The Relationship between Physical Fitness and Job Task Analysis in Firefighters who participate in Wellness Programs

By

Rebekah F. Seay, ACSM C-EP, CSCS

A thesis submitted to the Graduate Faculty of
Auburn University Montgomery
In partial fulfillment of the requirements for the Degree of
Master of Education in Exercise Science

Montgomery, Alabama
May, 6th 2017

The Relationship between Physical Fitness and Job Task Analysis in Firefighters who participate in Wellness Programs

Except where references have been appropriately made to the work of others, the work described in this thesis is my own or was done in collaboration with my advisory committee. This thesis does not include propriety or classified information

Rebekah F. Seay

Certificate of Approval:

Hank Williford
Thesis Committee Chair
Auburn University Montgomery
Kinesiology

Matthew Schubert
Thesis Committee Member
Auburn University Montgomery
Kinesiology

Deanne Allegro
Thesis Committee Member
Auburn University Montgomery
Kinesiology

Sheila Austin
Dean
Auburn University Montgomery
Kinesiology

The Relationship between Physical Fitness and Job Task Analysis in Firefighters who participate in Wellness Programs

Rebekah F. Seay

Rebekah F. Seay

Signature of Author

May 6, 2017

Date of Graduation

Table of Contents

Acknowledgements

I would like to take this opportunity to genuinely thank the faculty and staff of the AUM Department of Kinesiology for the support and effort you have all given me throughout my time at AUM. Each one of you has played a role in assisting and encouraging me throughout my master's program and have helped and allowed me to further in my passion for Kinesiology. I have thoroughly enjoyed working and learning under each one of you. I would like to take the time to say a special thank you to Dr. Hank Williford; you have guided me throughout my time at AUM and helped me develop as a student. I will always be grateful to you for allowing me the opportunity to obtain a position as a graduate teaching and research assistantship in the AUM Human performance lab. This opportunity has provided me with a greater level of knowledge and experience in Kinesiology. I would like to thank you for serving your students, myself included, the Kinesiology Department of AUM, and the exercise science field. I would like to thank Dr. Matthew Schubert for your support, encouragement, and mentorship. You have challenged me in many ways and have helped me develop a love for research. Thank you Dr. Williford and Dr. Schubert I would not be where I am today if it were not for each of you. I would also like to thank Deanne Allegro for being on my committee and guidance throughout my thesis. I am so appreciative of the lab I have been able to spend the past two years working in and the wonderful graduate assistants who I have worked alongside each day. A special thank you to Holly Clarke and Katie Spain, you each have been wonderful co-workers and become amazing friends. I would also like to say thank to my parents, David and Rhonda Seay, Matt and Anna Seay, my Grandparents Dan and Barbra Deloney, and Casey Carpenter. You have all supported me throughout

my master’s program and have been nothing but encouraging. Your love and support are irreplaceable. My strength is found in the Lord (Psalms 28:7).

Abstract

The purpose of this study was to examine the relationship between physical fitness variable related to Job Task Analysis (JTA) in firefighters who participate in wellness programs. The JTA consisted of five simulated firefighting tasks. A stair climb, hose hoist, forcible entry, hose advance, and victim rescue. Eighty-two experienced, career firefighters of the Montgomery Fire Department (34.95 ± 7.53 years) participated in JTA, wellness measurements, 1.5 mile run, 1 minute push-up test, and 1 minute curl-up test. Each subject had a body composition measurement performed by Air Displacement Plethysmograph (Bod pod). Significance was established at ($p < 0.05$) and Person moment correlation coefficients were calculated. Significant correlations were found between JTA completion time and age (r = 0.33, p 0.03), height (cm) (r = -0.41, p <0.01), LBM (kg) (r = 0.42, p <0.01), % body fat (r = -0.46, p <0.01), curl-ups (r = -0.34, p 0.02), push-ups (r = -0.26, p 0.02), and run time (min) (r = 0.52, p <0.01). After results were compiled a step wise multiple regression analysis was performed with JTA times against all fitness variables and determined that aerobic capacity and lean body mass accounted for 48.8% of the variation of job task analysis. Cardiovascular fitness (1.5 mile run time) and LBM significantly predicted JTA (run time $\beta = 0.53$, p <.01); LBM (β = -0.47, p <.01). Firefighting is one of the most physically demanding and unpredictable occupations. This data can help an exercise specialist choose the appropriate exercises to help firefighters better perform the tasks they have ahead of them. It is important for fire departments to have wellness programs that consist of the components necessary to improve performance. The focus of the program should consist of training to improve body composition, strength and endurance

Keywords: Cardiovascular Fitness, Lean body mass, Job Performance.

List of Tables and Figures

Abbreviation

PPE	Personal Protective Equipment
HR	Heart Rate
VO_2max	Total Oxygen Consumption
METs	Metabolic Equivalent of Task
BMI	Body Mass Index
ACSM	American College of Sports Medicine
JTA	Job Task Analysis
WC	Waist Circumference
BF%	Body Fat Percentage
DNF	Did Not Finish
DB	Dumbbell
BIA	Bioelectrical Impedance Analysis
RM	Repetition Maximum
WAnT	Wingate Anaerobic Cycling Test
SFGT	Simulated Fire Ground Test
CPAT	Candidate Physical Ability Test
FVC	Force Vital Capacity
BPM	Beats Per Minute
RER	Respiratory Exchange Ratio
W	Watts
LBM	Lean Body mass
PPA	Physical Performance Assessment
GXT	Graded Exercise Test

HRR	Heart Rate Reserve
BA	Breathing Apparatus
FM	Fat Mass
FFM	Fat-Free Mass
NFPA	National Fire Protection Association
EMT	Emergency Medical Technician
CVD	Cardiovascular Disease
AUM	Auburn University at Montgomery
MFRD	Montgomery Fire and Rescue Department
BP	Blood Pressure
SEE	Standard Error of Estimation

Review of Literature

Demands of the Job

The purpose of a firefighter is to save lives, remain safe, and keep their fellow firefighters safe. Firefighters need to be quick to make decisions because these decisions could mean the difference between getting themselves or a victim out of a dangerous situation or not getting out at all. However, if they are not physically able to perform their duties this could impact not only the firefighter, but their colleagues and potential victims. Dangerous situations are presented almost daily to firefighters, including fire suppressions, vehicular accidents, emergency medical situations (EMT), search and rescue, hazardous substances (gas leaks or chemical spills), and natural disasters (tornados, floods, earthquakes) (Taylor et al., 2015a).

Numerous studies have been conducted within the firefighting population related to physical demands inherent to this occupation. Firefighting is a strenuous job and is performed in a chaotic and hostile environment with conditions that cannot be predicted. There are approximately 1,134,400 career and volunteer firefighters in the United States (NFPA "U.S. Fire Department Profile" http://www.nfpa.org/news-and-research/fire-statistics-and-reports/fire-statistics/the-fire-service/administration/us-fire-department-profile). Each year 80,000 of these firefighters are injured on duty (Abel et al., 2015; Karter et al., 2012; Smith, 2011). It has been shown that 44% of all deaths of firefighters are a result of a heart attack (Bjerke, 2011; Durand et al., 2011; Ode et al., 2013). These facts illustrate the importance of maintaining a healthy lifestyle both on and off duty. Being a firefighter requires a great deal of physical attributes such as cardiovascular

endurance, muscular endurance and maintaining a healthy body composition. These attributes play a large role in the safety of firefighters. (Antolini et al., 2015; Calavalle et al., 2013; Michaelides et al., 2008; Nogueira et al., 2016; Ode et al., 2014; Rhea et al., 2004; Sheaff et al., 2010; Williford et al., 1999).

Cardiovascular Demands

Physical and environmental stressors can have a great impact on a firefighter's performance. Environmentally, dangerous situations can cause stress on the cardiovascular system such as extreme heat, hazardous gases and smoke, which can cause respiratory problems and also limit visibility (Durand et al., 2011; Smith, 2011; Taylor et al., 2015a). Physically, firefighters carry a tremendous amount of additional weight with them, including personal protective equipment (PPE), which weights approximately 22kg (Durand et al., 2011; Horowitz & Montgomery, 1993). In addition they carry ladders, hoses, and extraction tools. Carrying this equipment puts an additional amount of stress on the cardiovascular system. A firefighter's heart rate (HR) can quickly become elevated during emergency situations due to the aspects of their job. Studies have shown that carrying this extra weight can have an estimated oxygen cost (VO_2max) of approximately $44ml^{-1}\cdot kg^{-1}\cdot$min or 12.5 METs (Durand et al., 2011). The oxygen cost of performing various firefighting tasks has been shown to be between 23-49.0 $ml\cdot kg^{-1}\cdot min^{-1}$ (Glendhill & Jamnik, 1992; Michaelides et al., 2008; Schmidt & Mckune, 2012). Therefore, it is important that firefighters have good cardiovascular fitness.

