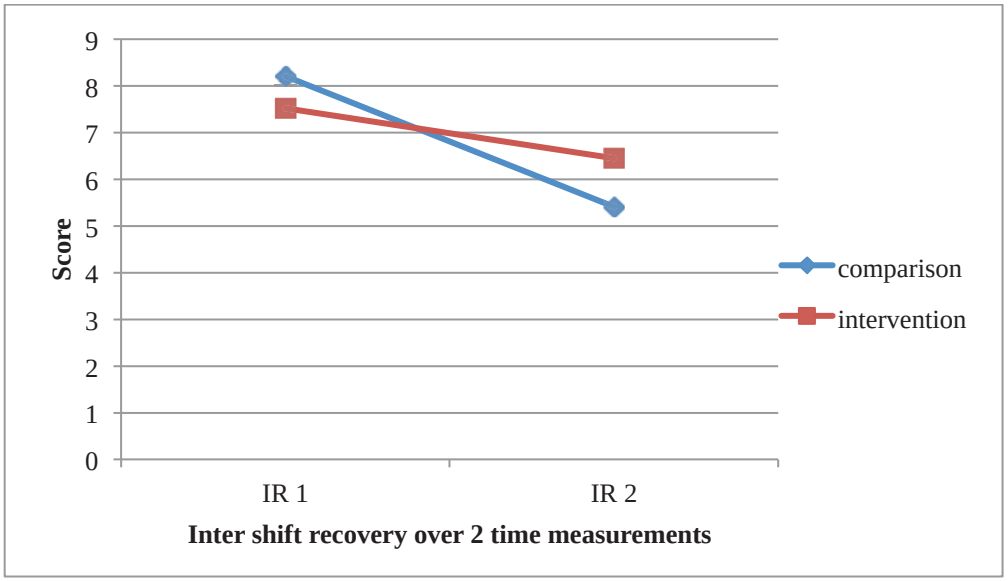

Figure 9. Comparison of inter-shift recovery mean scores for the intervention and comparison groups.

Chapter 5

Discussions and Implications

This chapter will include the discussion, implications, and limitations of this study. The chapter will begin with a discussion of findings followed by the implications and limitations of the study. The last section of the chapter will present implications for nursing theory, research, and practice.

Discussion of Findings

The findings were grounded in the principles of a team-based model to bring about behavioral change. Bandura's (1997) Social Learning Theory has an emphasis on shared determinism. An individual's behavior is influenced by the actions of others, the physical environment, and human characteristics. Bandura (1997) stated that these characteristics influence each other. Firefighters have a job that is both physically and mentally demanding. Firefighters are exposed to heat, stress, and life threating conditions and have a high prevalence of heart disease, obesity, musculoskeletal injuries, and hypertension. The participants in this study were offered one hour per week of training with a Tai Chi Master Instructor at their fire station over a 10-week period.

In a recent study, Promoting Healthy Lifestyles: Alternative Models' Effects (PHLAME), Moe et al. (2002) evaluated the efficacy of two strategies for improving nutrition and physical activity practices in fire fighters: a team-centered program and a one-on-one format targeting the individual. Bandura (1997) states that groups that share common environment can be a positive influence to bring about behavioral change. Moe et al. (2002) found the firefighters' unique work structure was ideal for a team-centered model for behavior change. The purpose of this study was

to identify if Tai Chi (a group-based approach) would improve modifiable cardiac risk factors and physiological endurance in firefighters through team participation.

Hypothesis One

The first aim of the study was to determine if firefighters who received Tai Chi would have improved cardiac risk factors. The cardiac risk factors measured in this study were heart rate, systolic blood pressure, diastolic blood pressure, and percent of body fat. Of the 60 firefighters recruited, only 31 were able to participate in the Tai Chi training, leaving 29 who were unable to receive the training. The contributing factors that prevented firefighters from partaking in the Tai Chi training included work scheduling complexities, budget cuts that resulted in shut down of firehouses, and temporary or permanent transfers to another station.

At midpoint of the study, it became evident there was a potential for losing half of the participants due to inability to attend any of the Tai Chi sessions. The City offers their employees a monetary incentive, paid to their flex spending account, if cardiac health indicators are periodically monitored by a health care professional. The firefighters agreed to stay in the study as a comparison group, due to this incentive. The creation of two groups ensured comparison and treatment. The groups were not randomly assigned; they were created by chance. The two groups were homogeneous in their demographic measures. Power and rigor was thus affected by losing half of the participants from the intervention. However, the effect size of the intervention was (r = 0.84), showing promise for the intervention as a meaningful strategy for increasing physical activity.

Results of the repeated measure paired samples t-tests to examine the cardiac risk factors mean scores of the firefighters also showed promising results. The firefighters who participated in Tai Chi had significant improvements in the cardiac measures of systolic and diastolic blood

pressure and body fat, along with a substantial decrease in heart rate. In contrast, the only significant finding for the firefighters who did not participate in Tai Chi was an increase in body fat.

