2010

Energy Expenditure of Structural Firefighters During a Typical Work Shift

Kimberly J. Affeldt
Ithaca College

ENERGY EXPENDITURE OF STRUCTURAL FIREFIGHTERS DURING A TYPICAL WORK SHIFT

A Masters Thesis presented to the Faculty of the
Graduate Program in Exercise and Sport Sciences
Ithaca College

In partial fulfillment of the requirements for the degree
Master of Science

By

Kimberly J. Affeldt

August 2010

Ithaca College
Graduate Program in Exercise & Sport Science
Ithaca, NY

CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Thesis of

Kimberly Affeldt

Submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health Sciences and Human Performance at Ithaca College has been approved.

Thesis Advisor: ______

Committee Member: ______

Candidate: ______

Chair, Graduate Progr
In Exercise &
Sport Sciences: ______

Dean of Graduate
Studies: ______

Date: 7 MAY 2010

ABSTRACT

This study examined the energy expenditure and heart rate of structural firefighters. Subjects included nine (N=9) full-time firefighters from Ithaca, NY, ranging in age from 21-48 years. All subjects completed four test days. Test day 1 included measurement of VO_{2max} and anthropometric data. During test days 2-4, activity count to estimate energy expenditure (EE) and heart rate (HR) were measured simultaneously using an Actiheart Monitor. During each shift (test days 2-4), subjects were required to document all activity at 15 minute increments. Activities were subsequently classified as emergency response (ER), simulation training (ST) or other shift activities (SA), and were synchronized with the activity count and heart rate data from the Actiheart. A 3x2 repeated measures ANOVA compared heart rate and activity count between ER and SA during the three test days. Data during ST was captured on only one firefighter therefore ST data was not included in the statistical analysis due to small sample size. As expected, mean HR was significantly higher during ER compared to SA. Surprisingly, EE during SA was significantly higher than EE during ER. The large difference could be due to the variety and intensity of tasks completed during SA and the amount of time during those activities. Accurate exercise prescription is essential to meet the physiological demands of the profession. Physical demands affect job performance and ultimately public safety. Shift activities like truck checks and truck washing should be considered when prescribing exercise to this population.

ACKNOWLEDGEMENTS

I would like to extend my greatest thanks to my thesis chairperson, Dr. Betsy Keller, for her guidance, support, and encouragement throughout the thesis process. I would also like to thank Dr. John Sigg for his knowledge and advice while completing my thesis. I would like to acknowledge Mini Mitter Co., Inc for their generosity in providing us with the Actiheart Monitors and computer software to complete this research. Thank you to my family. I could not have succeeded without their love and support. Finally, my utmost thanks to my husband Phil, for his motivation and help keeping things in perspective throughout this process.

TABLE OF CONTENTS

LIST OF TABLES

PROPOSAL

INTRODUCTION

Firefighting is a physically demanding job. Physiological stress experienced by firefighters is a result of many factors, including physical exertion while performing firefighting tasks, heat from metabolic energy production, insulative protective gear, and radiant heat of the fire (Smith & Petruzzello, 1998). Consequently, firefighting puts tremendous strain on the cardiovascular system. Sothman, Saupe, Jasenof, & Blaney (1992) found that during actual emergencies, firefighters operated at sustained intensities of 88 $\pm$6 % maximum heart rate (HR) for duration of 15 $\pm$7 min. The cardio-respiratory stress that firefighters experience, in combination with their high-risk profile for coronary artery disease, is a major concern. The health and well being of these firefighters directly affects their occupational risk, job performance, and ultimately public safety.

Considering the intense nature of their profession, it is essential for firefighters to have sufficient aerobic capacity to perform in a safe and efficient manner. Therefore, improving aerobic capacity is an important aspect of an exercise program, especially for firefighters. While exercise programs have proven effective for increasing firefighter's aerobic capacity (Roberts et al., 2002), it has not been clearly established as to what level these firefighters should train to safely perform job duties.

Moreover, there has been little research on the metabolic cost and energy expenditure of actual firefighting activities. Studies to date have measured energy expenditure in firefighters in a laboratory with simulated tasks or graded exercise tests (Ftaiti et al., 2001; Malley et al., 1999). Other studies reported metabolic cost of actual firefighting activities estimated from heart rate response (Richardson & Capra, 2001, Sothmann et al., 1992). No studies to date have evaluated energy expenditure during an active firefighter shift, including actual emergencies and routine duties. To effectively and safely prescribe exercise for this population, it is essential to understand the energy expenditure demands during a firefighting shift.

Statement of Purpose

The purposes of this study were to; 1) assess energy expenditure and heart rate during a firefighting shift using the Actiheart monitor (*Mini Mitter Co*., Inc., Bend, OR), to simultaneously quantify heart rate and physical activity, and 2) determine the exercise intensity that is appropriate to meet the demands of occupationally specific tasks during a firefighter shift.

Research Questions

The research questions for this study were:

1. What is the average energy expenditure during a typical firefighting shift?
2. What is the energy expenditure and heart rate response for actual firefighting emergencies, shift training and shift activities?
3. What is the net difference in energy expenditure between shift activities and emergencies?
4. Is shift training energy expenditure and heart rate response comparable to emergency response energy expenditure and heart rate response?

Assumptions of the Study

For the purpose of this study, the following assumptions were made at the start of the investigation:

1. The subjects were representative of professional full-time structural firefighters.
2. The Actiheart monitor is a valid instrument for assessing energy expenditure and heart rate in adult male firefighters.
3. Most energy expenditure associated with physical activity is best estimated by tracking the motions of the body's center of mass by wearing the activity monitor along the waistline.
4. Energy expenditure is a reliable and valid way to determine training intensity for firefighters.

Definition of Terms

The following terms were operationally defined for the purpose of this investigation:

1. Emergency Response – time during which the firefighter leaves the firehouse in response to an emergency call.
2. Shift Training- skills training organized by the fire department.
3. Shift Activities- all other time and activities not accounted for with emergencies and shift training.

Delimitations

The delimitations of this study were as follows:

1. Firefighters from the Ithaca Fire Department were used as subjects.

2. An electronic physical activity monitor was used to estimate energy expenditure during a firefighting shift.

Limitations

The limitations of this study were as follows:

1. The results may only apply to firefighters with demographics comparable to the Ithaca Fire Department.
2. Shift activities varied between firefighters in a normal and characteristic manner.
3. The Actiheart electronic physical activity monitor provided an estimation of energy expenditure.
4. Results may only apply to fire departments with similar emergency responses that are characteristic of the Ithaca, New York, area and the Ithaca Fire Department.

PROPOSAL

REVIEW OF LITERATURE

Introduction

Firefighting is a physically demanding job as a result of many factors including the protective equipment, heat from the fire, and the often sudden physical demands of the job. This puts firefighters at an increased risk for cardiovascular events and other complications. These factors combined outline the need for exercise training for firefighters. This review outlines both physiological and external factors affecting the physical demands of structural firefighting. Another major section is dedicated to examining cardiovascular disease risk factors and physical fitness in firefighters.

Physiological Factors

Firefighting places considerable strain on the body, especially the cardiovascular system, because of competing demands for blood flow to the metabolically active muscles and skin in response to thermoregulatory demands. The duration of the cardio-respiratory stress that firefighters experience can last up to 25 minutes (Barnard & Duncan, 1975). The strain placed on the cardiovascular system coupled with the nature and long duration of the activities places significant demands on both the anaerobic and aerobic energy systems (Gledhill & Jamnik, 1992).

Energy Expenditure

Gledhill and Jamnik (1992) sought to characterize the physical demands of firefighting. An initial task analysis of essential firefighting operations with current firefighting equipment was followed by an in-depth physical and physiological characterization of those tasks (Gledhill & Jamnik, 1992). During the most demanding firefighter operations (10% of those examined and also the most commonly encountered) the mean oxygen consumption (VO_2) was 41.5 $ml \cdot kg^{-1} \cdot min^{-1}$. Taking into account restrictions imposed by the use of the self-contained breathing apparatus (SCBA) and the duration of such operations, Gledhill and Jamnik (1992) recommended a minimum VO_{2max} standard for firefighters of 45 $ml \cdot kg^{-1} \cdot min^{-1}$.