Firefighters run a great risk for cardiovascular and respiratory illnesses as well as muscular injuries. It has been reported that firefighters who are considered to be below average for physical capacity are almost three times more likely to suffer from a cardiovascular episode, such as a heart attack, compared to a colleague who participates in regular exercise (Cady et al., 1985). According to the National Fire Protection Agency, approximately 45% of firefighter deaths in the years 1995-2009 were a result of cardiovascular death (Durand et al., 2011; Karter et al., 2012). As stated before, an array of physical demands are placed on firefighters. In order for them to perform their job effectively and efficiently they need to be in good physical shape, including but not limited to cardiovascular endurance and muscular strength and endurance. The National Fire Protection Agency and the International Association of Firefighters have recommended that firefighters have on-the-job physical fitness training sessions incorporated into wellness programs within the departments. (International Association of Fire Fighters, Washington DC, 2014)

Skeletal Musculature and Body Composition Standards

Firefighters in the United States and other countries have physical standards that need to be met in order for them to perform their jobs properly, safely, and efficiently. Most U.S. firefighters have only average physical fitness and tend to be considered overweight or obese by body mass index (BMI) (Roberts et al., 2002; Smith, 2011; Storer et al., 2014). It has been reported that 53% of firefighter candidates beginning training were overweight with a BMI range of 25.0 - 29.9 and 35% were obese with a BMI >30 (Soteriades et al., 2005). The BMI standards are compared to national normality's placed by the American College of Sports Medicine (ACSM) (ACSM's Guidelines for Exercise

Testing and Prescription, 2014, p.63). However, since BMI does not take into consideration body composition, it has been suggested that BMI may misclassify muscular firefighters (Ode et al., 2014). The accuracy of BMI versus body fat percentage in firefighters was evaluated and one study found that 12% of firefighters who were classified as overweight according to BMI had <18% body fat (Jitnarin et al., 2012). Two studies performing body fat percentage measurements on approximately 130 firefighters reported values between 13.8% –16.6%. These values would be considered good to normal (Rhea et al., 2004; Williford et al., 1999). More recent studies have also reported higher body fat values in male career firefighters in the age ranges of 25-37 years (Antolini et al., 2015; Dennison et al., 2012). Firefighters often have sedentary time when not on active calls or assignments. It is not surprising that body fat percentages have gone up in recent years, and closely reflects changes in body composition observed in the general population of the U.S. (Ogden et al., 2014). This could be related to decreases in fitness levels and higher levels of obesity that has been previously reported in firefighters. (Poston et al., 2011; Roberts et al., 2002; Smith, 2011; Storer et al., 2014)

Screening and Testing

Schmidt and Mckune (2012) stated that, "Testing the fitness levels of firefighters using standard fitness tests is important…but this fitness needs to translate into job performance." (Schmidt & Mckune, 2012). Generally, firefighters have been held to the same standards of recommended daily activity levels as the general population. However, it is important for fitness professionals and tactical strength and conditioning specialists to be able to identify fitness measurements that are specific to firefighters and their perform at a fire scene. Given the occupational demands of firefighting, firefighters

should be screened and tested before being allowed to respond to a call to ensure they are safely able to perform their duties. Unfortunately, federal law prohibits pre-employment physical examination of firefighter candidates (Roberts et al., 2002). However, emerging research has compared and contrasted the relationship between initial firefighting task(s) and different types of fitness modalities, specifically job fire simulation testing. This research can aid fire departments in identifying domains of physical performance that may require further development.

A job task analysis (JTA) is a test of physical fitness with specific challenges set in place to mimic the obstacles a firefighter might face when called to an emergency. Most JTA tests include 5-8 occupational tasks; for example: a three minute stair climb on a stair climb machine with 22-34kg weighted vest at 60 steps per minute or climbing five stories to the top of a training tower. Various hose tasks are performed such as a hose drag or hose pull and a hose advanced with a charged hose. The hose is approximately 15m long and weighs up to 17 kg. Equipment carry is a large part of the JTA. Firefighters are required to carry ventilation fans, sledge hammers, and other extraction tools as well as ladders. A ladder raise and extension of 7-10m ladder is another task. A forcible entry task can be performed by swinging a sledgehammer overhead into a 75kg I-beam until approximately 2m of movement is reached. The final task performed is a search and rescue simulation performed with a victim rescue. This is simulated with a 50-80 kg mannequin and dragged to safety (Groeller et al., 2015; Rhea et al., 2004; Schmidt & Mckune, 2012; Sheaff et al., 2010; Taylor et al., 2015b). Not every test has the same components, but each one evaluates the primary movements and functions of a firefighter's job.

Taylor (2015a) surveyed over 4000 firefighters to rank the importance of physical effort, frequency, and duration of over 30 different tasks that were identified as the most used on-duty. The list of essential task was narrowed down to 15 primary tasks. The 15 tasks were: rolling; coupling; dragging; and use of 38-mm or 70-mm hoses; location of hydrants; stair climbing with PPE, breathing apparatus and hose; being prepared for a fire attack; ladder usage; rescuing; use of a sledge hammer and bushfire equipment (Taylor et al., 2015a). Even though firefighters perform special tasks, they work in harsh environments, and must be prepared for the elements they will face. It is not realistic to have firefighters training and practicing in burning buildings or have them constantly putting out controlled fires, or have them perform all their training in a heat chamber. This is why other test and task simulations have been developed.

Firefighting has been characterized by the employment of aerobic and anaerobic energy systems. Preparing a screening or simulation test can be helpful when identifying the job task(s) that place(s) the greatest amount of physiological strain on firefighters. It has been reported that the hose line advance, forcible entry, ladder raise, lifting and lowering of objects, victim rescue and load carriage are performed by using the anaerobic energy system. Stair climb, hose operation, confined space maneuver, salvage, and overhaul tasks are performed primarily by the aerobic system (Abel et al., 2015). Therefore, it is important that these job task analyses evaluate specific movements, required energy systems, specific muscle groups and environmental aspects.

Predictors of Job Performance

Multiple studies have stated that physical fitness and its domains are related to job performance objectives and improvement in performance of firefighters. Job task performance is significantly associated with muscle strength (Rhea et al. 2004; Schmidt & Mckune, 2012; Williford et al. 1999), muscle endurance (Dennison et al., 2012; Rhea et al., 2004; Williford et al., 1999), body composition (Clark et al., 2002; Nogueira et al., 2016; Williford et al., 1999), absolute VO_2 (Cady et al., 1985; Dennison et al., 2012; Sheaff et al., 2010), and anaerobic power (Antolini et al., 2015; Rhea et al., 2004; Sheaff et al., 2010; William-Bell et al., 2009). Table 1 outlines many physiological measurements have been shown to be significantly related to job firefighter performance. This implies that high levels of overall fitness will aid firefighters in performing tasks such as climbing stairs, pulling and dragging a fire hose, carrying and hoisting equipment, raising ladders, forcibly entering a building, searching and rescuing victims and bringing them to safety.

Table 1 - Predictors of Job Performance

Reference	Performance Test	Subject Demographic	Training Components	Physiological Measurements	Significant Results
Antolini et al. 2015	Comparisons	23 Career Firefighters Age: 40.5 ± 8.3 years Height: 179.2 ± 6.6 cm Weight: 89.5 ± 13.0 kg	60 degree Abdominal Endurance Test Maximum Repetitions: Push Ups Bicep Strength Quadriceps Strength	BMI: 27.8 ± 3.6 kg/m^2 BF%: 24.2 ± 5.4% WC: 93.5 ± 10.1 cm HR Resting: 57.7 ± 8.2 bpm Vertical Jump Wingate Test Peak Power: 10.6 ± 1.1 W/kg Wingate Average power: 7.4 ± 1.0 W/kg VO_2max: 42.2 ± 6.5 ml·kg^{-1}·min^{-1}	Significant correlations found between body composition and: Push-ups Quadriceps Strength Wingate Average Power Vertical Jump
Calavalle et al. 2013	Stair Climb	35 Career Firefighters Age: 44.9 ± 4.79 years Height: 176.6 ± 6.6 cm Weight: 82.4 ± 10.9 kg		BMI: 26.4 ± 3.1 kg/m^2 BF%: 17.7 ± 5.4 HR Measurements VO_2max: 39.6 ± 6.1 ml·kg^{-1}·min^{-1} Submaximal Treadmill Test, Balke Protocol	Results: decrease workload in subjects who have reported at larger body mass than subjects with a smaller body mass.
Del Sal et al. 2009	Work Performance Test: Extinguishing Drill Hose Carry Pushing Water Pump Hose Pull Fire Extinguishing Return to initial conditions Total Combined Time: 18.77 Min.	13 Career Firefighters Age: 36.3 ± 6.9 years Height: 177.0 ± .70 cm Weight: 81.7 ± 7.7		BMI: 26.08 ± 2.55 kg/m^2 BF%: 23.61 ± 2.59% Heart Rate: Avg. During Session 90.0 ± 9.81 bpm Peak HR: 179.4 ± 12.4 bmp MET Level: 1.8 ± 0.2	Significant correlations with MET level: Age Weight
Dennison et al. 2012	Simulated Fire Ground Test (SFGT) Stair Climb Hose Drag Equipment Carry Ladder Raise Forcible Entry Search Rescue	12 Trained Career Firefighters Age: 31.8 ± 6.9 Height: 178.0 ± .60 cm Weight: 87.6 ± 14.3 kg 37 Untrained Career Firefighters Age: 31.0 ± 9.0 years	10 Repetitions: Cable Row Barbell Bench Press Deadlift DB Shoulder Press Planks *Circuit Training Method, 1 Minute Recovery	Trained: BMI: 27.7 kg/m^2 BF%: 24.9 ± 3.3 ml·kg^{-1}·min^{-1} Predicted VO_2peak: 45.6 ± 3.3 Untrained: BMI: 31.3 ± 5.2 kg/m^2 BF%: 25.5 ± 6.5 ml·kg^{-1}·min^{-1} Predicted VO_2peak: 40.2 ±. 5.2	Significant differences in trained and untrained: Body Mass BMI Predicted VO_2 Significant between baseline and exercise sessions:

	Total Time: Trained: 365.0 ± 56.4 s Untrained: 399.9 s (6 DNF)	Height: 180.0 ± .50 cm Weight: 102.0 ± 19.5 kg			Total SFGT Search
Michaelides et al. 2011	Ability Test (AT): Stair Climb Rolled Hose Lift and Move Keiser Sled Hose Pull and Hydrant Hook Up Rescue Charged Hose Overall Time: 7.07 ± 1.75 minutes	90 Career Firefighters Age: 33 ± 7 years Height: 181.2 ± 6.62 Weight: 97.04 ± 15.51	1RM Bench Press 1RM Squat Hand Grip Dynamometry Abdominal Strength Isometric 1 Min. Sit Ups	BMI: 29.55 ± 3.67 kg/m^2 BF%: 23.05 ± 5.58% (BIA) WC: 97.33 ± 10.96 cm Step Test Vertical Jump	Hand strength and 1RM squat were not correlated with fast AT Time. Poor performances was significantly correlated with: High Resting HR, BMI, BF%, Age and waist size.
Nogurira et al. 2015	Age and BMI	4,237 Career Firefighters Age Mean: 39 years	Age Groups: Classifications: 18-25 years = A 26-33 years = B 34-39 years = C 40-45 years = D 46-49 years = E	BMI 0.2% Underweight 30.8% Normal 54.3% Overweight 14.7% Obese	Body Composition: BMI Mean: 26.6 kg/m^2 BF% (3 site skinfolds): 21.7% BIA: 24.9% WC Mean: 90.0 cm 12 Min. Cooper Test Mean VO_2Max: 42.4 ml·kg^{-1}·min^{-1} 52.9% MET Level >12	VO_2 negatively correlated with: Age, WC, BMI, BIA
Rhea et al. 2004	Job Performance Task Hose Pull 21.1 ± 5.6 s Stair Climb while carrying high-rise Hose Pack: 85.7 ± 17.1 s Simulated victim drag: 37.6 ± 17.1 s Equipment Hoist: 17.3 ± 6.9 Overall Time: 161.8 ± 40.8 s	20 Career Firefighters Age: 34.5 ± 6.1 years	5RM free weight: Bench Press 217.6 ± 50.7 kg Back Squat 298.0 ± 192.9 kg Maximal effort repetitions: Bench Press performed with 45.5 kg Squat performed with 61.4 kg Bent-Over-Row performed with 20.5 kg DB Bicep Curls performed with 13.6 kg DB Seated Shoulder Press performed with 11.4 kg DB Hand Grip	BF% (Bod Pod): 16.6 ± 3.9% 12-Minute Cooper Test: 2,181.0 ± 386.9 m 400 m Sprit: 80.5 ± 12.6 s	Significant correlations between JPT: Bench Press Strength Hand Grip Bent-Over-Rows Shoulder Press Bicep Curls Squat endurance 400-m sprint time
Schmidt et al. 2012	Job Performance Task: (JPT) Hose Pull Stair Climb Simulated Victim drag	48 Career Firefighters Age: 30.2 ± 7.2 years Height: 171.0 ± .80 cm Weight:76.9 ± 12.5 kg	1RM Bench Press: 98.3 ± 23.7 kg 1RM Deadlift: 141.7 ± 22.94 kg 1RM Leg Press: 337.5 ± 81.3 kg Maximal effort repetitions:	BMI: 26.3 ± 3.34 BF%: 12.6 ± 6.1% (7-site skinfold) LBM: 66.9 ± 9.2 kg 400 m Run: 83.6 ± 15.03 s	Significant correlations with Revised JPT: LMM, Height, Hand Grip, Deadlift, Bent-Over Row, Bench Press,

	Simulated ladder raise Equipment hoist *Added/Revised: Ladder Raise Static Jas of Life Hold Sledge Hammer Test Attic Crawl Total Time: 407.75 ± 107.6 s		Bent-Over Row performed with 20 kg DB Bicep Curl performed with 14 kg DB Seated Shoulder press performed with 12kg DB Hand grip Dynamometer 2 min. Abdominal curl-up test 82.46 ± 17.22	20m shuttle test 7.33 ± 2.05 level/stage Predicted VO_2max: 37.56 ± 6.99 $ml \cdot kg^{-1} \cdot min^{-1}$	1RM and Multi. Reps, 400m Run, Shuttle Test, Shoulder Press
Sheaff et al. 2010	The Candidate Physical Ability Test (CPAT): Stair Climb Hose Drag and Pull Equipment Carry Ladder Raise and Extension Forcible Entry Search and rescue Ceiling breach	33 Career and Volunteer Firefighters Age: 27 ± 1.4 years Height: 181.7 ± 1.3 cm	5 nonconsecutive training days: 1 RM Leg Press, Chest Press, and Knee Extension, Muscle Endurance Knee Extension Isometric Fingertip force Stairclimbing	BMI: 28.1 ± 1.1 kg/m^2 BF%: 21.9 ± 1.4 (DEXA) VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) Graded Treadmill Test: 40.9 ± 1.7 $ml \cdot kg^{-1} \cdot min^{-1}$ Wingate Anaerobic Cycling Test (WAnT)	Correlations between completed CPAT: Peak Power 22% higher Mean Power 45% higher Absolute VO_2 23% higher Strongest significant correlation between CAPT and physiological components: Mean Power Absolute VO_2max Finger Isometric Force Upper Body Strength Max HR during stair climb None significant: lower body strength and body composition
Storer et al. 2014	Current Firefighters cardiovascular and health assessment compared to traditional cardiovascular risk factors	47 Career Firefighters Age: 43.1 ± 7.7 years Height: 180 ± 0.07 cm Weight: 91.1 ± 13.3 kg	Hand Grip (strength): 117 ± 15 kg Push-Ups: 37 ± 16 1 Minute Curl-up (abdominal endurance): 47 ± 23 Planks (core stabilization): 107 ± 47 s	BMI: 27.7 ± 3.4 kg/m^2 BF%: 20.9% ± 5.7% BIA 9.6% ± 5.0% Skinfolds Pulmonary Function Test (FVC) VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) 39.6 ± 9.4 $ml \cdot kg^{-1} \cdot min^{-1}$	

William-Bell et al. 2009	CPAT: Stair Climb Hose Drag Equipment Carry Ladder Raise and Extension Forcible Entry Search Rescue Ceiling Breach and Pull Overall Time: 8 Min. 32 sec.	57 Career Firefighters Age: 23.7 ± 4.6 years Completed: Height: 180 ± 6.9 cm Weight: 81.8 ± 12.2 kg Did not Complete: Height: 173.5 ± 10.6 Weight: 77.0 ± 17.0 kg	1RM Hand Grip Strength 1RM Bench Press 1RM Shoulder Press 1RM Leg Press Maximal effort repetitions: Leg Press Bench Press	Completed: VO_2max: 53.0 ± 7.4 HR Max: 188 ± 8 Wingate: Peak Power 633.8 ± 160.5 W Fatigue Index: 43.9 ± 11.8 RER: 1.02 Did not complete: VO_2max: 39.3 ± 5.2 HR Max: 200 ± 12 Wingate : Peak Power 413.1 ± 184.8 W Fatigue Index: 41.0 ± 4.9	A RER of 1.02 suggest a great deal of anaerobic metabolism. Hand Grip, Body Mass were considered to be 67% of variance
Williford et al. 1999	Physical Performance Assessment (PPA) Stair Climb: 53.5 ± 13.7 s Hoist: 32.1 ± 21.8 s Forcible Entry: 30.4 ± 18.6 s Hose Advance: 19.4 ± 18.9 s Victim Rescue: 48.1 ± 29.4 s Total Time: 303.5 ± 138.1 s	91 Career Firefighters Age: 31.7 ± 7.4 years Height: 177.3 ± 6.38 cm Weight: 83.97 ± 10.9 kg	Pull-Ups: 9.03 ± 4.79 Push-Ups: 41.02 ± 14.08 1.5 Mile Run: 737.60 ± 108.11 s Sit and Reach: 32.0 ± 8.5 cm Sit-Ups: 39.88 ± 7.75 Total Grip Strength: 116.75 ± 17.67	BF%: 13.8 ± 4.3 kg/m^2 Lean Body Mass (LBM): 71.5 ±7.7 kg	Significant correlations between PPA times and: Total Grip Strength Pull-Ups Push-Ups 1.5 mile Run Sit-Ups Weight BF%

BMI – body mass index; BF% - body fat percentage; WC – Waist circumference; HR – Heart rate (bpm); MET – Metabolic Equivalent; RM – Repetition Maximum; DNF – Did not finish; DB – Dumbbell; LBM – Lean Body Mass; RER – Respiratory Exchange Ratio; BIA – Bioelectrical Impedance Analysis; WAnT – Wingate Anaerobic Cycling Test

Research has reported that for optimal job performance and safety, firefighters should develop and maintain a VO_2max of approximately $42ml^{-1}\cdot kg^{-1}\cdot min$ (Michaelides et al., 2011; Roberts et al., 2002). In comparison, other data indicated that absolute VO_2 ($L\cdot min^{-1}$) and anaerobic fatigued resistance combined can significantly predict 82% of successful job task analysis overall time performance (Sheaff et al., 2010). Calavalle (2013), tested a group of firefighters for cardiovascular fitness and assessed the comparison between a treadmill graded exercise test (GXT) as a measurement of VO_2max. They used a five minute stair-climbing test to predict VO_2max. Both of these tests were performed with heart rate monitors, and HR was used to measure cardiovascular strain. The percentage of heart rate reserve (%HRR) was collected and the results of the two tests were compared. The stair climb test compared to a widely used GXT. They found that the test required a vigorous activity levels with %HRR mean values of 82.5% HRR. This was consistent with that of the treadmill GXT (Calavalle et al. 2013). The stair climb is a widely used method among fire departments to measure cardiovascular fitness and occupational performance. The stair climb test is used in most job task analysis tests or simulated fire ground tests to simulate a tower climb, stairs inside a building, etc. (Calavelle et al., 2013; O'Connell et al., 1986; Pawlak et al., 2015; Williford et al., 1999). The stair climb is performed with PPE, breathing apparatus (BA), and a charged hose and is considered as one of the most difficult tasks to perform (Taylor, 2015a). IT is important to have valid measurements of cardiovascular fitness when evaluating firefighter cardiovascular fitness.