The first research hypothesis was that individuals who received Tai Chi will have reduced cardiac risk factors. Again, the factors in this study were heart rate, systolic and diastolic blood pressure, and body fat. The study findings provided support for the stated hypothesis. The impact on cardiac measurements attributable to Tai Chi is well supported in the literature (Cheng, 2007; Lan et al., 2008; McCleary, 2009; Neal et al., 2000). Even modest improvements of blood pressure can result in reducing the risk of strokes by 35-40% and a 20-25% reduction possibly preventing cardiac failure (Neal et al., 2000). Cardiac failure is the leading cause of death in firefighters (Drew-Nord et al., 2009; Geibe et al., 2008; Fahy, 2005; Lund et al., 2001). Chang et al. (2008) found Tai Chi enhanced vagal and sympathetic modulation which improves cardiac function and heart rate. Upper body and abdominal fat increase the risk of hypertension, diabetes, hyperlipidemia, and heart disease (Allison, Fontaine, Manson, Stevens, & VanItallie, 1999). Regular physical fitness activities strengthen the upper and lower muscles, decrease the risk of muscular strains, and improve cardiovascular health (USFA, 2009). The prevalence of death due to cardiovascular disease is higher in the firefighter population than in the general public. Replication of the study with a more diverse population is warranted, for example, with groups with more ethnic and gender representation.

During this research study, the Tai Chi intervention groups' results may also be attributed to the intervention team's cohesiveness, culture, and team effort. A noticeable improvement was seen from the previous sedentary firefighters to a group who practiced Tai Chi together. Using the Social Learning Theory was an appropriate theoretical framework for this population.

Hypothesis Two

The second aim was that the individuals who receive Tai Chi will improve their overall physiological endurance. This is important in the working population because physical fitness and overall well-being are necessary to perform the demanding job functions of the firefighters. The second hypothesis was individuals who receive Tai Chi would improve their overall physiological endurance of wall squat, balance, and fatigue. The physiological endurance factors measured in this study were lower body strength, fatigue, life stress, and balance. The firefighters who participated in Tai Chi had improved lower body strength, whereas the firefighters who did not showed no improvement. The lower body strength was measured by wall squats. The firefighters challenged each other to do their best and not to hold their breath. Song, Lee, Lam and Bae (2003) reported Tai Chi promoted improvements in balance and muscle strength, flexibility, cardiovascular functioning, BMI, knee muscle strength, and endurance. According to Wu (2008), a pilot study with a Tai Chi intervention resulted in significant improvements in knee and hip flexion and lower leg strength.

In both the intervention and comparison groups, overall fatigue levels were low to moderate with mean scores ranging from 6.9 to 32.88. Acute fatigue decreased over time for both groups; with the greatest decrease from time one to time two; and then increasing at time three. The increase at time three was significant only for the intervention group. This pattern of scores was likely due to external work-related issues related to loss of team members due to brown outs and potential job loss threatened by the political climate at the timing of the second measurement. The first decrease could have been a researcher effect where the firefighters were more comfortable with the research intervention and presence of researchers impacting the ratings. The increase in chronic fatigue at time two was likely related again to brown-outs,

changing of workstations, and other scheduling issues. The inter-shift recovery results did not differ significantly in either group across time, indicating adequate recovery away from work.

In both the intervention and control groups, the balance scores were not different over time. The Holmes-Rahe Life Stress Inventory results were low for both groups, indicating a low probability of stress induced illness occurring over the coming year. Thus, it is unlikely that findings from this study were the result of personal situations.

Another contributing factor that may have affected the overall physiological endurance of the firefighters was that during the Tai Chi study, State Bill 5 (SB5) was a topic of discussion at most of the fire stations. Firefighters are public employees and the SB5 bill placed limitations on the bargaining rights of public employees. This bill allowed bargaining units to negotiate for wages, benefits, and working conditions; however it banned the ability to bargain for benefits and to strike (SB5, 2011). As previously stated in Chapter 4, both the intervention and comparison groups' chronic fatigue scores increased at the time of the second measurement period. This related to the same time as the political issues were occurring. Researchers have reported there are numerous stressors that firefighters face at work, these include long working hours, rotating shifts, life and death situations, posttraumatic stress, and a disconnection from family life (Shreffler, Meadows, & Davis, 2011; Nandi et al., 2004). When firefighters who work in extremely stressful working conditions are threatened with the loss of employment, bargaining rights, and the right to strike, chronic fatigue could occur. In November, SB5 was repealed; it would be interesting to re-administer the Occupational Fatigue Exhaustion Recovery Scale to the participants of the study to determine fatigue levels. Future studies may have different study results if fatigue was measured in a less stressful environment.

The non-significant balance results may be attributed to the short duration of the study. As previously discussed in Chapter Two, Tai Chi had the greatest effect on balance when practiced over an extended time frame. Hong, Xian, and Robinson (1999) concluded that long-term regular Tai Chi exercise had a positive effect on balance control, flexibility, and cardiovascular health. However, according to Lelard et al. (2010), there were no significant differences in postural control or walking ability after twelve weeks of Tai Chi training; but Tai Chi was helpful in maintaining balance in poorly lit environments or in total darkness.