Dreger & Peterson (2003) compared treadmill graded exercise tests in fire firefighters wearing gym clothes and full-gear including a breathing tank. Maximum oxygen consumption and power output were significantly lower in the full gear situation compared with the gym clothes situation. Also, personal protective equipment including a self-contained breathing apparatus has a negative impact on VO_{2max} and power output. The authors also measured oxygen consumption in firefighters while performing a physical fitness test during various work rates. Firefighters wearing personal protective equipment performed two trials of the fitness test: a paced trial approximately 8 minutes and a hard trial performed as fast as possible. Gas exchange variables were measured with a portable metabolic measurement system. The paced trial had lower average oxygen consumption than the hard trial. However, total oxygen consumption during the tests was the same.

These studies are the first to measure oxygen consumption of firefighters in simulated tasks. However, the assessments were done with fitness tests and laboratory testing. There still remains a lack of data regarding oxygen consumption and metabolic cost with firefighters during typical shifts and emergency response. The results from these studies also underscore the importance of aerobic fitness for firefighters.

Heart Rate Response

Heart rate response to both simulated fire drills and actual emergencies has been reported to reach maximal or near maximal values (Angerer et al., 2008; Ftaiti et al., 2001; Richardson & Capra, 2001; Smith et al., 1997; Smith et al., 2001; Sothmann et al., 1992). Studies varied in how maximal heart rate was determined. Some researchers chose to use age predicted heart rate while others chose treadmill and other exercise tests to determine maximum heart rates.

Smith et al. (2001) investigated the cardiovascular response of four trials of standardized tests in firefighter recruits. During short bouts of strenuous firefighting activity in a building that contained live fires, subjects reached age predicted max heart rate. This increase in heart rate response also required greater recovery time. Notably, there was a 30% reduction in cardiac output from the end of the first trial to the third trial. An increase in heart rate was not able to compensate for the reduction in stroke volume.

Sothmann and colleagues (1992) investigated heart rate response and oxygen consumption in experienced firefighters. Oxygen consumption was estimated from heart rate values using a measured treadmill $VO_{2\,max}$ and HR_{max} relationship. Heart rate response to actual emergencies was 88 $\pm$ 6% of exercise determined HR_{max}. Average estimated VO_2 for fire suppression activities was 25.6 $ml \cdot kg^{-1} \cdot min^{-1}$. This represents 60% of treadmill $VO_{2\,max}$ thus leaving sufficient reserve to meet unexpected metabolic demands common in actual fire fighting emergencies. The VO_2 reported by Sothman et al. (1992) is remarkably lower than more recent recommendations reported by Dreger and Peterson (2003). A possible explanation may be Sothman et al. (1992) used an estimation of VO_2 from heart rate while Dreger and Peterson (2003) used measured values.

More recently, Angerer and colleagues (2008) compared cardiocirculatory and thermal strain of firefighters during fire suppression exercises to an exercise stress test and aerobic exercise testing. Forty nine male professional firefighters were studied during a 30 minute fire operation in a large fire simulation plant. During the fire operation, maximum heart rates of 177 $\pm$ 23 bpm were recorded, with 7 subjects exceeding age predicted maximum heart rates. During the exercise stress test subjects were limited to 176 $\pm$ 3.3 bpm. During the annual aerobic exercise testing subjects reached 155 $\pm$ 13 bpm in turnout gear. During the fire operation maximum heart rates were higher than the stress test and the aerobic testing. Fire suppression causes extreme cardiovascular strain with high heart rates that were not sufficiently tested in medical exams. To increase the yield of screening for firefighters at risk of death during fire suppressions, the exercise should equal requirements in a real emergency (Angerer et al., 2008).

Heart Rate Estimation of VO_2

There is controversy regarding estimation of VO_2 from heart rate in firefighting. Heart rate estimation from controlled exercise tests may not consider uncontrollable factors in actual firefighting emergencies. A concern with using the HR x VO_2 relationship from a treadmill or other exercise tests is the error induced by such factors as heat and upper-body work inherent to structural fires (Sothmann et al., 1991; Sothmann et al., 1992) as well as psychological stress. Firefighters performed treadmill tests and a simulated fire suppression protocol while VO_2 and heart rate were measured to determine the relationship. The VO_2 during the simulated setting was approximately 20% less than the VO_2 that would have been predicted by treadmill testing at a corresponding heart rate. Accurate assessment of VO_2 provides important information for determining energy expenditure requirements of physically demanding tasks of firefighters (Sothmann et al., 1991).

External Factors

Thermoregulation is variable and modified by heat transfer interactions between skin surface area, clothing, and environments (Pascoe et al., 1994). Evaporation of sweat provides the most important means of cooling the body. When clothing interferes with evaporation of sweat from the skin, it increases skin and core temperature and lowers cooling efficiency. As sweat rate increases and vapor gradient decreases, the amount of evaporation possible will decrease, causing the skin to become wetted. Skin wettedness above 20% of the skin surface area becomes uncomfortable (Pascoe et al., 1994). Since clothing interferes with evaporation, skin wettedness continues to increase and will affect thermal comfort (Pascoe et al., 1994).

Gear

It has been suggested that changes in firefighting uniforms will affect physiological demands of firefighting. However, some studies have reported that there is no significant difference in physiological variables between types of gear (Malley et al., 1999; Smith & Petruzzello, 1998). In attempts to standardize the protective clothing, the National Fire Protection Agency required firefighters to wear bunker pants with low boots to provide greater protection (standard configuration). They also recommended a heat resistant hood be worn to protect the head and neck region. Standard configuration compared with a hip-boot configuration resulted in similar cardiovascular strain at maximal to near maximal limits. Also, firefighter's perceptions of effort were greater in the standard configuration of gear (Smith & Petruzzello, 1998). Most recently, Petruzzello, Gapin, Snook and Smith (2009) examined perceptual and physiological heat strain in laboratory and field-based studies. Using recently developed strain indices, The Physiological Strain Index and The Perceptual Strain Index, it was reported that even relatively brief bouts of exercise (5-15 minutes) while wearing heavy impermeable clothing resulted in high levels of heat strain.

In the mid 1990's the New York City Fire Department (FDNY) replaced traditional over-coats with modern, heavier over-coats. The modern uniforms provide greater burn protection but also resulted in greater heat retention. New York City firefighters sought to wear short sleeve shirts and shorts instead of long pants (modified modern uniform). They found that firefighters reached maximal heart rate during exercise regardless of uniform type and that exercise time decreased in modern uniforms compared with a modified modern uniform or traditional uniform (Malley et al., 1999).

Interestingly, Huang and colleagues (2009) found that wearing rubber boots compared to leather boots was more effective at resisting fatigue. Furthermore, force production during simulated stair climbing was improved with rubber boots as well.

Punaxaillo, Lusa and Luukkonen (2003) examined the effect of protective equipment on balance in younger and older firefighters. Wearing fire protective equipment significantly impaired postural and functional balance. Postural balance with eyes closed was more negatively affected among older versus younger subjects. These findings should be taken into consideration when developing fire protective equipment and training protocols for firefighter fitness.

Dreger, Jones and Peterson (2006) examined the effects of breathing apparatus and fire protective clothing on maximal oxygen uptake. Twelve male firefighters completed two randomly ordered graded exercise treadmill tests. Personal protective equipment and the self contained breathing apparatus had a negative impact on VO_{2max}. These findings underscore the importance of considering gear when evaluating the physiological demands of fire suppression and fitness levels of firefighters.

Richmond and colleagues (2008) examined the physical demands of firefighter search and rescue using different configurations of hose length and breathing apparatus. Replacing a short duration breathing apparatus with extended duration apparatus eliminated air supply as a limiting factor in performance, however, this increased the challenge of managing thermal strain due to the long duration spent in hot conditions.