In addition to cardiovascular fitness, maintaining a healthy body composition is also needed to perform tasks specific to firefighters. Several studies have found that VO_2max and body composition, specifically body fat, have the greatest effect on a firefighter's overall physical fitness abilities (Barr et al., 2009; Kales, et al., 2007). Firefighters who have a greater fat mass percentage tend to have greater difficulty performing essential occupational tasks (Bugajaska et al., 2007). Correlations have suggested that there is high potential for body fat percentage as a predictor of job task performance (Antolini et al., 2015; Nogueria et al., 2016; Williford et al., 1999). However, body composition and cardiovascular fitness are not the only components shown to be predictors of JTA times, muscular strength has been reported to correlate with body composition and JTA performance. Upper body strengthening exercises have been shown to decrease body fat percentage and have also been shown to be a predictor of JTA performance as well (Michaelides et al., 2011; Sheaff et al., 2010). Studies that have assessed upper body strength have used 1-5 repetition maximum (RM) bench press, hand grip dynamometry, max effort push-up tests, and other upper body exercises; such as bicep curls, lateral pull down, and bent-over-rows. Lower body strength and endurance test have also been assessed, but has not been found to be a significant a predictor of job performance in firefighters (Michaelides et al., 2008; Michaelides et al., 2011; Rhea et al., 2004; Sheaff et al., 2010). It was reported that 5RM bench press ($r = -0.66$) and hand grip strength test ($r = -0.71$), along with the number of maximum repetitions performed for muscular endurance measurements in bench press ($r = -0.73$), bent-over-row ($r = -0.61$), shoulder press ($r = -0.71$), and bicep curls ($r = -0.69$) were all found to be significant ($p < 0.05$) to JTA performance times (Rhea et al., 2004). A 1RM and 5RM

bench press and hand grip strength were specifically found to be significantly correlated with the hose pull and victim rescue tasks in three studies (Michaelides et al., 2011; Rhea et al., 2004; Schmidt & Mckune, 2012). Muscular endurance exercises, bent-over-rows, bicep curls and shoulder press, were found to be significantly related to hose pull, victim drag, and equipment hoist ($p = < 0.05$) (Rhea et al., 2004; Schmidt & Mckune, 2012). Given the wide variety of equipment that firefighters must carry and operate, upper body strength is needed to operate effectively. Several studies have looked at tests using a combination of specific firefighting tasks coupled with more common weight room exercises (Dennison et al., 2012; Michaelides et al., 2008; Michaelides et al., 2011; Rhea et al., 2004). Others have used common field or body weight exercises to assess muscular strength and endurance to predict job task analysis performance. Push-ups, pull-ups, and a 1 minute abdominal sit-up tests are examples of field measurements that have been used. Studies have found one or all three were significant predictors of total JTA times (Antolini et al., 2015; Davis et al., 1982; Frost et al., 2015; Williford et al., 1999). However, multiple studies have stated that physical fitness is correlated to job performance objectives and improvement of performance in firefighters. Job task performance time has been shown to be significantly correlated with muscular strength and muscular endurance (Dennison et al., 2012; Rhea et al., 2004, Schmidt & Mckune, 2012; Williford et al., 1999). Absolute VO_2 and anaerobic power have also been shown to be significantly related to job task performance times (Antolini et al., 2015; Cady et al., 1985; Dennison et al., 2012; Rhea et al., 2004; Sheaff et al., 2010; William-Bell et al., 2009; Williford et al., 1999). In addition to these physical factors body composition has

also been shown to correlated with times of job task performance (Clark et al., 2002; Nogueira et al., 2016; Williford et al., 1999).

Body Composition Improvement with Training

The human body consists of multiple body compartments, including fat mass, lean (muscle) mass, total body water, and bone mineral content. Generally, body composition is assessed using a two-compartment model; that is, fat mass (FM) and fat-free mass (FFM). Other measurements often reported related to body composition include waist circumference (a proxy of visceral adiposity), body weight, and body mass index. It has been reported that firefighters who are well trained may not see a change in body weight when starting a training program. However, it is common to observe shifts in body composition. This is typically caused by a significant decrease in fat mass combined with an increase of fat-free mass, which can cause body weight to stay relatively the same (Roberts et al., 2002).

Given the nature of their job, general exercise guidelines may not be applicable to firefighters. Therefore, tactical strength and conditioning personnel must consider studies that specifically address the physical tasks, demands, and needs of firefighters; and how implementing training programs have improved cardiovascular capacity, muscle endurance and body composition. American firefighters are considered to be overweight (79.5%) and obese (33.5%) (Poston et al., 2011), training programs can help combat this and help firefighters maintain a healthy body composition. Hilyer (1999), showed that body fat percentage decreased significantly after a 24 month training program implemented in Birmingham, AL fire stations (Hilyer et al., 1999). From a health

perspective, cardiovascular disease is the leading cause of death among firefighters (Kales et al., 2003; Ode et al., 2013), and obesity is a positive risk factor for cardiovascular disease (Clark et al., 2002; Durand et al., 2011; Soteriades et al., 2005). If firefighters can decrease their body fat percentage they can improve their health and job performance. Exercise training alone can significantly decrease body fat percentage. In a training study conducted by Pawlak (2015), a mean body fat loss was reported to be 2.5 kg without dietary modifications. To further support this finding two subjects were unable to complete the job task analysis test at the beginning, completed the test at the end of training, and lost an average of 6 kg during the 12 weeks of training (Pawlak et al., 2015).

When evaluating physical fitness and body composition in firefighters, it is important to remember that some have been training and performing these occupational tasks longer than others. It is important to be able to evaluate fitness for all levels of firefighters, trained, untrained or newly recruited firefighters. Most untrained firefighters and new recruits have a 20% lower VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) than what has been suggested as a safe value for a firefighter (Roberts et al., 2002). In addition BMI and body mass have been reported to be higher in untrained firefighters even though body fat percentage has not been shown to be a significant determinant between trained and untrained firefighters (Dennison et al., 2012). Implementing training programs for new recruits and career firefighters can be beneficial to body composition and job task performance as reported earlier. Body composition should be considered to be an important indicator of health and fitness performance among firefighters.

Fire Department Training Programs

The duties and tasks of a firefighter are both mentally and physically demanding. The physical demands placed on the body when performing the job task of a firefighter include both musculoskeletal and cardiorespiratory stress. The National Fire Protection Agency, International Association of Firefighters, and International Association of Fire Chiefs have recommended that firefighters have on-the-job physical fitness training and incorporate wellness programs within the departments. (International Association of Fire Fighters, Washington DC, 2014). Health and fitness are high priority issues when it comes to being a firefighter (McDonough et al., 2015). Firefighters need to be ready to perform a high level physical task at any time. Multiple tests and assessments have been performed to determine the physical fitness requirements of career firefighters and after completion of each investigation, researchers have expressed a concern and need for fire departments to have health and fitness requirements as well as a way for firefighters to get on the job fitness training (Sal et al., 2009; Holmér & Gavhed, 2007; Michaelides et al., 2008; Roberts et al., 2002; William-Bell et al., 2009). Another recent needs analysis performed by the National Fire Protection Association (NFAP) continued to stress the importance and need for wellness programs. The NFPA reported that 70% of fire departments do not have any type of exercise or health program for the firefighters (NFPA, 2011). Limited reports have been found on fire department health and wellness programs. However, implementing health and wellness programs for fire departments is one of the first steps toward making an effort to improve the health and fitness abilities of firefighters. As previously stated heart attacks account for 45% of on-duty firefighter deaths (Ode et al., 2013). There are many risk factors that contribute to cardiovascular

disease: men ≥45, family history of myocardial infraction, coronary revascularization, or sudden death from a heart attack in any direct family members (father less than 55 years of age or mother less than 65 years of age), current smoker, sedentary lifestyle, less than 30 minutes of moderate intensity activity 3 days per week, a BMI ≥30 kg/m^2, blood pressure ≥140/90mmHg, LDL ≥130 mg·dL, HDL <40 mg·dL, or total cholesterol ≥200 mg·dL, and fasting blood glucose between 100-125 mg·dL, can all be risk factors for CVD as stated by the American College of Sports Medicine (ACSM's Guidelines for Exercise Testing and Prescription, 2014, p.27). Sacred Heart University Exercise Science faculty created a fitness program for the Fairfield Fire Department in Connecticut. They included educational information, nutrition programs, stress management, peer fitness training, supervised group training and various health measurements such as body composition, cardiovascular test and flexibility measurements. After training sessions were conducted physiological measurements were collected and they found a decrease in resting heart rate and blood pressure. Aerobic capacity and maximal push-ups increased approximately 10% (Bjerke, 2011). Hilyer (1999) was one of the first to employ an "In-Station" physical training program. In 1989 he equipped half of the fire stations in Birmingham, Alabama with training equipment and the other half he provided a training program to be performed without equipment. It was concluded that the firefighters at the fire stations with equipment showed significant improvement in body fat, upper body strength, and flexibility (Hilyer et al., 1999). Exercising while on duty, however, can raise concerns. In a study performed by Dennison (2012), they compared scores of a simulated fire ground test (SFGT) in trained and untrained firefighters. They compared the baseline times of the SFGT to the times of the

SFGT after an exercise session. This allowed them to see whether or not exercising while on duty could hinder their performance during an actual emergency call. The time to complete the SFGT took longer after performing an exercise session versus the baseline SFGT. Specifically, significant changes were seen during the search and rescue portion of the SFGT. However, firefighters are a key component to every city and county they serve, and improving the health and physical fitness abilities of firefighters should be a top priority (Dennison et al., 2012).