Additional contributing factors are related to the number of sessions and group or individual's additional practice of Tai Chi. Of the 31 participants in intervention group, there was an average attendance of 5.90 of the 10 Tai Chi lessons and reported practice of Tai Chi an average of 9.90 times over the course of the study. Prior to participating in the study, 35.5% of the firefighters in the intervention group reported they exercised less than one time per week and 34.5% of the firefighters in the comparison group reported exercising more than three times a week. It appears that the intervention group was not as committed to weekly exercise as the comparison group. The intervention group was encouraged to practice three times a week in addition to the one hour of Tai Chi instruction; nevertheless the study was a voluntary exercise program with self-reporting of Tai Chi practice or training from the Master Instructor. The firefighters were given logs to record the training and practice; however, they were not used.

Even though Tai Chi did not have an immediate impact on improving overall physiological endurance, the study had a significant impact on reducing cardiac risk factors. According to Neal et al. (2000), even modest reductions in blood pressure can result in a 35-40% reduction in strokes and a 20-25% reduction in coronary heart disease. In this study the intervention group's average for the initial heart rate was 66.4 and the final average heart rate

was 63.5, a 2.9 point reduction or a 4.4% change. The initial average systolic blood pressure was 125.7 mmHg and the final average systolic blood pressure was 116.16 mmHg, a 9.54 point reduction or a 7.6% change. The initial average diastolic blood pressure was 74.1 mmHg and the final average blood pressure was 70 mmHg, a 4.1 point reduction or a 5.86% change.

Many of the firefighters stated they enjoyed the Tai Chi training, and that they would continue with this form of exercise, and a few firefighters had already enrolled in additional Tai Chi training. Subsequently, a follow-up intervention is warranted for the firefighters. An important part to all health achievements is sustainability. To maintain the current reduction in cardiac risk factors and to facilitate continued improvements, additional weekly Tai Chi practice is warranted with continued practice over longer periods of time. The researchers at the CDC (2012) recommends that employers should initiating flexible times at the beginning and ending of the workday to provide opportunities for the engagement of physical activity. The researchers at the CDC (2012) also recommend that programs should include social support practices to improve participation.

Since the results were positive and Tai Chi was accepted by the firefighters, there is the potential of acquiring additional funding to research the effect on cardiac risk factors in other firefighter groups. Further research would help to facilitate generalizability.

Threats to External Validity

The study targeted firefighters who work full-time in the City of Cincinnati. The majority of the firefighters were male, married, Caucasian, and between 20-49 years old. There were 51 Caucasians, 2 female, and 9 African-Americans in the current study. Although the study has an under-representation of non-Caucasian ethnic groups, according to the fire chief, the sample is representative of fire stations in the City of Cincinnati, Ohio. This homogeneous target

population may not be representative of other fire stations. The study should be replicated in other firefighter groups to establish generalizability.

Threats to Internal Validity

The purpose of experimental research studies is to determine if a treatment, the independent variable, has made an effect on the dependent variable. Internal validity helps to determine if the causal relationship is due to change in the dependent variable or other extraneous factors (Portney & Watkins, 2000). Cook and Campbell (1979) identified several types of internal threats that could potentially interfere with the relationship between the independent and dependent variables. The following is the identification of possible threats to the study's internal validity and a discussion of how these threats were controlled.

Maturation. One of the testing modalities to determine physiological endurance was balance. For each of the balance tests, the participants stood in the same position and were measured on four different test conditions. These conditions were: (a) eyes open on the force plate, (b) eyes closed on the force plate, (c) eyes open standing on four inches of foam on top of the face plate, and (d) eyes closed standing on four inches of foam on top of the force plate. The four test conditions were repeated at each measurement encounter. With the first testing condition the subjects were uncomfortable and felt awkward and struggled to maintain balance. With the second set of tests the subjects became acclimated to the testing condition and had improved results as demonstrated by smaller measurements. It is possible that the firefighters learned what to expect and performed better in the sway testing.

Attrition. At the midpoint of the study, 29 participants had not attended the Tai Chi sessions because of the manpower changes in the economic restructuring of the fire stations. Instead of losing these participants, the firefighters agreed to stay in the study as the comparison group,

using the incentive of receiving fifty dollars added to their flex spending accounts. The creation of the two groups, comparison and treatment, resulted in a change in research design, allowing for for the quasi-experimental research study in which there was a comparison group. Although the groups were not randomly assigned, they were created by chance and the two groups were homogeneous.

Testing. Improved performance testing effects may have occurred with the lower body strength measure, the wall squats. The competitive spirit that exists within this male dominated culture was manifested with the wall squat measure. The position for the wall squat is as follows: back must be flat against a wall, feet separated and positioned a foot away from the wall, the body is lowered down to a 90 degree angle, and they held this position until they could no longer maintain the proper form. The individuals bragged about their results and challenged others to meet or beat them. These competitions occurred in both the control and intervention groups; however, only the intervention group had statistically significant results. The comparison group however, may not have had the same team bonding as the intervention due to the recent changes in fire houses.

An additional testing bias may have occurred within the initial cardiac measurements. Lower blood pressure and heart rates could have been the result of reactive measurements. During the initial measurements, the firefighters were generally concerned about the confidentiality of their protected medical information and were unfamiliar with the research team. This could have resulted in increased heart rate and blood pressure. The second blood pressure and heart rate measurements were significantly lower than the first measurements. The reliability of the changes due solely to Tai Chi is questionable. It is quite possible that their confidence in the PI to keep their results confidential along with Tai Chi may have facilitated the

changes. The firefighters may have been more relaxed with the second measure than with the first.