Thermal Stress

Firefighting activities involve strenuous physical work, which is often performed in hot and hostile environments. Thermal strain results from the external stress of heat radiating from the fire and exercise-induced metabolic heat stress that is trapped due to the encapsulation provided by protective clothing (Smith et al., 1997). Smith and colleagues (1997) sought to examine the relative contributions of activity and external heat stress on the total thermal stress experienced by firefighters. There were significant increases in HR, tympanic temperature, blood lactate and perceived exertion in both a neutral (no fire) and hot environment. The increases were much greater following the hot condition. The addition of a live fire, a common situation for firefighters, contributed to increased cardiovascular strain.

Limited studies have examined the performance of firefighters in chemical protective suits during non-fire emergencies such as hazardous materials incidences. Richardson & Capra (2001) evaluated the physiological responses in a fully encapsulated chemical protective suit to simulated tasks at varying temperatures. The temperatures ranged from 30 to 40 degrees Celsius, which represent temperatures normally seen in the summer months. Increases in air temperature resulted in increased heart rate, recovery time, body temperature and blood pressure (Richardson & Capra, 2001).

Type of protective clothing also affects the thermal stress of firefighting activities. Ftaiti et al. (2001) sought to determine heart rate response and thermal stress in various fireproof jackets. French firefighters exercised at 70% of VO_{2max} for 15 minutes in five different jacket configurations: one leather and four textile types. Exercise in the leather jacket resulted in the highest tympanic temperature and heart rate. The physiological responses induced by textile jackets were correlated to jacket weight. Jackets with greater weight induced greater increases in tympanic temperature and heart rate. It was concluded that jackets made of textile material and lighter weight created less physiological stress during treadmill running.

Cardiovascular Disease Risk Factors

Heart disease has long been recognized as a significant health risk for firefighters. This population is not immune to the effects of aging. Age related changes in firefighters mirror those of the general population as seen with increases in percent body fat, resting blood pressure, and total blood cholesterol (Davis et al., 2002). However, the physical demands of firefighting remain high no matter what the professional firefighter's age. The combination of these two factors is why firefighters experience more occupational fatalities due to heart attack than persons in any other profession (Kay et al., 2001).

Being overweight may pose significant health and safety risks to firefighters and could adversely affect job performance. Kales and colleagues (1999) reviewed medical examination records of 333 firefighters and found that 290 (87%) were overweight according to Body Mass Index (BMI). There are adverse associations between BMI and resting blood pressures, serum cholesterol and vital capacity. Elevated blood pressure and cholesterol increase both cardiovascular disease risk and occupational risk. More recently, Kales and colleagues (2007) examined the duty specific risks of death from coronary heart disease among on-duty firefighters from 1994 through 2004. Certain emergency firefighting duties were associated with a risk of death from coronary artery disease that was markedly higher than the risk of non-emergency duties. Fire suppression was associated with the highest risk (Kales et al., 2007).

Clark and colleagues (2002) evaluated the usefulness of BMI as a screening tool for general health in firefighters. Body mass index was found to be a useful screening tool for general health and duty fitness status among firefighters. Screening tools such as this may be useful in identifying individual firefighters for health and fitness intervention measures. Donovan and colleagues (2009) documented the levels of cardiorespiratory fitness and metabolic syndrome in 214 male firefighters from Colorado. Thirty two firefighters met the diagnostic criteria for metabolic syndrome and 54 firefighters failed to achieve generally accepted minimum cardiorespiratory fitness levels. Increased levels of fitness were associated with improved metabolic profile in male firefighters (Donovan et al., 2009).

Soteriades and colleagues (2005) examined the distribution of BMI and its association with major cardiovascular disease risk factors in Massachusetts firefighters. Subjects were part of a statewide medical surveillance program over five years. The mean BMI of 332 firefighters increased from 29 at baseline to 30, and prevalence of obesity increased from 35% to 40%. The proportion of firefighters with extreme obesity increased four-fold from 0.6% to 2.4%. Obese firefighters were more likely to have hypertension and low HDL cholesterol at follow-up. Firefighters with extreme obesity had an average of 2.1 cardiovascular disease risk factors in contrast with 1.5 in normal weight firefighters. Obesity shows worsening trends over time and is a major concern among firefighters. Periodic medical evaluations coupled with exercise and dietary guidelines are needed to address this problem (Soteriades et al., 2005). Notably, Soteriades and colleagues (2008) found that obesity is associated with higher risk of job disability in firefighters.

Additionally, cholesterol screening is an established preventative measure for cardiovascular disease risk factors. Given the cardiovascular disease risk in firefighters, lipid profiling of firefighters is an important component to consider when evaluating such risk. Soteriades et al., (2002) investigated the lipid profile of 285 firefighters over a period of four years. Throughout the four-year period mean total cholesterol decreased significantly. Likewise, the proportion of firefighters taking lipid-lowering medication increased from 3% at baseline to 12% at follow-up. Triglyceride level increased over the four-year period. Despite regular examinations, a large number of firefighters had persistently high cholesterol and only a small number were receiving adequate treatment.

Firefighter's knowledge of modifying cardiovascular disease risk factors is an important aspect to consider when evaluating overall risk. Kay et al. (2001) found that a majority of 90+ firefighters did not think of themselves as overweight even though their calculated body mass index indicated otherwise. Firefighters recognized reducing caloric intake as an effective way to decrease body fat. However, making dietary changes was seen as confusing and not a priority for this population. Most firefighters have heard or read that food choice can prevent the development of heart disease, obesity, hypertension, cancer and diabetes. Although firefighters seemed aware of the effects of nutrition and lifestyle on cardiovascular disease risk, 37% reported that they enjoyed what they ate and did not want to change (Kay et al., 2001).

Summary

There are many factors that contribute to the physical demands of firefighting including gear, thermal stress, heart rate response, and energy expenditure. The increased physiological stress and prevalence of cardiovascular disease risk factors creates a potentially fatal combination for this population. This review highlights the importance of exercise and educational intervention for firefighters. There is no published research on actual energy expenditure and heart rate response during a typical shift of structural firefighters. It has also not been established what level of fitness firefighters should maintain to safely and effectively perform their job duties. This is essential information to help reduce cardiovascular disease and other risks given the high physical demands of this profession.

PROPOSAL

METHODS

Subjects were nine male firefighters (N=9) from the Ithaca Fire Department in Ithaca, New York. All subjects completed a graded treadmill test to determine maximum oxygen consumption (VO_{2max}). Energy expenditure was estimated with the Actiheart Monitor (*Mini Mitter Co.*, Inc., Bend, OR) during the firefighting shift on three separate occasions. The Actiheart Monitor was also used to record heart rate throughout the shift. Subjects maintained an activity log to document all emergency and training activities during the shift. Data regarding energy expenditure, heart rate, and activity documentation enabled the characterization of physical activity demands and physiological intensity of actual firefighting duties. Using this information, we aimed to more accurately determine the energy demand and minimum aerobic capacity for firefighters, and develop exercise guidelines that are occupationally specific to minimize the risk of cardiovascular events in firefighters.

This chapter describes in detail the methodology of the study. The methods section is subdivided as follows; (a) subjects, (b) design, (c) measurement and procedures, (d) data analysis.

Subjects

After approval of protocol by Ithaca College's Human Subjects Research Committee, the study commenced. Nine male professional firefighters (N=9) from the Ithaca Fire Department located in Ithaca, NY, were recruited for the study. Each subject had a minimum of two years experience as a full-time paid firefighter. All subjects completed a health history form to determine cardiovascular risk status. Exclusion criteria included two or more risk factors for cardiovascular disease, past or present coronary or pulmonary disease, metabolic disorders, or any orthopedic considerations that could have limited the subject's participation.

Design

All subjects attended an information session. During this session subjects were apprised of testing procedures, maintaining the activity log, and proper use of the Actiheart Monitor (*Mini Mitter Co*., Inc., Bend, OR). Subjects had the opportunity to ask questions and practice using the equipment. At the conclusion of the informational meeting, dates and times for testing were scheduled and subjects read and signed an informed consent form (Appendix A). Health history forms were given to those who chose to participate (Appendix B).

There were a total of four test days for each subject. Test day 1 included measurement of VO_{2max} during a graded treadmill test. Test days 2-4 involved monitoring energy expenditure, heart rate, and physical activities during two 10-hour firefighter shifts and one 14-hour shift.