Conclusion

Several studies have observed and validated that higher job performance measures positively correlate with an increase in aerobic capacity and endurance, upper-body strength and endurance, lower body muscular endurance, and greater anaerobic power (Cady et al., 1985; Davis et al., 1982; O'Connell et al., 1986; Rhea et al., 2004; Williford et al., 1999), all of which are training modalities. Firefighters are people of the community, they have families they may not be able to make it to the gym on their days off, and if providing them with exercise training programs within each department and station so they are better able to prepare for the work they have ahead of them. This seems to be the most important aspect of establishing health and wellness programs within fire departments around the world.

Introduction

Firefighting is a profession that is tasked with saving lives and being able to protect themselves and their colleagues. Firefighting is a physically and mentally demanding occupation and firefighters need to be ready to perform a variety of physical tasks while on duty. If they are not physically able to perform their duties, it can impact not only the firefighter, but their colleagues and potential victims. Dangerous situations are presented almost daily to firefighters, including fire suppression, vehicular accidents, emergency medical situations (EMT), search and rescue, hazardous substances (gas leaks or chemical spills), and natural disasters (tornados, floods, earthquakes) (Sal et al., 2009; Taylor et al., 2015a).

Numerous studies have been conducted within the firefighting population related to the physical demands inherent to this occupation. Firefighting is a strenuous job and is performed in a chaotic and hostile environment with conditions that can never be predicted. There are approximately 1,134,400 career and volunteer firefighters in the United States (NFPA "U.S. Fire Department Profile" http://www.nfpa.org/news-and-research/fire-statistics-and-reports/fire-statistics/the-fire-service/administration/us-fire-department-profile), and each year 80,000 of these firefighters are injured on duty (Abel et al., 2015; Karter et al., 2012; Smith, 2011). It has been shown that 45% of all deaths of firefighters are the result of a heart attack (Durand et al., 2011; Kales et al., 2007; Karter et al., 2012). These facts illustrate the importance of maintaining a healthy lifestyle both on and off duty. Being a firefighter requires optimal levels of all domains of physical fitness, cardiovascular fitness, muscle strength and endurance, body composition, and

flexibility (Antolini et al., 2015; Calavalle et al., 2013; Michaelides, 2008; Nogueira et al., 2016; Ode et al., 2014; Rhea et al., 2004; Sheaff et al., 2010; Williford et al., 1999).

Firefighters run a great risk for cardiovascular disease (CVD) and muscular injuries. Cady (1985), reported that firefighters who are considered to be below the average aerobic capacity are three times more likely to suffer from a cardiovascular episode on duty (Cady et al., 1985). The reported minimal VO_2max for firefighters for optimal job performance and safety is considered to be approximately 44 $ml \cdot kg^{-1} \cdot min^{-1}$ (Durand et al., 2011; Michaelides et al., 2011; Roberts et al., 2002). Firefighters have physical standards that need to be met in order to perform their jobs properly, safely, and efficiently, but currently no national standards are in place. Variations of fire suppression simulation tests have been developed throughout different fire departments, such as Job Task Analysis, Work Performance Test (Sal et al., 2009), and Simulated Fire Ground Test (Dennison et al., 2012). These simulation tasks are used by the individual fire departments to assess each firefighter's physical ability. Cardiovascular capacity, muscular strength, muscular endurance, anaerobic power and body composition are typically measured. Most U.S. firefighters have only average physical fitness and 79.5% are considered to be overweight with 33.5% being obese (Poston et al., 2011; Storer et al., 2014). Womack (2000), as stated that firefighters have long periods of sedentary behavior (Womack, 2000), and this could be linked with decreased physical fitness capacity and the elevated levels of obesity. Excess body fat negatively impacts job performance (Poston et al., 2011). Obesity is linked with increased risk of cardiovascular disease, and an increase in fat mass is a decrement to physical fitness and job performance in firefighters. Therefore, identifying appropriate job task analysis and

fitness programs is crucial to performance (Antolini et al., 2015; Dennison et al., 2012; Hilyer et al., 1999; McDonough et al., 2015; Pawlak et al., 2015).

Previous studies have examined the relationship between simulated firefighting tasks and physical fitness (Rhea et al., 2004; Smith, 2011; Williford et al., 1999), and others have evaluated relationship between simulated fire suppression task and selected physical fitness parameters (Groeller et al., 2015; Pawlak et al., 2015; Schmidt & Mckune, 2012). The aim of this study is to examine the relationship between various fitness components and the Job Task Analysis (JTA) employed by the Montgomery Fire Department. This study will further contribute to the literature by evaluating a fire department that has a wellness program, and how the wellness programs physical fitness components relate to firefighter JTA.

Methods

The primary purpose of this investigation was to evaluate the relationship between fire fighter physical fitness and firefighter job performance. Eight-two male firefighters completed fitness and body composition testing, and the JTA. The JTA is conducted annually in order to evaluate the performance of each firefighter to complete tasks relevant to their occupation. In addition, each firefighter is evaluated on a number of components of physical fitness. All testing took place at the Montgomery Fire Rescue Training Division, with the exception of body composition testing that took place in the Human Performance Lab at Auburn University Montgomery (AUM). All subjects were experienced firefighters and full time employees of the Montgomery Fire and Rescue Department (MFRD), Montgomery AL, USA. The Montgomery Fire Department has approximately 425 full-time firefighter personnel. MFRD firefighters are required to have a body composition evaluation performed each year. Firefighters have the choice of a being evaluated based upon a height and weight chart (Figure 1) (a standardized height and weight chart based on age and gender developed by the military) or evaluated by a full body composition analyses. Body composition measurements were performed with the use of Air Displacement Plethysmograph (Bod pod). The firefighters must meet the guidelines set by the MFRD based on age, gender, height and weight or be ≤24%BF if over the age of 30 years and ≤20%BF if 29 years or younger (Montgomery Fire and Rescue Department. (2015) *Weight Policy*. Montgomery, Alabama). Of the 425 fire fighters, 82 had their body composition evaluated at AUM, and were included in the study as part of the subgroup population of the firefighters.

The Montgomery Fire and Rescue has a Physical Fitness Policy and all firefighters must comply with the policy. Part of the policy includes an annual fitness evaluation. The evaluation consisted of push-ups, curl-ups, and 1.5 mile run. Each year the Montgomery Fire Department performs a physical fitness evaluation. The physical fitness evaluations consist of maximal number of curl ups performed in 1 minute or until exhaustion, maximal number of push-ups performed in 1 minute or until exhaustion, and the amount of time to complete a 1.5 mile run. Standards for each fitness component were as follows: curl ups were performed with arms crossed over chest, the elbows had to touch the thighs for the repetition to be counted, push-ups were performed with the arms close to the body, firefighters were required to tap the chest to the ground and immediately push-up, body had to stay in a full plank position with no arch of the hips and abdomen. The 1.5 mile run was performed on a 1.5 mile course on concrete at the training center. Normal athletic clothing, athletic shorts and t-shirt issued by the fire department and the firefighter's personal training shoes were worn to complete the fitness evaluation (Montgomery Fire and Rescue Department. (2015) *Job Task Assessment*. Montgomery, Alabama).

For the body composition evaluation firefighters reported to the Human Performance Laboratory at AUM and the following data was evaluated: age (years), height (cm), weight (kg), % body fat (%BF), lean body mass (LBM). Height was measured to the nearest 0.5 cm with a stadiometer and weight to the nearest 0.1 kg using the digital scale from the Bod Pod. Body composition was measured by whole-body air displacement plethysmography (Bod Pod, Life-Measurement Instruments, Concord, CA). Subjects were dressed in appropriate clothing: spandex, tight fitting bike shorts, and lycra

swim cap was worn. Proper protocol was followed before performing body composition test. Subjects abstained from exercise and eating for at least two hours prior to test and subjects had not showered within the last two hours (no wet hair or wet skin).

The Montgomery Fire and Rescue's Annual Job Task Analysis test was designed to test a firefighter's ability to perform a job task that is similar to what is required of firefighters during fire suppression. The JTA was validated as a test that relates to actual firefighter performance by the Human Performance laboratory at Auburn University Montgomery (Williford et al., 1999). The JTA was administered by the Division of Training. Participants reported to the Division of Training, and completed an informed consent form. This study was approved by the institutional Review Board at Auburn University at Montgomery (#2017-028). Heart rate, respiration, and oxygen saturation were measured. Blood pressure (BP) was also evaluated and had to be < 140/90mmHg in order to perform the test. Within 30 days of completing the JTA each firefighter was required to be evaluated by a physician and pass a generalized medical examination. Before starting the JTA each MFRD employee performed a 10 minute warm-up composed of stretches specific to the JTA, such as; quadriceps stretches, side reach for latissimus doris, toe touches for the hamstring muscle group as well as straddle holds, sitting adductor stretch and side lunges for the hip joint and hip flexors, and the overhead triceps extension stretch. (Montgomery Fire and Rescue Department. (2015) *Job Task Assessment*. Montgomery, Alabama).

The Job Task Analyses (JTA) was performed in full Personal Protection Equipment (PPE): including turnout coat and pants, helmet, gloves, boots, Nomex hood, and breathing apparatus (BA). The JTA consisted of the following simulations. The

standard for the MFD is that the JTA must be completed within 9 minutes and 30 seconds.