Another potential fidelity issue was variability in data collection times. The firefighters' initial measurements were taken when they consented to be in the study. The second set of measurements was taken after five weeks of Tai Chi instructions. The measures were taken after the Tai Chi Master Instructor had given five weeks of training; however, each participant may not have been present for each of the training sessions and could have been measured after attending a lessor number of sessions. Participation in Tai Chi training was effected by the firefighters' vacation days, transfers to other fire stations not participating in the study, and unscheduled days.

Another potential issue in variability was how each measurement was taken. According to Breen, Shakeshaft, Slade, D'Este, and Mattick (2011), data that are collected in the natural environment may have certain advantages for assessing interventions' true effects. These data may lack the validity and reliability of data collected in laboratory or controlled conditions. The initial procedure was for the PI or research assistant to take the study participants' heart rate, blood pressure, body fat, balance, and wall squat. These procedures were subject to change if a firefighter was called into action, a delay in the set-up of the force plate or the failure of the body fat analyzer occurred, or a firefighter transferred to another fire station before the completion of all measurements. Overall, these procedures were followed, although even small variances may affect the final results.

Instrumentation. The FUTREX – 6100/XL body composition analyzer was used to determine the individuals' percent of body fat and muscle mass. The FUTREX-6100/XL analyzer is a near infrared interactance (NIR) device that determines the body essential, reserve, and excess body

fat (FUTREX, 2010). The FUTREX-6100 instrument worked quite well during the initial and midpoint data collection points. While collecting the final measures, the analyzer quit working. The manufacturer was contacted to help identify the problem and a loaner machine was not available. The FUTUREX-6100 was shipped for repair and not returned for 10 days. However, other data were collected during this time without the analyzer. When the machine was returned, we continued to collect percent of body fat for the firefighters who were missed. This resulted in eight firefighters whose final body fat measure was not collected, four in each of the intervention and control groups. Over the next month, daily attempts were made to collect the missing data without avail. The units were constantly on brown-out; firefighters were either detailed out, off on a Kelly day, on a personal holiday, or on vacation. The coding for the data analysis excluded missing data and did not substitute the mean score in place of the missing data. Overall, there should not have been a significant change in either group.

Selection. A convenience sample was used for the Tai Chi study. The original estimated sample size of 50 to 60 participants were needed for an a =. 05 and power of .80. The study began with the recruitment of sixty participants. Originally all study participants volunteered to be in the intervention group. However, 29 of the 60 participants self-reported they were unable to attend the Tai Chi sessions and agreed to remain in the study as the comparison group. A major limitation for this study is the potential bias of whether the comparison group self-selected to not participate in Tai Chi training. The firefighters in the comparison group were not randomly assigned as the group was formed by chance. According to Portney and Watkins (2000), important differences between groups are controlled with random assignment. Both the intervention and comparison groups were homogenous. One notable difference between the groups was the level of physical activity, with the comparison group more active in intentional

physical activity. Perhaps because the comparison group was more active, there would not be significant changes to their cardiac associated risk factors. The reverse could be possible for the intervention group, because they were so inactive, they may have significantly increased their physical activity to account for the results identified in the study.

Sample size. The total number of participants for the study was 60 participants. The intervention group (n = 31) provided adequate power to produce a large effect size (r = 0.84) for the firefighters who practiced Tai Chi. This effect may have had a number of possible biases, including non-random assignment and a convenience sampling. The 31 participants in the intervention group are considered to be a small sample size and may not be representative of larger populations. None-the-less, the effect size indicates a strong potential for using Tai Chi as an intervention in studies with larger sample sizes.

Implications

Theory

Thoughts, people, feelings, and situations influence behavior changes (Sallis, Hovell, Hofstetter, & Barrington, 1982). Bandura's (1977) Social Learning Theory provided an accurate framework of how firefighters could achieve behavior changes with Tai Chi. Bandura identified attention, retention, motor reproduction, and motivation as processes that bring about health promotion.

As predicted, the Tai Chi Master Instructor provided the basic movements in Tai Chi and required the firefighters' attention throughout the instructional process. The PI frequently witnessed the firefighters practicing and was told that they practiced together to ensure retention of the Tai Chi movements and to help fine-tune the basic movements and stances. Motor reproduction was observed when the firefighters were able to demonstrate their mastery of the

movements. The firefighter had increased motivation to improve their health as they saw improvements in blood pressure, heart rate, body fat, and lower body strength. Firefighters at stations with the greatest number of Tai Chi sessions and more frequent practice sessions were stations with a house officer who was a health champion and participated in the group sessions. These individuals were committed to physical fitness and the health of their group. The champions challenged the firefighters to learn Tai Chi and attended sessions whenever possible.

Sallis, Hovell, Hofstetter, & Barrington (1992) surveyed 1739 community over a two-year period related to the respondents' vigorous physical activities. The survey was grounded in Social Learning Theory. Sallis et al. (1992) found the tenants of Social Learning Theory accounted for 12.3% to 15% of the studied explained variances. Moe et al. (2002) conduced a pilot study that found the team-centered model of Social Learning Theory was a better model to bring about behavioral changes in firefighters. Elliot et al. (2007) repeated the pilot study from 2002 with 599 participants and again reported that Social Learning Theory was a better model to bring about behavioral changes in firefighters.