The first day of testing was done in the exercise physiology laboratory at Ithaca College. The subjects performed a maximum graded treadmill test. There was a minimum of two days between test days 1 and 2 to allow adequate recovery.

Test days 2-4 were the same design. Subjects wore the Actiheart monitor for the duration of the firefighting shift. During each shift, subjects were required to document all activity in an activity log. The shift testing was done on three separate occasions to account for typical variation among shift activities. Data collection for each subject took place in a maximum time frame of three weeks.

MEASUREMENT

Maximum Oxygen Consumption

Maximum oxygen consumption (VO_{2max}) was measured during a graded treadmill test using open circuit spirometry with a Parvomedics (Parvomedics, Sandy, UT) metabolic measurement system. Subjects wore a two-way breathing valve, nose clip, and headgear to support the mouthpiece. Subjects wore the Actiheart Monitor to assess heart rate during the treadmill test. Subjects were given a 2-minute warm-up at a walk. The test protocol consisted of jogging at a self-selected pace at 0% grade which was increased 2.5% every two minutes until volitional exhaustion or fatigue. Heart rate and oxygen consumption were recorded at the end of each stage and at maximal exertion. The test was terminated when the subject reached volitional fatigue or showed signs or symptoms that are not consistent with a normal exercise response (e.g., chest pain, dizziness, shortness of breath, etc.).

Health History Questionnaire

The questionnaire (Appendix B) was used to determine the subject's cardiovascular disease risk status and to identify exclusion criteria. Those who were interested in participating, following the informational meeting, completed the questionnaire.

Activity Log

The activity log (Appendix C) required subjects to record activity in 15-minute increments during test days 2-4. Subjects classified activities as emergency response, simulation training, or other shift activities. This allowed for the investigator to match the activity log data with energy expenditure values obtained from the Actiheart throughout the entire shift.

Actiheart Monitor

The Actiheart Monitor (*Mini Mitter Co.*, Inc., Bend, OR) was used to estimate and record energy expenditure and heart rate. It consists of a triaxial accelerometer and ECG signal processor. Heart rate and activity counts are recorded synchronously at 15-second intervals. The Actiheart consists of a larger, round main sensor, and a lead to the positive electrode. The small monitor (10 g) is attached to one of two electrodes placed on the chest and the lead wire is attached to the other. Data from the monitor was downloaded using an interface and analyzed using the Actiheart software program (*Mini Mitter Co.*, Inc., Bend, OR).

Data Analysis

Descriptive statistics including mean and standard deviation were calculated for physical and physiological characteristics of subjects. Data from each shift was subdivided into minutes of simulation training (ST), emergency response (ER), and other shift activities (SA). The relative energy expenditure during a shift was determined as the ratio of energy expenditure during ST, ER, and SA and maximum energy expenditure calculated from the VO_{2max} test. A 3 x 2 repeated measures ANOVA was used to compare heart rate and energy expenditure between ST, ER, and SA during the three test days. Alpha level was set at $p < 0.05$.

PROPOSAL REFERENCES

Angerer, P., Kadiez-Gebhardt, S., Delius, M., Raluca, P., & Nowak, D. (2008). Comparison of cardiocirculatory and thermal strain during a fire suppression to exercise stress test and aerobic exercise testing. *American Journal of Cardiology, 102*(11), 1551-1556.

Barnard, R. & Duncan, H. (1975). Heart rate and ECG responses of firefighters. *Journal of Occupational Medicine, 17*, 247-250.

Clark, S., Rene, A., Theurer, W. M., & Marshall, M. (2002). Association of body mass index and health status in firefighters. *Journal of Occupational and Environmental Medicine, 44*(10), 940-946.

City of Phoenix (2000). Firefighter Recruit Candidate Physical Ability Test (CPAT). Available at http://www.ci.mesa.az.us/fire/firecpat/00_pdf/OrientationGuideW-Cover.pdf

Davis, S. C., Jankovitz, K. Z., & Rein S. (2002). Physical fitness and cardiac risk factors of professional firefighters across the career span. *Research Quarterly for Exercise and Sport, 73*(3), 363-368.

Donovan, R., Nelson, T., Peel, J., Lipsey, T., Voyles, W., & Israel, R.G. (2009) Cardiorespiratory fitness and metabolic syndrome in firefighters. *Occupational Medicine (Lond), 59*, 487-492.

Dreger, R. W. & Peterson, S. R. (2003). Measurement of VO_{2max} for firefighers: A new approach. *Canadian Society of Exercise Physiology Annual Meeting*, Brock University. Ontario, CA. October 1 – 4.

Dreger, R. W. & Peterson, S. R. (2003). Measurement of oxygen consumption during the CF/DND Fire Fit Test. *Canadian Society of Exercise Physiology Annual Meeting*, Brock University. Ontario, CA. October 1 – 4.

Dreger, R.W., Jones, R.L., & Peterson, S.R. (2006). Effects of the self-contained breathing apparatus and fire protective clothing on maximal oxygen uptake. *Ergonomics*, *49*(10), 911-920.

Ftaiti, F., Duflot, J. C., Nicol, C., & Grelot, L. (2001). Tympanic temperature and heart rate changes in firefighters during treadmill runs performed with different fireproof jackets. *Ergonomics*, *44*(5), 502-512.

Gledhill, N. & Jamnik, V. K. (1992) Characterization of the physical demands of firefighting. *Canadian Journal of Sport Science*, *17*(3), 207-213.

Heil, D. P. (2002). Estimating energy expenditure in wildland firefighters using a physical activity monitor. *Applied Ergonomics*, *33*(5), 405-413.

Huang, C. J., Garten, R.S., Wade, C., Webb, H.E., & Acevedo, E.O. (2009). Physiological responses to simulated stair climbing in professional firefighters wearing rubber and leather boots. *European Journal of Applied Physiology*, *107*(2), 163-168.

Kales, S. N., Polyhronopoulos, G. N., Aldrich, J. M., Leitao, E. O. & Christiani, D. C. (1999). Correlates of body mass index in hazardous materials firefighters. *Journal of Occupational and Environmental Medicine*, *41*(7), 589-595.

Kales, S.N., Soteriades, E.S., Christophi, C.A., & Christiani, D.C. (2007). Emergency duties and deaths from heart disease among firefighters in the United States. *New England Journal of Medicine*, *356*(12), 1207-1215.

Kay, B. F., Lund, M. M., Taylor, P. N., & Herbold, N. H. (2001). Assessment of firefighters' cardiovascular disease-related knowledge and behaviors. *Journal of the American Dietetic Association, 101*(7), 807-809.

Malley, K. S., Goldstein, A. M, Aldrich, T. K., Kelly, K. J., Weiden, M., Coplan, N., Karwa, M. L., & Presant, D. J. (1999). Effects of firefighting uniform (modern, modified modern, and traditional) design changes on exercise duration in New York City firefighters. *Journal of Occupational and Environmental Medicine, 41*(12), 1104-1115.

Pascoe, D. D., Bellinger, T. A., & McCluskey, B. S. (1994). Clothing and exercise: Influence of clothing during exercise/work in environmental extremes. *Sports Medicine, 18*(2), 94-108.

Petruzzello, S.J., Gapin, J.I., Snook, E., & Smith, D.L. (2009). Perceptual and physiological heat strain: Examination in firefighters in laboratory and field-based studies. *Ergonomics, 52*(6), 747-754.

Punaxallio, A., Lusa S., & Luukkonen, R. (2003). Protective equipment affects balance abilities differently in younger and older firefighters. *Aviation Space and Environmental Medicine, 74*(11), 1151-1556.

Richardson, J. E. & Capra, M. F. (2001). Physiological responses of firefighters wearing level 3 chemical protective suits while working in controlled hot environments. *Journal of Occupational and Environmental Medicine, 43*(12), 1064-1072.

Richmond, V.L., Rayson, M.P., Wilkinson, D.M., Carter, J.M., & Blacker, S.D. (2008). Physical demands of firefighter search and rescue in ambient environmental conditions. *Ergonomics, 51*(7), 1023-1031.