1. Stair Climb – Firefighters picked up a 30m hose that is 4.45 cm in width, placed the nozzle over their left shoulder and carried the hose up five stories. The hose weighed approximately 22kg.
2. Hoisting – At the top of the five story drill tower a rope is attached to a 15.2m hose weighing 16.36 kg, the firefighter used the rope to pull the hose up and over the railing of the tower.
3. Forcible Entry/Ventilation – To imitate a forced entry, the firefighter stood over an I-beam weighing 75 kg. The firefighters used a 4.09 kg sledge hammer overhead swing to move the I-beam 1.52 m.
4. Hose Advance – A hose that is approximately 45m in length was filled with water and laid in a zig-zag formation. The firefighters hoisted the hose over his shoulder and proceeded forward carrying the hose 30m to the end marker.
5. Victim Rescue – The firefighter proceeded to the mannequin, weighing 80 kg, took hold of the mannequin under the shoulders and raised the torso off the ground, lifted the mannequin into an upright position and walked backward 30m to finish the test.

Figure .1 Height Weight Chart Standards

HEIGHT WEIGHT STANDARDS
MAXIMUM WEIGHTS

MEN

HEIGHT	AGE IN YEARS			
IN INCHES	29 & BELOW	30 TO 39	40& ABOVE	50 & ABOVE
	MAXIMUM	MAXIMUM	MAXIMUM	MAXIMUM
60	153	158	163	168
61	155	160	165	170
62	158	163	168	173
63	160	165	170	175
64	164	169	174	179
65	169	174	179	184
66	174	179	184	189
67	179	184	189	194
68	184	189	194	199
69	189	194	199	204
70	194	199	204	209
71	199	204	209	214
72	205	210	215	220
73	211	216	221	226
74	218	223	228	233
75	224	229	234	239
76	230	235	240	245
77	236	241	246	251
78	242	247	252	257
79	248	253	258	263
80	254	259	264	269
81	260	265	270	275

NOTE: A weight allowance of 6 pounds for clothing is included in the above chart.

Statistical Analyses

The statistical analysis consisted of descriptive statistics, including means ± SD for age (yrs), height (cm), weight (kg), lean body mass (LBM), percent body fat (%bf), JTA time (sec), push-ups and curl-ups. In order to evaluate the relationships between the fitness variables and JTA, correlations coefficients were calculated (Pearson r). Significance was established at $p < 0.05$. A linear stepwise multiple regression analysis was performed in order to evaluate the best predictors of JTA based on fitness variables and body composition. Differences between predicted JTA time and measured JTA time were assessed via paired-samples *t*-tests. All data were analyzed with SPSS/PASW version 23.0 (Somers, NY, USA).

Results

Table 2 shows the descriptive statistics of the 82 firefighters (n = 82). The mean age of the MFRD subject group for this study was 34.95 ± 7.53. Using the mean age the firefighters scores for 1.5 mile run, 1 minute push-up test, and 1 minute curl-up test were compared to the generalized norms. ACSM has broken down physical fitness scores into fitness categories superior, excellent, good, fair, poor and very poor. ACSM reports a 1.5 mile run time of 11 minutes 6 seconds to 11 minutes 54 seconds in the good category for the age group of 30-39 and excellent for ages 40-49. Men in the age group of 30-39 years were reported to have 30+ push-ups in 1 minute as an excellent score. The 40-49 years age group, were reported as excellent if they were able to achieve 25+ push-ups. The firefighters of the MFRD mean push-up repetitions were 40+, this places them well above the average of the general population. The curl-up test scores were reported to be

well above average if men were able to complete 75+ curl-ups in the age groups of 30-39 and 40-49 years. However, the mean average of the MFRD was 43.15 ± 6.85 for curl-ups. Given the scores of the MFRD they are placed in the average to above average categories in the 60-75 percentiles.

Table 2. Firefighters Characteristics (mean ± SD)
(n = 82)

Variable	Mean ± SD
Age (yrs)	34.95 ± 7.53
Height (cm)	180.91 ± 6.22
Body Mass (kg)	96.37 ± 10.06
BMI	29.42 ± 2.48
LMB (kg)	71.81 ± 6.45
% Body Fat	25.14 ± 6.08
Curl-ups	43.15 ± 6.85
Push-ups	43.94 ± 12.01
Run Time (min)	11.81± 1.12
Total JTA time (sec)	262.8 ± 48.60

Table 3 shows the correlation coefficients between JTA time and each of the assessed variables. Job task analysis times were found to be significantly correlated with all variables with the exception of body mass.

Table 3. Relationship between JTA times and all variables
(n = 82)

Variable	Pearson's *r*	*p* Value
Age (yrs)	0.33	0.03
Height (cm)	-0.41	<0.01
Body Mass (kg)	-0.08	0.50
BMI	0.25	0.02
LMB (kg)	0.42	<0.01
% Body Fat	-0.46	<0.01
Curl-ups	-0.34	0.02
Push-ups	-0.26	0.02
Run Time (min)	0.52	<0.01

After calculating the physiological values and the fitness performance variables to overall JTA times, height, LBM, % body fat (%BF) and run time were found to be statistically significant. Table 4 shows the results of the step wise multiple regression analysis. All of the body composition and fitness variables were entered into the model. Model 1 consists of run time only and Model 2 consists of run time and LBM.

The results of the regression produced two models to predict JTA. Model 1 consisted of only 1.5 mile run time against JTA (run time $\beta = 0.52$, $p < .01$), constant ($p = .91$). Model 1 was not as great of a predictor as Model 2. Model 2 consisted of 1.5 mile run time and LBM and explained 48.8% of the variance ($R^2 = 0.49$, $F_{(2,81)} = 37.5$, $p < .01$). It was found that cardiovascular fitness (1.5 mile run time) and LBM significantly predicted JTA (run time $\beta = 0.53$, $p < .01$); LBM ($\beta = -0.47$, $p < .01$). For Model 2 the multiple regression equation was JTA sec = 243.22 + (23.11 * run time min) – (3.53 * LBM).

Table 4. Regression Equations to predict JTA time

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	Model	B	Std. Error	Beta		
1	(Constant)	-5.90	49.82	.518	-.118	.91
	Run Time min	22.73	4.20		5.41	<0.01
2	(Constant)	243.22	59.95	.526	4.06	<0.01
	Run Time min	23.11	3.54	-.469	6.53	<0.01
	LBM	-3.53	0.61		-5.82	<0.01

To validate the new regression equation, JTA was a calculated prediction equation and compared with the criterion measured values. The mean of the actual JTA times were 262.57 ± 48.62 seconds. The mean of JTA times using the Model 2 regression equation

reported a mean of 262.59 ± 33.94 seconds and revealed a mean difference between actual and predicted of 0.02 ± 34.8 seconds. The Pearson correlation revealed a significant and strong relationship ($r = 0.70$, $p < 0.01$) between measured and predicted JTA time. Finally, a paired-samples *t*-test was performed comparing JTA predicted from the regression equation and measured JTA. The difference was negligible and the means of JTA time between measured and predicted were not significantly different ($p = 1.00$). The standard error of estimation (SEE) of the Model 2 regression equation was 3.84.

Discussion

Firefighting is a dangerous occupation and it is essential that firefighters obtain a high level of fitness. Identifying the fitness impact related to firefighting characteristics would allow firefighters to meet the requirements of their job (Davis et al., 1982; Michaelides et al., 2008; Schmidt & Mckune, 2012). The present investigation evaluated the relationship between firefighter physical fitness and firefighter performance on job tasks. The JTA times, which consisted of a stair climb, hoist, forcible entry/ventilation, hose advance and victim rescue. JTA were also were predicted based on the fitness and body composition variables consisting of a 1.5 mile run, curl-ups, push-ups, and body composition measurements (LBM, %BF, BMI, and mass). Pearson correlations indicated LBM (kg) ($r = 0.42$, $p < 0.01$), % body fat ($r = -0.46$, $p < 0.01$), BMI ($r = 0.25$, p 0.02), and run time (min) ($r = 0.52$, $p < 0.01$) were significantly correlated with total JTA time for the group. The model 2 regression analyses found that LBM and runtime accounted for 48.8% of the variation within the JTA times of the subjects. These findings would imply that muscular strength, muscular endurance, and aerobic capacity are significantly related to JTA.

Significant Findings

Job Demands

Firefighting as an occupation is a combination of physical work and environmental stress. Firefighters are placed in uncertain situation from fire suppression to victim rescue. As a firefighter it is important to maintain adequate fitness levels. Muscular strength and aerobic capacity has been proven to be two leading contributors of success during on-duty firefighter performance. The firefighting occupation demands near maximal energy use during a fire scene.

Cardiovascular Endurance

It has been reported that the estimated oxygen consumption (VO_2max) of a firefighter is approximately 42 ($ml \cdot kg^{-1} \cdot min^{-1}$) to 49 ($ml \cdot kg^{-1} \cdot min^{-1}$) (Durand et al., 2011; Glendhill & Jamnik, 1992; Schmidt & Mckune, 2012). Aerobic capacity is important for firefighters. Using a 1.5 mile run as a measure of aerobic capacity we observed a significant correlation with JTA times ($r = 0.52$, $p < 0.01$). This indicates that aerobic capacity is an important factor related to firefighter performance. For this investigation VO_2max was predicted from the following formula: VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) = 88.02 + (3.716 x gender) – (0.0753 x body weight (lbs)) – 2.767 x mile run time (min)) (George et al., 1993). The accuracy of prediction of this equation was reported to be ($r = 0.90$), SEE = 2.8 $ml \cdot kg^{-1} \cdot min^{-1}$. The mean predicted VO_2 max value from this study was 43.09 ± 3.95 ($ml \cdot kg^{-1} \cdot min^{-1}$), which is similar to the reported mean of oxygen consumption needed by firefighters to perform their job. William-Bell (2009) completed a study in younger male firefighters (mean age 24.3 ± 5.6 years) and compared VO_2max values of

the individuals who did and did not complete a fire simulation test. The firefighters who completed the simulation test reported a VO_2 max of 53.00 ± 7.4 ($ml \cdot kg^{-1} \cdot min^{-1}$), those who did not complete the simulation test had a VO_2max value of 39.3 ± 5.2 ($ml \cdot kg^{-1} \cdot min^{-1}$) (William-Bell et al., 2009).