Culture

According to Arnault (2009), culture impacts various aspects of health and illness and the behavioral practices of health promotion. This study would not have been successful without the firefighters' acceptance of our study group into their culture. The fire chief introduced the researcher to the largest fire stations that had two groups, such as an EMS and hook and ladder, for each of their units. The fire chief believed that having access to a larger number of firefighters would help with the recruitment efforts. When accompanied by the fire chief, no one signed up for the study. Afterwards, it was revealed that the firefighters felt the study results would not be kept confidential. With repeated visit and assurance of HIPAA confidentiality, they

slowly began signing up. Repeated trips were made to the eleven units enrolled in the study. As the firefighters, begun to recognize the study group, they became more accepting. They frequently offered us food and refreshments and began joking around. By the end of the study, the firefighters were asking medical questions about blood pressure, nutrition, medication, and sleeping problems.

Champion

According to Newton and Sofian (2007), the achievement of high levels of participation in the firefighter population is dependent upon trusted strong leaders. The Social Learning Theory identified the importance of a fire station leader who served as a health promotion champion. Firefighters must take responsibility for their own health. When motivated by a health conscious leader that they admire, they are more likely to make better choices about their health. The PI witnessed the interaction between the champion and the other members of the team. The champion encouraged the firefighters to practice along with him. The champion mastered the Tai Chi movements and helped the others to do the same. The presence and contribution of the champion may not be measureable, but his commitment to fitness may influence the sustainability of Tai Chi.

Research

Future research studies are needed with a similar population as well as with firefighter populations that are more ethnically diverse and have a larger gender balance. To improve fidelity with the intervention, it would be beneficial to offer weekly vouchers to the firefighters that could be used at Tai Chi centers at several locations, such as a YMCA, worksites, and through video conferencing. The study should be extended to at least six months to allow more time for the activity to become a habit that would be missed if not engaged in and to allow for

greater benefits of the activity. Studies with longer durations, however, may result in an increased attrition rate, but this could be addressed through the role of champion. There are many advantages to conducting measurements on a monthly basis. Monthly tracking would help to identify trends and identify situations that may require medical referrals. Although it would be helpful to conduct the study in a more stable environment to increase reliability, the reality is that economic and political events will continue to influence the work environment of public employees. The potential for historical events will always impact a field study.

Additional data could be collected with any successive studies. The firefighter could be given a quality of life questionnaire, an occupational stress inventory, and a nutrition questionnaire. These questionnaires would provide valuable insight into the overall quality of life of firefighters that was not collected in the first study. From observing the Cincinnati firefighters, it seemed that there was a decrease in family connection, an increase in off-duty alcohol use, poor nutrition, and an excessive amount of time watching television instead of exercising.

Practice

Each fire station had a plethora of exercise equipment that gathered dust. Fire stations would an excellent place to institute a health-related physical activity that has been shown to improve cardiac risk factors. Tai Chi does not require expensive equipment, storage space, or special clothing. Tai Chi can be practiced in a group or by an individual and by all age groups with varying degrees of intensity.

The prevalence of heart disease in firefighters is well documented in the literature, yet there are no documented programs that have successfully reduced the cardiac risk factors. The focus of future research should be the reduction of preventable cardiovascular risk factors and measures to improve the firefighter's general health status, which is congruent with the National

Occupational Research Agenda (NORA) (2009) Strategic Goal 1.5.4 that states, “By 2014, create effective evidence-based interventions for occupational cardiovascular disease risk factors and disseminate the information to career and volunteer fire service personnel through existing organizations” (p. 8). The 31 firefighters who participated in this study had statistically significant improvements in their cardiac measures. These finding are important to the health and welfare of the volunteer and career firefighters and will be disseminated to the participants, city fire officials, and reported in the literature.

Significance to Nursing

The results from this study will add to the body of nursing science. Occupational health nurses are more involved in worksite health promotion. Tai Chi could be implemented in many worksite settings to improve workers health, improve safety, and reduce cardiovascular risk factors. Improving workers’ health through health promotion activities would be an essential step towards meeting the Healthy People 2020 workplace goal, “Promote the health and safety of people at work through prevention and early intervention” (Healthy People, 2012). Additionally, Tai Chi is congruent with the National Occupational Research Agenda (NORA) (2009) Strategic Goal 1.5.4.: to create effective evidence-based worksite interventions to decrease cardiovascular disease risk factors.

Summary

In the general American population, one in four deaths is attributable to cardiovascular disease (CDC, 2010). Mortality for heart disease is even higher in firefighters. In the past five years, 48.6% of the firefighters’ work related deaths have resulted from a cardiovascular event (NORA, 2009). Improvement of cardiac status can be obtained by reducing cardiac risk factors (NFPA, 2010). The premise of the current study was to test the effectiveness of practicing Tai

Chi to reduce preventable cardiac risk factors, such as systolic and diastolic blood pressure, heart rate, and body fat, to lessen the burden of cardiovascular disease in firefighters, and to improve the overall physiological endurance to carry out the demanding and essential functions of their job.