Roberts, M. A., O'Dea, J., Boyce, A., & Mannix, E. T. (2002). Fitness levels of firefighter recruits before and after a supervised exercise training program. *Journal of Strength and Conditioning Research, 16*(2), 271-277.

Smith, D. L, Manning, T. S., & Petruzzello, S. J. (2001). Effect of strenuous live-fire drills on cardiovascular and psychological responses of recruit firefighters. *Ergonomics, 44*(3), 244-254.

Smith, D. L. & Petruzzello, S. J. (1998). Selected physiological and psychological responses to live-fire drills in different configurations of firefighting gear. *Ergonomics, 41*(8), 1141-1154.

Smith, D. L., Petruzzello, S. J., Kramer, J. M., & Minser, J. E. (1997). The effects of different thermal environments on the physiological and psychological responses of firefighters to a training drill. *Ergonomics, 40*(4), 500-510.

Soteriades, E. S., Kales, S. N., Liarokapis, D., Christoudias, S. G., Tucker, S. A., & Christiani, D. C. (2002). Lipid profile of firefighters over time: Opportunities for prevention. *Journal of Occupational and Environmental Medicine, 44*(9), 840-846.

Soteriades, E.S., Hauser, R., Kawachi, I., Christiani, D.C., & Kales, S.N. (2008). Obesity and risk of job disability in male firefighters. *Occupational Medicine, 58*(4), 245-250.

Soteriades, E.S., Hauser, R., Kawachi, I., Liarokapis, D., Christiani, D.C., & Kales, S.N. (2005). Obesity and cardiovascular disease risk factors in firefighters: A prospective cohort study. *Obesity Research, 13*(10), 1756-1763.

Sothmann, M., Saupe, K., Raven, P., Pawelczyk, J., Davis, P., Dotson, C., Landy F., & Siliunas, M. (1991). Oxygen consumption during fire suppression: Error of heart rate estimation. *Ergonomics, 34*(12), 1469-1474.

Sothmann, M., Saupe, K., Jasenof, D., & Blaney, J. (1992). Heart rate response of firefighters to actual emergencies. *Journal of Occupational and Environmental Medicine*, *34*(8), 797-800.

MANUSCRIPT

INTRODUCTION

Firefighting is a physically demanding job. Physiological stress experienced by firefighters is a result of many factors, including physical exertion while performing firefighting tasks, heat from metabolic energy production, insulative protective gear, and radiant heat of the fire (Smith & Petruzzello, 1998). Consequently, firefighting puts tremendous strain on the cardiovascular system. Sothman, Saupe, Jasenof, & Blaney (1992) found that during actual emergencies, firefighters operated at sustained intensities of 88$\pm$6 % maximum heart rate (HR_{max}) for a duration of 15$\pm$7 min. The cardio-respiratory stress that firefighters experience in combination with their high-risk profile for coronary artery disease is a major concern. Recent research by Kales and colleagues (2007) found that fire suppression was associated with the highest risk of death from cardiovascular disease compared with non-emergency duties. The health and well-being of these firefighters directly affects their occupational risk, job performance, and ultimately public safety.

Considering the intense nature of their profession, it is essential for firefighters to have a sufficient aerobic capacity to perform in a safe and efficient manner. Therefore, improving aerobic capacity is an important aspect of an exercise program, especially for firefighters. While exercise programs have proven effective for increasing firefighter's aerobic capacity (Roberts et al., 2002), it has not been clearly established as to what level these firefighters should train to effectively prepare for safe performance of job duties.

Moreover, there has been little research on the metabolic cost and energy expenditure of actual firefighting activities. Studies to date have measured energy expenditure in firefighters in a laboratory using simulated firefighting tasks or graded exercise tests (Ftaiti et al., 2001; Malley et al., 1999). Other studies reported metabolic cost of actual firefighting activities estimated from heart rate response (Richardson & Capra, 2001, Sothmann et al., 1992). No studies to date have simultaneously evaluated heart rate and energy expenditure during an active firefighter shift, including actual emergencies and routine duties. To effectively and safely prescribe exercise for this population, it is essential to understand the energy expenditure demands during a firefighting shift. Therefore, the purposes of this study were, 1) to simultaneously assess energy expenditure and heart rate during one 14-hour and two 10-hour firefighting shifts, and, 2) determine the exercise intensity for exercise prescription that is appropriate to meet the demands of occupationally-specific tasks during a firefighter shift.

METHODS

Subjects

Subjects included nine (N=9) apparently healthy male professional firefighters from Ithaca, a small city in central New York. The Human Subjects Research Board at Ithaca College approved the research protocol for this investigation. Permission was also granted from the chief of the Ithaca Fire Department. All subjects attended an information session. During this session subjects were apprised of testing procedures, received instructions to maintain an activity log and for proper use of the Actiheart Monitor (*Mini Mitter Co.*, Inc., Bend, OR) to measure heart rate and physical activity simultaneously. Subjects also had the opportunity to ask questions and practice using the equipment. All subjects completed informed consent and health history forms.

Test Schedule

Subjects completed four test sessions on separate days. Test day 1 included measurement of VO_{2max} during a graded treadmill test using open circuit spirometry. Expired gases were collected and analyzed using a metabolic measurement system (Parvomedics, Sandy, UT). During test days 2-4 activity count to estimate energy expenditure and heart rate were measured simultaneously. Physical activities during two 10-hour firefighter shifts and one 14-hour shift were recorded every 15 minutes in the activity log.

OUTCOME MEASURES

Heart Rate and Activity Count

During test days 2-4, subjects wore the Actiheart Monitor for the duration of the shift to measure activity count and heart rate. The Actiheart is a triaxial accelerometer and ECG signal processor. Heart rate and activity counts were recorded synchronously at 15-second intervals. The Actiheart consists of a 33 mm diameter main sensor, connected by a short lead (120 mm) to a smaller (7 mm) secondary sensor. The small main sensor (10 g) is attached to one of two electrodes placed on the chest and the secondary sensor is attached to the other electrode. Data from the monitor was downloaded using an interface and analyzed using the Actiheart software program (version 2.0).

Activity Log

During each shift (test days 2-4), subjects were required to document all activity on a log sheet at 15 minute increments. Activities were subsequently classified as emergency response (ER), simulation training (ST), or other shift activities (SA). This enabled the activity log data to be synchronized with the activity count and heart rate from the Actiheart throughout the entire shift.

Statistical Methods

Descriptive statistics including mean and standard deviation were calculated for anthropometric and physiological characteristics of the subjects. Data from each shift were categorized into minutes of ST, ER, and SA. A 3 x 2 repeated measures ANOVA was used to compare heart rate and activity count between ER and SA during the three test days. Data during ST was captured on only one firefighter, therefore ST data was not included in the statistical analysis due to the small sample size. Missing data points were estimated by using the mean of subject scores for test days 2, 3, and 4. When an interaction was found, a one-way ANOVA was run on the main effects to determine significance. Alpha level was $p < 0.05$.

RESULTS

Nine male professional firefighters from Ithaca, New York completed four test sessions on separate days. Table 1 presents anthropometric and physiological data obtained during test day 1.

Table 1

Subject characteristics (N=9)

	Mean (SD)		Range
Age (yr)	32.8	(7.4)	21.0 - 48.0
Height (cm)	179.4	(5.8)	168.0 -185.0
Weight (kg)	92.2	(22.9)	63.2 -144.1
BMI (kg/m^2)	28.4	(5.5)	22.4 - 40.8
HR_{max} (bpm)	186.0	(11.0)	160.0 - 200.0
VO_{2max} ($L \cdot min^{-1}$)	4.4	(0.8)	3.2 - 5.7
VO_{2max} ($ml \cdot kg^{-1} min^{-1}$)	49.0	(7.7)	38.1 - 62.9

Test subjects ranged in age from 21 to 48 years. Mean BMI was 28 kg/m^2 which characterized the group as overweight (ACSM, 2006).

Table 2 represents HR and energy expenditure (EE) values for shift activities (SA) and emergency response (ER) compared with total shift (TS) values.