Body Composition

Body composition is an important variable when it comes to firefighter performance. Numerous studies have compared BMI to JTA performance outcomes and many have reported that a higher BMI was associated with decreased VO_2max values (Nogueira et al., 2016; Smith, 2011; Storer et al., 2014). Michaelides (2011), found that when comparing JTA times with body composition measurements, BMI (r = 0.82) and % body fat (r = 0.38) were significantly correlated with poor performance (Michaelides et al., 2011). During this investigation BMI(r = 0.25, p <0.01), LBM (r =0.42 p <0.01) and %BF (r =-0.46, p 0.02) were all significantly correlated with overall complete of the JTA times. LBM and the 1.5 mile run, an aerobic capacity measurement used to predict VO_2max, were used to significantly predict JTA times. Similarly to this study, Williford (1999), found that LBM (r = -0.47, p <0.01) and % body fat (r = 0.30, p <0.01) were significantly correlated with JTA times (Williford et al., 1999).

Upper Body Muscular Strength and Endurance (Push-Up Test)

Rhea (2004), showed a significant correlation between upper body strength and the completion time of a job task performance. 5RM bench press was found to be significantly correlated with total performance (r = 0.66, $p \leq 0.05$), hose pull (r = 0.80, $p \leq 0.05$), victim drag (r = 0.65, $p \leq 0.05$), stair climb (r = 0.39, $p \leq 0.05$), and equipment

hoist (r = 0.68, $p \leq 0.05$) (Rhea et al., 2004) Michaelides (2008), also reported that upper body muscular endurance from push-ups to exhaustion were related to JTA completion time ($p < 0.05$) (Michaelides, 2008). Michaelides (2011) also reported a statically significant (r = 0.64, $p < 0.01$) correlation between the push-up test and total JTA times when coupled along with fitness variables (Michaelides, 2011). Mayhew (1991), evaluated push-ups as a measure of upper body strength and found that a 1 minute push up test was significantly correlated to a 1RM bench press (r = 0.47) (Mayhew et al., 1991). In this study push-ups were found to be significantly related to JTA (r = -0.26, p = 0.02). However, in this study no resistant training strength measurements were taken and even though push-ups were found to be significant, they were not as significant as other variables.

Abdominal Strength and Endurance (Curl Up Test)

In the present study curl ups were found to be significant (r = -0.34, p 0.02) to JTA times. The curl up test has been found to be a reliable measurement of abdominal strength and endurance by having a correlation of (r = 0.67) when compared to a full sit up test (Diener et al., 1995). Michaelides (2011), found a 1 minute curl up test to be significantly correlated with overall JTA times when coupled with push-ups and step test (r = 0.42, $p < 0.01$) (Michaelides et al., 2011). Other studies have found positive correlations with abdominal exercises and specific variables of JTA. One minute maximum curl ups were reported to be correlated with over all JTA time (r = -0.41, p <0.01) and stair climb test (r = 0.32, p <0.01) (Williford et al., 1999). This study the aim was to compare the curl up test to JTA performance. It was found to be significant, but

was not as significant as other variables and when put into the regression equation model was not a predictor for JTA times.

Firefighter Wellness Programs

The Montgomery Fire and Rescue Department has a wellness program for their employees. Through this wellness program firefighters are evaluated on upper body muscular endurance and strength by performing a 1 minute maximal effort push-up test, abdominal strength, and endurance with a 1 minute maximal effort curl up test, and aerobic capacity from 1.5 mile run performance. The wellness program was developed regarding the health and fitness of firefighters (Montgomery Fire and Rescue Department. (2015) *Job Task Assessment*. Montgomery, Alabama). The Montgomery Fire and Rescue Department is one of the few fire departments to have an implemented wellness program. The MFRD provided free weights and other exercise equipment and allows the firefighters to exercise one hour per day while on duty. The MFRD also has programs designed for those who do not complete the JTA in the required time frame to help them train for reevaluation. Birmingham, Alabama had one of the first reported wellness programs, which started in 1984 (Hilyer et al., 1999). Half the fire stations were provided with equipment (free weights) and the others were not. Each station was evaluated on %BF, 1.5 mile run time, 1RM bench press, 1 minute sit-up test and flexibility. Baseline measurements were taken and after two years of the wellness program being implemented fitness variables were evaluated again and significant improvements were seen in the fire stations with equipment in %BF, bench press, flexibility (sit and reach) and over all fitness all was found to be significantly higher ($p < 0.05$) (Hilyer et al., 1999). The MFRD and the fire department in Birmingham, Alabama

took a fitness based approach when creating and implementing their wellness programs. In Dallas, Texas a health and wellness program was implemented into the fire station with medical based wellness focus. They were assisted by Baylor Health Care System and provided the firefighters were full medical examinations with specific focus on a blood panel evaluating total cholesterol (mg/dL), blood pressure, triglycerides (mg/dL), and glucose (mg/dL) (Winter et al., 2010). Each of the three wellness programs listed above have a different focus but the primary focus of each program is the wellbeing and health of the firefighters involved. While other departments may have wellness programs, there is not a complete list or a significant amount of research within this area.

Conclusion

Firefighting is one of the most dangerous, physically demanding, and unpredictable occupations. Being a firefighter comes with great responsibility, each firefighter is tasked with providing protection and safety to the community they work within. Firefighters have unpredictable job and never know what type of emergency situation they will face. To better prepare firefighters for on the job situations a job performance test was created. A JTA is a test of physical fitness with specific challenges set in place to mimic the obstacles a firefighter might face when called to an emergency. Most JTA tests include 5-8 occupational tasks; for example: a stair climb, victim rescue, equipment hoist, hose pull, and forcible entry. Many have researched these specific tests to find whether or not there are certain fitness variables, muscular endurance, muscular strength, aerobic endurance, anaerobic power, and body composition, which can predict or improve performance among the JTA (Antolini et al. 2015; Rhea et al., 2004; Roberts et al., 2002; Smith, 2011; Storer et al., 2014; Taylor et al., 2015a; William-Bell et al.,

2009). Throughout the research multiple variables have been reported to increase performance, however, the conclusion of this study was that firefighters need to maintain a healthy body composition and a high cardiovascular fitness capacity to properly and safely perform their duties. This study found that LBM and run time to be significant predictors of job task analysis times. While muscular strength and endurance were found to be significantly related to fire fighter performance, aerobic capacity and LBM were found to be the best predictors of JTA times. It is important for fire departments to have wellness programs that consist of the components necessary to improve performance. The focus of the program should consist of training to improve body composition, strength and endurance.

References

Abel, M. G., Palmer, T. G., & Trubee, N. (2015). Exercise Program Design for Structural Firefighters. *Strength and Conditioning Journal, 37*(4), 8-19. doi:10.1519/ssc.0000000000000123

Antolini, M. R., Weston, Z. J., & Tiidus, P. M. (2015). Physical fitness characteristics of a front-line firefighter population. *Acta Kinesiologiae Universitatis Tartuensis, 21*(0), 61. doi:10.12697/akut.2015.21.06

Bjerke, W. (2011). Health and Fitness Programs for Firefighters. *Strength and Conditioning Journal, 33*(2), 55-57. doi:10.1519/ssc.0b013e31820bc6f2

Barr, D., Gregson, W., & Reilly, T. (2010). The thermal ergonomics of firefighting reviewed. *Applied Ergonomics, 41*(1), 161-172. doi:10.1016/j.apergo.2009.07.001

Bugajska, J., Zuzewicz, K., Szmauz-Dybko, M., & Konaraska, M. (2007). Cardiovascular Stress, Energy Expenditure and Subjective Perceived Ratings of Fire Fighters During Typical Fire Suppression and Rescue Task. *International Journal of Occupational Safety and Ergonomics, 13*(3), 323-331.

Cady, L. D. Jr., Thomas, P. C. & Karwasky R. J., (1985). Program for Increasing Health and Physical Fitness of Fire Firefighters. *Journal of Occupational Medicine, 27*(2), 110-114

Calavalle, A. R., Sisti, D., Mennelli, G., Andolina, G., Sal, M. D., Rocchi, M. B., . . . Stocchi, V.(2013). A Simple Method to Analyze Overall Individual Physical Fitness in Firefighters. *Journal of Strength and Conditioning Research, 27*(3), 769-775. doi:10.1519/jsc.0b013e3182600554

Clark, S., Rene, A., Theurer, W. M., & Marshall, M. (2002). Association of Body Mass Index and Health Status in Firefighters. *Journal of Occupational and EnvironmentalMedicine, 44*(10), 940-946. doi:10.1097/00043764-200210000-00013

Davis, P. O., Dotson, C. O., & Maria, D. L. (1982). Relationship between simulated fire fighting tasks and physical performance measures. *Medicine & Science in Sports & Exercise, 14*(1). doi:10.1249/00005768-198214010-00013

Dennison, K. J., Mullineaux, D. R., Yates, J. W., & Abel, M. G. (2012). The Effect of Fatigue and Training Status on Firefighter Performance. *Journal of Strength and Conditioning Research, 26*(4), 1101-1109. doi:10.1519/jsc.0b013e31822dd027

Diener, M. H., Golding, L. A., & Diener, D. (1995). Validity and reliability of a one-minute half sit-up test of abdominal strength and endurance. *Sports Medicine, Training and Rehabilitation, 6*(2), 105-119.

Durand. G., Tsismenakis, A. J., Jahnke, S. A., Baur, D. M., Christophi, C.A., & Kales, S. N. (2011). Firefighters' Physical Activity: Relation to fitness and cardiovascular disease risk. *Medicine & Science in Sports & Exercise*, *43*(9), 1752-1759. doi:10.1249/MSS.0b013e318215cf25.