A review of current research studies provided strong evidence of how Tai Chi greatly improved cardiac risk factors in individuals who are healthy and at high risk for cardiac disorders. Tai Chi had not been implemented as an alternate form of exercise in the firefighter population; however, in the current study, this form of mind-body exercise provided statistically significant findings of reduced cardiac risks factors in firefighters.

The first goal of the study was to determine if Tai Chi is beneficial in reducing cardiac risk factors within the firefighter's population of Cincinnati. The between-subject comparison of firefighters in the Tai Chi intervention group had statistically significant findings. The significant changes in mean scores from the initial to final measures were found in systolic blood pressure, diastolic blood pressure, and body fat. Additionally, the firefighters' overall heart rate was reduced. The between-subjects comparison for the control group had only one statistically significant finding, which was an increase in body fat from the second to the final measure.

The second goal of the study was to determine if Tai Chi was beneficial in improving physiological endurance in lower body strength, fatigue, and balance. The total time that the firefighters were able to maintain the time wall squat position from the initial to the final measure was a statistically significant improvement. There were several noteworthy changes in the fatigue scale results. The chronic fatigue score was increased and the acute fatigue was decreased. However, the inter-shift recovery did not change. The balance measures were not

improved. Of the 31 firefighter in the intervention group, 29 (93.5%) were at a low risk of developing stress-induced disease measured on the Holmes-Rahe Life Stress Inventory

Firefighters are at an increased risk for heart disease and it is important to reduce their cardiac risk factors. The results from participating in Tai Chi in this study were positive. The study followed adherence to the protocol, except in instances of instrument failure and a need to delay measurements due to unforeseen circumstances. Tai Chi was taught by a Master Instructor, the cardiac and lower body measures were measured by individuals who were trained on the measurement technique, and balance measures were conducted by the same individual who was trained on the measurement technique and had experience with the equipment. Because this was a field study, the issue of fidelity with the protocol implementation and measurements in different firehouses still remains an issue that may be controlled in other studies.

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Appendix A

A1: Adult Consent Form for Research

University of Cincinnati

Department: College of Nursing

Principal Investigator: Jane Christianson, RN, MSN

Faculty Advisors: Tracey L, Yap, RN, PhD

Title of Study: Tai Chi as a possible way to reduce cardiovascular risk factors in firefighters.

Introduction:

You are being asked to take part in a research study. Please read this paper carefully and ask questions about anything that you do not understand.

This research is sponsored by: The National Institute for Occupational Safety and Health Pilot Research Project Training Program of the University of Cincinnati Educational and Research Center.

Who is doing this research study?

The person in charge of this research study is Jane Christianson, RN, MSN of the University of Cincinnati (UC) Department of Department of Nursing.

She is being guided in this research by: Tracey L.Yap, RN, PhD

There may be other people on the research team helping at different times during the study.

What is the purpose of this research study?

The purpose of this study is to test the effectiveness of Tai Chi as a means to increase the physical fitness in firefighters and reduce the risks of coronary heart disease in this population.

Who will be in this research study?

About 60 working firefighters will take part in this study. The criterion to participate in this study is:

- You are a firefighter working in the greater Cincinnati area.
- All males and females working firefighters of any age are will participate in this study.
- Firefighters from any cultures or ethnic groups will participate.
- If you are female and pregnant, you will be excluded from participation

What if you are an employee where the research study is done?

Taking part in this research study is not part of your job. Refusing to be in the study will not affect your job. You will not be offered any special work-related benefits if you take part in this study.

What will you be asked to do in this research study, and how long will it take?

You will be asked to:

- Participate in a one hour a week session of Tai Chi for ten weeks.
- Practice Tai Chi two additional times a week for ten weeks.
- Complete a survey called Occupational Fatigue Exhaustion/Recovery (OFER) scale to measure your fatigue three times during the study.
- Allow the researchers to take measurements of your weight, height, waist circumference, percent of body fat, balance, upper and lower body strength, three times during the study.

It will take about:

- Tai chi sessions will take one hour per week.
- Two additional practice sessions will take approximately two hours per week.
- Completion of the survey will take about 10 minutes.
- The physical measurements will take about 30 minutes.

The research will take place at your fire station.

Are there any risks to being in this research study?

- It is not expected that you will be exposed to any risk by being in this research study.
- It is not expected that you will be exposed to any risk by allowing your information to be used in this research study.
- The risk is not expected to be more than you would have in daily life.
- If you experience a previously unknown risk or side effect from the participation in Tai Chi, psychological distress, or abnormal measurements, the researchers can give you information about people who may be able to help you.
- To reduce the possibility of any risk, you want to discuss the research requirements with your personal physician before participating in the study.

Are there any benefits from being in this research study?

The benefit from participating in the Tai Chi group could be improved physical fitness, decreased cardiac risk factors, and improved balance.

Will you have to pay anything to be in this research study?

You will not have to pay anything to take part in this study.

What will you get because of being in this research study?

You will not receive any payment for participation in this research study. You will receive a Tai Chi instructional reference worth $10.00 for participating in the study.

Do you have choices about taking part in this research study?

It is your choice to consent or decline to participate in the study. You may withdraw from the study at anytime during the study. If you withdraw on or after the fifth week, your partial data will be included in the study.

How will your research information be kept confidential?

Information about you will be kept private by:

- The researcher will use a study ID instead of your name on all research forms.