Table 2

Summary of EE (kcals) and HR (bpm) during Shift Activities (SA), Emergency Response (ER), and Total Shift (TS) conditions (N=9)

	Mean	SD	95% CI	
			Lower	Upper
HR-SA	81.3^	3.1	74.1	88.3
HR-ER	90.4	2.9	83.8	97.1
HR-TS	79.5	10.1	75.7	83.3
EE-SA	500.9*	48.6	388.7	613.1
EE-ER	62.2	11.4	35.8	88.5
EE-TS	558.0	235.7	469.1	647.9

^ ($p<0.05$) Statistically significant difference between HR-SA and HR-ER.
* ($p<0.05$) Statistically significant difference between EE-SA and EE-ER.

As expected, mean HR was significantly higher during ER compared to SA. However, the upper confidence interval value of HR-ER was only 97.1 bpm. Surprisingly, EE during SA was significantly higher than EE during ER. The large difference in upper and lower confidence intervals for EE-SA could be due to the variety of tasks completed during SA on different test days.

Table 3 represents all data collected during test days. Mean EE, EE rate, total time in activities, HRmax and HR are shown for test days 2-4.

Table 3

Summary of variables measured during Shift Activities (SA) and Emergency Response (ER)

	Shift Activities				Emergency Response				
	Mean	SD	95% CI		Mean	SD	95% CI		p value
Total EE (kcals)	500.9*	48.7	388.7	613.1	62.2	11.4	35.8	66.5	0.000
EE Rate (kcals/min)	0.9	0.4	0.7	1.0	1.2	1.0	0.8	1.6	0.171
Total Time (min)	605.6*	12.6	576.4	634.7	49.5	7.0	33.5	65.6	0.000
HRmax (bpm)	148.9*	8.0	130.3	167.4	120.6	6.9	104.8	136.4	0.008
Mean HR (bpm)	81.3*	3.1	74.1	88.4	90.4	2.9	83.8	97.1	0.000

* (p<0.05) Statistically significant differences between SA and ER.

Mean HR was only 9 bpm higher during ER compared with SA. This could be due to the limited number of physiologically demanding emergency responses during the data collection. Surprisingly, HR_{max} was significantly higher during shift activity (148.9 bpm) compared to ER (120.6 bpm). However, firefighters exercised, cleaned trucks, or performed truck checks during shifts; activities that were categorized as SA time. According to the activity logs, a majority of emergency responses were to fire alarms and not to building fires. Consequently, total time in SA (605 min) was greater than ER (49 min), and total EE was higher during SA compared to ER (p<0.05). The limited time of ER resulted in a smaller EE Rate ($kcal \cdot min^{-1}$). While EE Rate appears higher during ER versus SA (1.2 vs 0.9 kcals/min, respectively), the difference was not significant.

DISCUSSION

The present study was conducted to characterize heart rate and energy expenditure during an actual firefighter work shift. From this information we aimed to determine the appropriate exercise intensity to meet the occupationally specific demands of the job.

During emergency responses (ER) heart rate was higher than during other shift activities (SA). The difference in energy expenditure between conditions mirrored the difference in heart rate. The rate of energy expenditure (EE Rate) was 33.3% greater in ER than SA but this difference was not statistically significant. This could be due to the nature of infrequent ER activities. Emergency responses that were quantified included a car fire and extrication, fire alarm responses with building walk-through in full thermo-protective gear, and EMS calls. In other studies heart rate response to both simulated fire drills and actual emergencies have been reported to reach maximal or near maximal values (Ftaiti et al., 2001; Richardson & Capra, 2001; Smith et al., 1997; Smith et al., 2001; Sothmann et al., 1992). Given the implication of these results, it is important that further research be conducted with a larger sample size and within fire departments that more frequently deal with emergency responses and structural fires to more accurately characterize the physiological demands of firefighting.

Another important finding relevant to job specific demands is that maximum heart rate was higher during shift activities. Upon review of individual activity log data, this difference is largely attributed to strenuous truck washing and truck checks. Once a week, fire trucks were washed and all equipment was checked. When activity logs were compared with Actiheart data, peak heart rate during SA was higher than during ER.

This is an important aspect of a work shift that should be considered when determining the physical demands of occupationally specific tasks. The higher peak HR during SA could also be attributed to firefighters who exercised on shift. At all stations firefighters had access to at least one piece of cardiovascular exercise equipment, and at some stations strength training equipment was available. When individual activity log information was matched with Actiheart data, some peak heart rates occurred during bouts of exercise.

Individuals should be able to maintain an exercise intensity of 77% HR_{max} for extended periods of time (at least 20 minutes) and in situations of physical and emotional distress according to American College of Sports Medicine (ACSM, 2006). Using data collected from firefighter shifts and a maximal treadmill test, Table 4 shows the percentage of firefighters in the present study who achieved ACSM recommended $\%HR_{max}$ during SA and ER.

Table 4

Summary of ACSM recommended $\%HR_{max}$ (77-90%), for physical activity, and the percentages of firefighters from this sample who achieved those levels.

	ACSM Recommended % HR_{max}		
	77%	85%	90%
% of firefighters with peak HR ≥ ACSM guidelines during SA	77.8	66.7	44.4
% of firefighters with peak HR ≥ ACSM guidelines during ER	33.3	11.0	0.0
% of firefighters with max HR ≥ ACSM guidelines during maximal treadmill test	100.0	100.0	100.0

Data in Table 4 indicates that 33.3% of firefighters reached 77% HR_{max} during ER and only 11% reached 85% or more of HR_{max} during ER. No firefighters obtained 90% HR_{max} during ER. During SA, 77.8% of firefighters worked at 77% HR_{max} and only 44.4% reached 90% of HR_{max}. According to Barnard and Duncan (1975) and ACSM guidelines, firefighters should be physically prepared to endure cardio-respiratory stress for 20-25 minutes. In the current study, some firefighters did not obtain ACSM recommended 77-90% HR_{max} during SA and ER nor did they perform for 20-25 minutes at such intensity. Emergency responses were not as physically demanding as shift activities. This underscores the idea that the intensity of shift activities, including washing the truck and checking equipment, should be considered when prescribing exercise to this population. All firefighters reached 90% or above of HR_{max} during the max treadmill test. This indicates that the population in this study was capable of reaching 90% HR_{max} if ER or SA required them to do so, but it is not clear from the data how many could perform job duties safely for extended periods of time at that intensity. According to Angerer et al. (2008) firefighters reached higher heart rates during simulated fire operations compared with a stress test or annual aerobic test. This underscores the notion that firefighters need to be prepared to endure and perform under extreme cardiorespiratory strain and that traditional exercise testing may not sufficiently indicate their ability to do so.

In the current study, there were firefighters who never reached 77% of HRmax during either SA or ER. Routine job duties do not prepare firefighters for extreme conditions they can be faced with during emergency response. According to Kales and colleagues (2007) fire suppression is associated with the highest risk of death from cardiovascular disease compared with other non-emergency duties. Given the amount of time spent in low-intensity shift activities and the infrequency of physically demanding emergency responses, appropriate exercise programs are essential to maintain the fitness level of firefighters who will, and do, face intense fire suppression emergencies.

Sotereriades and colleagues (2005) found that obesity rates and cardiovascular risk factors worsened over time. This indicates that appropriate exercise prescription and dietary guidelines are needed to address this problem. With regard to exercise prescription and aerobic capacity, a limitation of this study is the small number of emergency responses and also the nature of those responses. There were a limited number of emergency responses. There were no emergency responses to building fires. Thermal stress due to environment was not well represented in this study. The majority of emergency responses were to fire alarm calls that occasionally required a building walk-through, or were cancelled en route. Likewise, ER activities were not of typical length or intensity compared to those reported by Barnard and Duncan (1975). Therefore, cardiovascular drift due to dehydration was not a factor in the present study.

The firefighter activities evaluated in this study were real. There was no simulation of any activity. There were no changes to any equipment or to fire protection gear. Thus accurate exercise prescription is essential to meet the expected physiological demands of a true emergency situation for firefighters. Likewise, shift activities such as truck checks and truck washing should be considered when prescribing exercise to this population. Physical demands affect job performance and underscore the importance of firefighter fitness. As explained by Davis et al. (2002), age-related changes in firefighters mirror those of the general population, however, their job demands remain the same.