Frost, D. M., Beach, T. A., Callaghan, J. P., & Mcgill, S. M. (2015). Exercise-Based Performance Enhancement and Injury Prevention for Firefighters. *Journal of Strength and Conditioning Research, 29*(9), 2441-2459. doi:10.1519/jsc.0000000000000923

George, J. D., Vehrs, P. R., Allsen, P. E., Fellingham, G. W., & Fisher, A. G. (1993). VO2max estimation from a submaximal 1-mile track jog for fit college-age individuals. *Medicine & Science in Sports & Exercise, 25*(3). doi:10.1249/00005768-199303000-00017

Gledhill, N., & Jamnik, V. K. (1992) Characterization of the Physical Demands of Firefighting. *Canadian Journal of Sport Science, 17*(3), 207-213. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/1325260

Groeller, H., Fullagar, H. H., Sampson, J. A., Mott, B. J., & Taylor, N. A. (2015). Employment Standards for Australian Urban Firefighters. *Journal of Occupational and Environmental Medicine, 57*(10), 1083-1091. doi:10.1097/jom.0000000000000527

Hilyer, J. C., Weaver, M. T., Gibbs, J. N., Hunter, G. R., & Spruiell, W. V. (1999). In-Station Physical Training for Firefighters. *Strength and Conditioning Journal, 21*(1), 60. doi:10.1519/00126548-199902000-00015

Holmér, I., & Gavhed, D. (2007). Classification of metabolic and respiratory demands in firefighting activity with extreme workloads. *Applied Ergonomics, 38*(1), 45-52. doi:10.1016/j.apergo.2006.01.004

Horowitz, M. R., & Montgomery, D. L. (1993). Physiological profile of firefighters compared to norms from the Canadian population. *Canadian Journal of Public Health, 84*(1), 50-52. Retrieved from https://www.researchgate.net/publication/14699374

Hylton, J., Haynes, G., & Stein, G. P. (n.d.). U.S. fire department profile. Retrieved April 25, 2017, from http://www.nfpa.org/news-and-research/fire-statistics-and-reports/fire-statistics/the-fire-service/administration/us-fire-department-profile

International Association of Fire Fighters Chiefs. (2014). *IAFF/IAFC/ ACE Peer Fitness Training Certification Program.* Washington DC: IAFF, Fire Fighter Quarterly

Jitnarin, N., Poston, W. S., Haddock, C. K., Jahnke, S., & Tuley, B. C. (2012). Accuracy of body mass index-defined overweight in fire fighters. *Occupational Medicine, 63*(3), 227-230. doi:10.1093/occmed/kqs213

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. doi:10.1056/nejmoa060357

Kales, S. N., Soteriades, E. S., Christoudias, S. G., & Christiani, D. C. (2003). Firefighters and on-duty deaths from coronary heart disease: a case control study. *Environmental Health, 2*(1). doi:10.1186/1476-069x-2-14

Karter, M. (2012). *Patterns of Firefighter fire-ground injuries* (National Fire Association 1-27): Quincy, MA

Mayhew, J. L., Ball, T. E., Arnold, M. D., & Bowen, J. C. (1991). Push-ups as a Measure of Upper Body Strength. *Journal of Applied Sport Science Research, 5*(1), 16-21.

Mcdonough, S. L., Phillips, J. S., & Twilbeck, T. J. (2015). Determining Best Practices to Reduce Occupational Health Risks in Firefighters. *Journal of Strength and Conditioning Research, 29*(7), 2041-2044. doi:10.1519/jsc.0000000000000839

Michaelides, M. A., Parpa, K. M., Thompson, J., & Brown, B. (2008). Predicting Performance on a Firefghter's Ability Test From Fitness Parameters. *Research Quarterly for Exercise and Sport, 79*(4), 468-475. doi:10.1080/02701367.2008.10599513

Michaelides, M. A., Parpa, K. M., Henry, L. J., Thompson, G. B., & Brown, B. S. (2011). Assessment of Physical Fitness Aspects and Their Relationship to Firefighters' Job Abilities. *Journal of Strength and Conditioning Research, 25*(4), 956-965. doi:10.1519/jsc.0b013e3181cc23ea

Montgomery Fire and Rescue Department. (2015) *Job Task Assessment*. Montgomery, Alabama

Montgomery Fire and Rescue Department. (2015) *Weight Policy*. Montgomery, Alabama

National Fire Protection Association Fire Analysis and Research Division. (2011). *Third Needs Assessment of the U.S. Fire Service*. Quincy, MA

Nogueira, E. C., Porto, L. G., Nogueira, R. M., Martins, W. R., Fonseca, R. M., Lunardi, C. C., & Oliveira, R. J. (2016). Body Composition is Strongly Associated With Cardiorespiratory Fitness in a Large Brazilian Military Firefighter Cohort. *Journal of Strength and Conditioning Research, 30*(1), 33-38. doi:10.1519/jsc.0000000000001039

O'Connell, E. R., Thomas, P. C., Cady, L. D., & Karwasky, R. J., (1986) Energy cost of Simulated Stair Climbing as a Job-Related Rask in Firefighting. *Journal of Occupational Medicine, 28*(4) 282-284.

Ode, J., Knous, J., Schlaff, R., Hemenway, J., Peterson, J., & Lowry, J. (2013). Accuracy of body mass index in volunteer firefighters. *Occupation Medicine, 64*(3), 193-197. doi:10.1093/occmed/kqt143

Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2014). Prevalence of Childhood and Adult Obesity in the United States, 2011-2012. *Jama, 311*(8), 806. doi:10.1001/jama.2014.732

Pawlak, R., Clasey, J. L., Palmer, T., Symons, T. B., & Abel, M. G. (2015). The Effect of a Novel Tactical Training Program on Physical Fitness and Occupational Performance in Firefighters. *Journal of Strength and Conditioning Research, 29*(3), 578-588. doi:10.1519/jsc.0000000000000663

Pescatello, L. S. (2014). *ACSM's guidelines for exercise testing and prescription*. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins.

Poston, W. S., Haddock, C. K., Jahnke, S. A., Jitnarin, N., Tuley, B. C., & Kales, S. N. (2011). The Prevalence of Overweight, Obesity, and Substandard Fitness in a Population-Based Firefighter Cohort. *Journal of Occupational and Environmental Medicine, 53*(3), 266-273. doi:10.1097/jom.0b013e31820af362

Rhea, M. R., Alvar, B. A., & Gray, R. (2004). Physical Fitness and Job Performance of Firefighters. *The Journal of Strength and Conditioning Research, 18*(2), 348. doi:10.1519/r-12812.1

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. doi:10.1519/00124278-200205000-00016

Sal, M. D., Barbieri, E., Garbati, P., Sisti, D., Rocchi, M. B., & Stocchi, V. (2009). Physiologic Responses of Firefighter Recruits During a Supervised Live-Fire Work Performance Test. *Journal of Strength and Conditioning Research, 23*(8), 2396-2404. doi:10.1519/jsc.0b013e3181bb72c0

Schmidt, C. & Mckune, A. (2012). Association between Physical Fitness and Job Performance in Fire-fighters. *Ergonomics SA, 24*(2), 44-57.

Sheaff, A. K., Bennett, A., Hanson, E. D., Kim, Y., Hsu, J.,… Hurley, B. F. (2010). Physiological Determinants of the Candidate Physical Ability Test in Firefighters. *Journal of Strength and Conditioning, 24*(11), 3112-3122. doi:10.1519/JSC.0b013e3181f0a8d5

Smith, D. L. (2011). Firefighter Fitness. *Current Sports Medicine Reports, 10*(3), 167-172. doi:10.1249/jsr.0b013e31821a9fec

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. doi:10.1038/oby.2005.214

Storer, T. W., Dolezal, B. A., Abrazado, M. L., Smith, D. L., Batalin, M. A., Tseng, C., & Cooper, C. B. (2014). Firefighter Health and Fitness Assessment. *Journal of Strength and Conditioning Research*, *28*(3), 661-671. doi:10.1519/jsc.0b013e31829b54da

Taylor, N. A., Fullagar, H. H., Mott, B. J., Sampson, J. A., & Groeller, H. (2015a).Employment Standards for Australian Urban Firefighters. *Journal of Occupational and Environmenta Medicine,57*(10), 1063-1071. doi:10.1097/jom.0000000000000525

Taylor, N. A., Fullagar, H. H., Mott, B. J., Sampson, J. A., & Groeller, H. (2015b). Employment Standards for Australian Urban Firefighters. *Journal of Occupational and Environmental Medicine,57*(10), 1063-1071. doi:10.1097/jom.0000000000000525

Williams-Bell, F. M., Villar, R., Sharratt, M. T., & Hughson, R. L. (2009). Physiological Demands of the Firefighter Candidate Physical Ability Test. *Medicine & Science in Sports & Exercise, 41*(3), 653-662. doi:10.1249/mss.0b013e31818ad117

Williford, H. N., Duey, W. J., Olson, M. S., Howard, R., & Wang, N. (1999). Relationship between fire fighting suppression tasks and physical fitness. *Ergonomics,42*(9), 1179-1186. doi:10.1080/001401399185063

Winter, F. D., Seals, N., Martin, J., & Russell, B. (2010). Implementation of the first wellness-fitness evaluation for the Dallas Fire-Rescue Department. *Proceedings (Baylor University. Medical Center), 23*(3), 235-238.

Womack, W. W., Green, S. G., and Course, S. F. (2000). Cardiovascular Risk Markers in Firefighters: A longitudinal study. *Cardiovascular Reviews & Reports, 21*(0197), 544-548.