- The master list with the study ID numbers will be kept in a locked cabinet in the Nursing Institute of Research office. Only the researcher and faculty adviser will have access to the cabinet and information
- Limit the access to research data to only the research team.
- Your name will not be included in reporting of the results.
- The research data and spreadsheets will be stored on a password-protected computer at the College of Nursing at the University of Cincinnati.

The records from the study will be kept confidentially at the University of Cincinnati, College of Nursing for five year in order to comply with federal and university guidelines. After that it will be destroyed by the researcher.

Every effort will made to ensure your identity is not disclosed to anyone beyond the research team.

Where confidential information will be stored.

- The consent forms, and de-identified worksheets of measurements will be locked cabinets in the faculty researcher's campus office.
- The master list of the ID numbers will be locked in a secure cabinet in the Nursing Institute of Research at the college of Nursing. Only the researcher and faculty advisor will have access to the locked cabinet.

How long he research data and consent documents will be kept before removal of identifiers and/or destruction.

- Personal identifiers such as your name, birth dates, and ethnicity will be deleted within one week of collecting this information
- Federal regulations require that your signed consent documents must be kept for a minimum of three years after the study is closed.
- In compliance with the University of Cincinnati recommendation the original spreadsheets will be kept for two years after the study is closed.

How records will be destroyed.

- The research records will not contain personal information only assigned ID numbers.
- The computerized records which will be store in a secured service at the Center for Academic Technologies & Educational Resources at the College of nursing will be erased after the compliance periods have ended.
- All research papers, spreadsheets, consent documents, and master ID listing will be shredded after the compliance periods have ended.

The use of identifiers in publication/presentation.

- The data from this research study may be published; but you will not be identified by name.

Agents of the University of Cincinnati, the National Institute for Safety and Health may inspect study records for audit or quality assurance purposes.

What are your legal rights in this research study?

Nothing in this consent form waives any legal rights you may have. This consent form also does not release the investigator, National Institute for Health and Safety, or its agents from liability for negligence.

What if you have questions about this research study?

If you have any questions or concerns about this research study, you should contact Jane Christianson, RN, at her office 513-558-5122 or by her cell phone 513-646-9396.

Or, you may contact Dr. Tracey Yap at 513-558-5305

The UC Institutional Review Board – Social and Behavioral Sciences (IRB-S) reviews all non-medical research projects that involve human participants to be sure the rights and welfare of participants is protected.

If you have questions about your rights as a participant or complaints about the study, you may contact the Chairperson of the UC IRB-S at (513) 558-5784. Or, you may call the UC Research Compliance Hotline at (800) 889-1547, or write to the IRB-S, 300 University Hall, ML 0567, 51 Goodman Drive, Cincinnati, OH 45221-0567, or email the IRB office at irb@ucmail.uc.edu.

Do you HAVE to take part in this research study?

No one has to be in this research study. Refusing to take part will NOT cause any penalty or loss of benefits that you would otherwise have.

You may start and then change your mind and stop at any time. To stop being in the study, you should tell Jane Christianson, RN (513-646-9396).

Agreement:

I have read this information and have received answers to any questions I asked. I give my consent to participate in this research study. I will receive a copy of this signed and dated consent form to keep.

Participant Name (please print) _____

Participant Signature _____ Date _____

Appendix A

A1: Sign in Sheet for Firefighters Who Consent to Participate

Signature of Person Obtaining Consent _____ Date _____

Name	Code Number	Date	Firehouse Location

Appendix B

Activity Sheet for Reporting Tai Chi Practice

Code #	Station	Date	Date	Date	Date	Date	Date	Date	Date

Appendix C

Demographic Data

The following information will be combined with your measurement of blood pressure, percent of body fat, waist circumference, weight, height, upper and lower body strength, and your answers to the fatigue questionnaire. This information will help to determine if by practicing Tai Chi, there has been a reduction in cardiac risk factors of firefighters in greater Cincinnati. This information does not determine if you have heart disease. Your information will not be shared with your employer or any other 3rd party. Your information will be combined with everyone else who is participating in the study and resulted and only reported as totals.

Please answer the following personal information. Please only use your Assigned Code number.

Thank you for completing this questionnaire, the information is very important to the study.

Code Number	
Questions	**Answer**
Do You currently smoke?	
If you smoke, how many packs a day?	
What is your age?	
What is your gender?	
What is your ethnicity/race?	

How long have you been a firefighter?

What is your marital status?

What type of alcohol do you drink?

How often do you drink alcohol?

Do you currently exercise?

How often do you exercise?

What form of exercise do you practice?