Further research is essential to help reduce the cardiovascular events and other risks given the high demands of the profession, which ultimately affects public safety.

MANUSCRIPT REFERENCES

American College of Sports Medicine. (2006). *ACSM's Guidelines for Exercise Testing and Prescription* (7th ed.). New York:Lippincott Williams & Wilkins.

Angerer, P., Kadiez-Gebhardt, S., Delius, M., Raluca, P., & Nowak, D. (2008). Comparison of cardiocirculatory and thermal strain during a fire suppression to exercise stress test and aerobic exercise testing. *American Journal of Cardiology, 102*(11), 1551-1556.

Barnard, R. & Duncan, H. (1975). Heart rate and ECG responses of firefighters. *Journal of Occupational Medicine, 17*, 247-250.

Davis, S. C., Jankovitz, K. Z., & Rein, S. (2002). Physical fitness and cardiac risk factors of professional firefighters across the career span. *Research Quarterly for Exercise and Sport, 73*(3), 363-368.

Ftaiti, F., Duflot, J. C., Nicol, C., & Grelot, L. (2001). Tympanic temperature and heart rate changes in firefighters during treadmill runs performed with different fireproof jackets. *Ergonomics, 44*(5), 502-512.

Kales, S.N., Soteriades, E.S., Christophi, C.A., & Christiani, D.C. (2007). Emergency duties and deaths from heart disease among firefighters in the United States. *New England Journal of Medicine, 356*(12), 1207-1215.

Kay, B. F., Lund, M. M., Taylor, P. N., & Herbold, N. H. (2001). Assessment of firefighters' cardiovascular disease-related knowledge and behaviors. *Journal of the American Dietetic Association, 101*(7), 807-809.

Malley, K. S., Goldstein, A. M, Aldrich, T. K., Kelly, K. J., Weiden, M., Coplan, N., Karwa, M. L., & Presant, D. J. (1999). Effects of firefighting uniform (modern, modified modern, and traditional) design changes on exercise duration in New York City firefighters. *Journal of Occupational and Environmental Medicine, 41*(12), 1104-1115.

Richardson, J. E. & Capra, M. F. (2001). Physiological responses of firefighters wearing level 3 chemical protective suits while working in controlled hot environments. *Journal of Occupational and Environmental Medicine, 43*(12), 1064-1072.

Roberts, M. A., O'Dea, J., Boyce, A., & Mannix, E. T. (2002). Fitness levels of firefighter recruits before and after a supervised exercise training program. *Journal of Strength and Conditioning Research, 16*(2), 271-277.

Smith, D. L, Manning, T. S., & Petruzzello, S. J. (2001). Effect of strenuous live-fire drills on cardiovascular and psychological responses of recruit firefighters. *Ergonomics, 44*(3), 244-254.

Smith, D. L. & Petruzzello, S. J. (1998). Selected physiological and psychological responses to live-fire drills in different configurations of firefighting gear. *Ergonomics, 41*(8), 1141-1154.

Smith, D. L., Petruzzello, S. J., Kramer, J. M., & Minser, J. E. (1997). The effects of different thermal environments on the physiological and psychological responses of firefighters to a training drill. *Ergonomics, 40*(4), 500-510.

Soteriades, E.S., Hauser, R., Kawachi, I., Liarokapis, D., Christiani, D.C. & Kales, S.N., (2005). Obesity and cardiovascular disease risk factors in firefighters: A prospective cohort study. *Obesity Research, 13*(10), 1756-1763.

Sothmann, M., Saupe, K., Raven, P., Pawelczyk, J., Davis, P., Dotson, C., Landy F., & Siliunas, M. (1991). Oxygen consumption during fire suppression: Error of heart rate estimation. *Ergonomics*, *34*(12), 1469-1474.

Sothmann, M., Saupe, K., Jasenof, D., & Blaney, J. (1992). Heart rate response of firefighters to actual emergencies. *Journal of Occupational and Environmental Medicine*, *34*(8), 797-800.

APPENDICES

APPENDIX A

Informed Consent Form

1. Purpose of the Study

The purpose of this study is to determine the energy expenditure of a typical work shift of structural firefighters.

2. Benefits of the Study

You may benefit from this study because you will learn what your maximum aerobic capacity is. Your results may also aid in the development of exercise training guidelines for your personal benefit as well as other firefighters. You are welcome to have a copy of your results once the study is completed. (See principal investigators.)

3. What You Will Be Asked To Do

If you agree to participate you will be asked to attend an information session and complete a health history form. During the info session you will get more details about test procedures and schedules, maintaining an activity log, and proper use of the Actiheart Monitor. You will have the opportunity to ask questions and practice using the equipment. At the commencement of the informational meeting, dates and times for testing will be scheduled.

You will participate in four days of testing. The first day of testing will be done in the exercise physiology laboratory at Ithaca College. You will perform a maximal exercise test (VO_{2max}) using a treadmill. For the treadmill test you will wear gym shorts, tee shirts and sneakers. You will wear a mouthpiece, nose clip, and headgear to support a breathing valve used to collect expired gases. You will also wear the Actiheart Monitor to assess heart rate during the treadmill test. You will be given a 2-minute warm-up at a walk. The testing protocol will consist of jogging at a self-selected pace at 0% grade and will increase by 2.5% every two minutes. The test will continue until you reach exhaustion or show signs or symptoms that are not consistent with a normal exercise response.

There will be a minimum of 2 days between test days 1 and 2. The 3 shift testing sessions will be the same. You will wear the Actiheart monitor for the duration of the 10-hour firefighting shift. The Actiheart consists of a small device, worn on the waist, as well as two ECG pads placed on the chest. The main device is worn over regular clothing but below any additional equipment or gear you may be required to use for fire protection. During each shift, you will be required to document all activity in an activity log. At the end of the firefighting shift, you will remove the monitor. The 10-hour shift testing will be done on three separate occasions to ensure data collected is representative of a typical firefighting shift. All testing, and your participation, will be completed in a maximum time period of 3 weeks. Your total estimated participation will include 3 shifts (10 hours each) and 1-2 hours of treadmill testing and additional data collection like filling out a health history questionnaire.

4. Risks

Potential risks of participation in this type of study are no greater (or even less) than risks associated with your current job. You could encounter difficulty breathing or shortness of breath, dizziness, chest pain/discomfort, excessive perspiration, and fatigue. The risk of a cardiac event in VO_{2max} testing is 1 event per 187,500 hours of testing. The risk of death from VO_{2max} testing is 1 death per 346,000 hours of testing. In the case of cardiac event, first-aid will be immediately administered and additional medical personnel will be summoned. Additional risks could include physical injuries during testing including but not limited to sprains, strains, abrasions, and contusions. To minimize risk, adequate warm-up will be provided. If serious injury occurs, emergency medical personnel will be summoned by one of the on-site investigators. You may stop participation or withdraw from the study at anytime without question. In the case that you do withdraw, your data will be excluded from the study.

5. Compensation for Injury

In the case of other injuries, you will be referred to your primary care physician. If you suffer an injury that requires treatment or hospitalization as a direct result of this study, the cost of such care will be charged to you. You will be responsible to pay all costs not covered by insurance. Ithaca College will not pay for any care, lost wages, or provide other financial compensation.

6. If You Would Like More Information About the Study

Please contact the principal investigator, Kimberly Affeldt, for more information about this study or to get a copy of the results. She can be reached at 607-227-3023 weekdays or at Kaffeld1@ithaca.edu.

7. Withdrawal from the Study

I understand that I may stop participating or withdraw from this study at any time without question. If I withdraw, the data gathered from my testing session will be destroyed and not used in the study. The investigators would appreciate if you would inform them of your decision not to continue participation. Your individual data will not be shared with supervisory personnel. Only aggregate data will released.

8. How the Data Will Be Kept in Confidence

All data collected will be confidential. All data (paper, computer printouts) will be kept in a locked cabinet in a secure laboratory or office. Computer files will be maintained on a computer protected by a password. Your data will be identified with an alphanumeric code. The key for this code will be accessible only by the investigators and will be kept in a secure location.