Appendix D

Data Collection Data Sheet

ID #	Age	Gender	Marital Status	Eth/Race	Smoking Status	Exercise Patterns	Alcohol Cons	F FF Yrs.	Heart rate	Pulse	Wall Squat	Body Fat	Balance

Appendix E

Occupational Fatigue/Exhaustion Recovery (OFER) Scale

These statements are about your experience of FATIGUE and STRAIN at Work and Home OVER THE LAST FEW MONTHS

Circle a number from 0-6 “Strongly Disagree” to Strongly Agree” which best indicates your response

Code # _____ Date_____

	Strongly Disagree	Disagree	Slightly Disagree	Neither Agree or Disagree	Slightly Agree	Agree	Strongly Agree
1) I often feel I’m at the end of my rope with my work	**0**	**1**	**2**	**3**	**4**	**5**	**6**
2) I often dread waking up to another day of my work	**0**	**1**	**2**	**3**	**4**	**5**	**6**
3) I often wonder how long I can keep going at my work	**0**	**1**	**2**	**3**	**4**	**5**	**6**
4) I feel that most of the time I’m just “living to work”	**0**	**1**	**2**	**3**	**4**	**5**	**6**
5) Too much is expected of me in my work	**0**	**1**	**2**	**3**	**4**	**5**	**6**
6) After a typical work period I have little energy left	**0**	**1**	**2**	**3**	**4**	**5**	**6**
7) I usually feel exhausted when I get home from work	**0**	**1**	**2**	**3**	**4**	**5**	**6**
8) My work drains my energy completely every day	**0**	**1**	**2**	**3**	**4**	**5**	**6**
9) I usually have lots of energy to give to my family or friends	**0**	**1**	**2**	**3**	**4**	**5**	**6**

10) I usually have plenty of energy left for any hobbies and other activities after I finish work	**0**	**1**	**2**	**3**	**4**	**5**	**6**
11) I never have enough time between work shifts to recover my energy completely	**0**	**1**	**2**	**3**	**4**	**5**	**6**
12) Even if I'm tired from one shift, I'm usually refreshed by the end of the next shift.	**0**	**1**	**2**	**3**	**4**	**5**	**6**
13) I rarely recover my strength fully between work shifts	**0**	**1**	**2**	**3**	**4**	**5**	**6**
14) Recovering from work fatigue between work shifts isn't a problem for me	**0**	**1**	**2**	**3**	**4**	**5**	**6**
15) I'm often still feeling fatigued from one shift by the time I start the next one	**0**	**1**	**2**	**3**	**4**	**5**	**6**

Scoring CF_____AF_____ IR_____ Total_____

Appendix F

The Holmes-Rahe Life Stress Inventory

The Social Readjustment Rating Scale

INSTRUCTIONS: Mark down the point value of each of these life events that has happened to you during the previous year. Total these associated points.

Life Event	Mean Value
1. Death of spouse	100
2. Divorce	73
3. Marital separation from mate	65
4. Detention in jail or other institution	63
5. Death of a close family member	63
6. Major personal injury or illness	53
7. Marriage	50
8. Being fired at work	47
9. Marital reconciliation with mate	45
10. Retirement from work	45
11. Major change in the health or behavior of a family member	44
12. Pregnancy	40
13. Sexual difficulties	39
14. Gaining a new family member (i.e.. birth, adoption, older adult moving in, etc.)	39
15. Major business readjustment	39
16. Major change in financial state (i.e.. a lot worse or better off than usual)	38

17. Death of a close friend 37

18. Changing to a different line of work 36

19. Major change in the number of arguments w/spouse (i.e.. either a lot more or a lot less than usual regarding child rearing, personal habits, etc.) 35

20. Taking on a mortgage (for home, business, etc..) 31

21. Foreclosure on a mortgage or loan 30

22. Major change in responsibilities at work (i.e. promotion, demotion, etc.) 29

23. Son or daughter leaving home (marriage, attending college, joined mil.) 29

24. In-law troubles 29

25. Outstanding personal achievement 28

26. Spouse beginning or ceasing work outside the home 26

27. Beginning or ceasing formal schooling 26

28. Major change in living condition (new home, remodeling, deterioration of neighborhood or home etc.) 25

29. Revision of personal habits (dress manners, associations, quitting smoking) 24

30. Troubles with the boss 23

31. Major changes in working hours or conditions 20

32. Changes in residence 20

33. Changing to a new school 20

34. Major change in usual type and/or amount of recreation 19

35. Major change in church activity (i.e.. a lot more or less than usual) 19

36. Major change in social activities (clubs, movies, visiting, etc.) 18

37. Taking on a loan (car, TV, freezer, etc.) 17

38. Major change in sleeping habits (a lot more or a lot less than usual) 16

39. Major change in number of family get-togethers ("") 15

40. Major change in eating habits (a lot more or less food intake, or very different meal hours or surroundings) 15

41. Vacation 13

42. Major holidays 12

43. Minor violations of the law (traffic tickets, jaywalking, disturbing the peace, etc.) 11

Now, add up all the points you have to find your score.

- ***150 points or less*** means a relatively low amount of life change and a low susceptibility to stress-induced health breakdown.
- ***150 to 300 points*** implies about a 50% chance of a major health breakdown in the next 2 years.
- ***300 or more points*** raises the odds to 80% according to the Holmes-Rahe statistical prediction model.

Appendix G

The Wall Squat Procedure

- To start the wall squat test first stand with the back flat against a wall;
- Feet a foot away and shoulder width apart;
- Squat down, keeping the small of your back pressed firmly into the wall and knees are over the toes;
- Going down in a comfortable position, feeling any excess strain on the knees;
- Hold this position for up to one minute, or no longer maintain proper form;
- Results are recorded in seconds;
- Repeat the test two more times and use the best reading, however allow a rest period to allow the legs to recover (Wall squat test, 2010).