I have read the above and I understand its contents. I agree to participate in this study. I acknowledge that I am 20 years of age or older. I have received a copy of this consent form for my own records.

Name (PRINT): ____________________________

Signed (SIGN): ___________________________ Date: _________

APPENDIX B

Health History Questionnaire

Name____________________ Date of Birth_______________ Age______

1. **Date of last physical exam**______________________________Month/Year

2. **Date of last fitness test**_________________________________Month/Year

3. **Circle any who have died of heart attack before age of 55:**

   Father Brother Son

4. **Circle any who have died of heart attack before age of 65:**

   Mother Sister Daughter

5. **Circle operations you have had:**

Back	Heart	Kidney	Eyes	Joint	Neck
Ears	Hernia	Lung	Other: (please specify)__________		

____

6. **Circle any of the following of which you have been diagnosed or treated for by a physician or health care professional:**

Alcoholism	Diabetes	Kidney Problems	Anemia, sickle cell
Emphysema	Anemia, other	Epilepsy	Neck Strain
Asthma	Eye Problems	Obesity	Mental Illness
Back Strain	Gout	Phlebitis	Bleeding trait
Hearing loss	Rheumatoid arthritis	Bronchitis, chronic	heart problem
Stroke	Cancer	High blood pressure	Thyroid Problem
Cirrhosis, liver	Hypoglycemia	ulcer	concussion
Hyperlipidemia	congenital defect	infectious mononucleosis	

Other____

7. **List all medications you are presently taking or have take within the past 6 months:**____

____

8. **Circle any of these symptoms you have had within the previous 6 months:**

Cough up blood   abdominal pain   low-back pain   leg pain

Arm/shoulder pain   chest pain   swollen joints   feel faint

Dizziness   Palpitations/fast heart beat   breathless with slight exertion

Unusual fatigue with normal activity   Other Symptoms________________

____

If you circled any of the above symptoms, please list how often they occur:__

____

9. **Are you a current smoker or have quit in the previous 6 months? (circle one)**

Yes   No

10. **Do you exercise regularly?**

Yes   No

11. **If yes, how often do you exercise?**_______________**(days/week)**

And, how long do you exercise for?________________________

12. **Can you jog 3 miles continuously at a moderate pace without discomfort?**

Yes   **No**

13. **Please list any additional information that might cause you problems during a fitness test**____

____

APPENDIX C

Activity Log

Name______________________
Shift #______________________ **Date**______________________
Shift Start Time:______________ **Shift End Time:**______________

Time*	Type of Activity SA, ST, or ER**	Brief Description	

*** Activities should be recorded every 15 minutes of the shift**
****SA = Shift Activities ST = Simulation Training**
ER = Emergency Response

APPENDIX D

ANOVA Summary Tables

Table A

ANOVA Summary Table for EE Rate (SA vs ER)

Source	SS	df	Mean Square	f	Sig.
Condition	1.185	1	1.185	1.925	.171
Error	2.152	8	.616		

Table B

ANOVA Summary Table for Total EE (SA vs ER)

Source	SS	df	Mean Square	f	Sig.
Condition	2598661.407	1	2598661.407	87.444	.000
Error	237745.259	8	29718.157		

Table C

ANOVA Summary Table for Mean HR (SA vs ER)

Source	SS	df	Mean Square	f	Sig.
Condition	1138.963	1	1138.963	94.549	.000
Error	96.370	8	12.046		

Table D

ANOVA Summary Table for HR_{max} (SA vs ER)

Source	SS	df	Mean Square	f	Sig.
Condition	10780.907	1	10780.907	12.154	.008
Error	7096.259	8	887.032		

Table E

ANOVA Summary Table for Total Time (SA vs ER)

Source	SS	df	Mean Square	f	Sig.
Condition	4173892.019	1	4173892.019	1543.161	.000
Error	21638.148	8	2704.769		

APPENDIX E

Raw Data

ID #	Age	Height	Weight	BMI	RHR	APMHR	MHR	Abs VO_{2max}	Rel VO_{2max}	Test Day	Total EE	HR max	Mean HR	Mean EE	Total Time
FF2	48	183	87	26.0	72	172	160	3.31	38.1	1	278	93	61	0.5	550
										2	198	128	60	0.3	861
										3	374	127	65	0.7	562
FF3	21	178	98.6	31.1	60	199	191	5.23	53	1	860	173	80	1.5	589
										2	368	174	67	0.4	838
										3	846	170	81	1.4	593
FF4	34	188	144.1	40.8	74	186	181	5.71	39.6	1	418	135	80	0.7	587
										2	1013	159	85	1.7	590
										3	827	159	73	1.5	572
FF5	26	168	63.2	22.4	70	194	191	3.2	50.6	1	507	155	86	0.9	586
										2	576	204	90	1.0	592
										3	702	176	94	0.9	794
FF7	32	180	95	29.3	58	188	186	4.4	46.3	1	918	164	82	1.6	586
										2	410	142	70	0.5	836
										3	604	159	73	1.1	572
FF8	33	185	90.9	26.6	72	187	200	4.38	48.1	1	380	120	75	0.6	612
										2	512	116	78	0.9	592
										3	238	120	77	0.3	812
FF9	31	180	98.2	30.3	74	189	189	4.66	47.4	1	1070	140	80	1.4	831
										2	589	134	87	1.0	585
										3	693	122	88	1.2	571
FF10	36	178	82.3	26.0	62	184	189	4.59	55.3	1	462	198	81	0.9	540
										2	303	143	68	0.4	831
										3	498	162	83	0.9	562
FF11	34	175	70.9	23.2	73	186	183	4.46	62.9	1	466	178	92	0.8	605
										2	463	158	96	0.8	594
										3	493	158	96	0.8	594

Shift Activities					Simulation Training					Emergency Response				
Mean EE	Mean HR	HR max	Total EE	Total Time	Mean EE	Mean HR	HR max	Total EE	Total Time	Mean EE	Mean HR	HR max	Total EE	Total Time
0.5	61	93	278	550	0	0	0	0	0	0	0	0	0	0
0.2	63	113	147	801	0	0	0	0	0	0.9	72	113	51	60
0.6	65	127	341	532	0	0	0	0	0	1.1	78	116	33	30
1.5	77	173	680	469	0	0	0	0	0	1.5	80	159	180	120
0.4	86	174	350	823	0	0	0	0	0	1.2	110	140	18	15
1.4	82	170	777	548	0	0	0	0	0	1.5	85	113	69	45
0.6	79	128	357	571	0	0	0	0	0	3.8	103	135	62	16
1.7	98	159	891	530	1.5	85	96	67	45	3.6	101	120	55	15
1.4	72	159	712	527	0	0	0	0	0	2.6	80	100	115	45
0.9	84	155	488	557	0	0	0	0	0	0.6	98	133	18	29
1	91	204	499	512	0	0	0	0	0	1	101	145	76	80
0.9	95	176	671	770	0	0	0	0	0	1.3	103	129	30	24
1.4	77	139	640	466	0	0	0	0	0	2.3	87	164	278	120
0.5	87	142	377	821	0	0	0	0	0	2.2	107	136	34	15
1	74	159	513	511	0	0	0	0	0	1.5	83	140	91	61
0.6	75	120	380	612	0	0	0	0	0	0	0	0	0	0
0.9	77	116	492	577	0	0	0	0	0	1.4	78	100	20	15
0.3	77	120	238	812	0	0	0	0	0	0	0	0	0	0
1.3	80	140	1070	831	0	0	0	0	0	0	0	0	0	0
0.9	90	134	451	493	0	0	0	0	0	1.5	95	129	138	92
1.2	89	122	615	511	0	0	0	0	0	1.3	87	104	78	60
0.9	81	198	462	540	0	0	0	0	0	0	0	0	0	0
0.3	65	143	252	766	0	0	0	0	0	0.8	74	93	51	65
0.9	83	162	498	562	0	0	0	0	0	0	0	0	0	0
0.8	93	178	454	590	0	0	0	0	0	0.8	118	150	12	15
0.8	95	158	404	519	0	0	0	0	0	0.8	104	136	59	75
0.9	98	158	488	549	0	0	0	0	0	0.1	80	127	5	45