Firefighter VO2 testing: Does a Predictive or Direct Measurement Model Provide the Most Accurate Results?

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by

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Abstract

The study was intended to review the perceptions of firefighters when completing a VO2 max test process versus a predictive VO2 process and identify if they are concerned about receiving accurate VO2 results. This required the use of a generic qualitative inquiry to collect data following two days of individualized VO2 testing and interviews for participants.

The problem is that some firefighters and agencies are accepting predictive evaluations as an accurate measurement of their firefighters VO2 scores and associated MET score. While a predictive VO2 process may provide a generalized MET score, literature and research has identified inaccuracies associated with the predictive VO2 process that puts firefighters at risk.

The results identified that most participants felt that the VO2 max test was physically harder to perform, yet it provided them with a more individualized VO2 measurement and associated MET score. The results also identified that both the VO2 max and predictive process only focused on a snapshot of cardiovascular needs when compared to actual fireground activities. It was determined that even with the logistical challenges associated with a VO2 max and in-line evaluation, that participants agreed that the in-line evaluation provided more VO2 accuracy.

Moving forward, it is recommended that fire agencies support or move toward a process that provides firefighters with a VO2 score that supports their personal health and well ness goals with an accurate and individualized MET score. This process will provide accurate results to measure a firefighter's ability to complete the 13 essential job functions and associated 12 MET requirement identified by NFPA (2022) 1982.

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CHAPTER 1. INTRODUCTION

Over the last 10 years, the U.S. Fire Administration reports that stress and overexertion resulted in 46.3% of firefighter deaths and that 41.8% of these fatalities were due to a heart attack (U.S. Fire Administration [USFA], 2022). This statistic supports the fact that firefighting is an arduous profession that requires intense physical prowess and cardiovascular resiliency to perform critical lifesaving job related skills. These skills cover a broad spectrum of physical activities that require firefighters to wear a Self-Contained Breathing Apparatus (SCBA) while performing tactical objectives involving "hose line operations, extensive crawling, lifting, carry heavy objects, ventilating roofs or walls, using power or hand tools, [and] forcible entry" (National Fire Protection Agency [NFPA], 2022, p. 23). These physical challenges require firefighters, sometimes labeled tactical athletes, to be accountable for a high level of physical fitness that may ultimately save a citizen's life or their own (Green, 2019). To measure a firefighter's level of fitness, the NFPA has created various standards that are recommended for firefighters to ensure health and wellness. The current evaluation process used to evaluate a firefighter's cardiovascular health involves the option of using a sub-maximal predictive calculation or a more accurate maximal calculation. While the sub-maximal evaluation process may be supported by some firefighters as it requires less time to complete, less personnel to perform, supervise the process, and only requires an estimated 85% of a true VO2 max to be completed, this modality may not provide the most accurate health and wellness calculation. In order to ensure firefighters, receive the highest level of cardiovascular evaluation possible, the research will look to identify if firefighters feel the predictive sub-maximal evaluation or a direct maximal evaluation provides the best evaluation of their cardiovascular health. Providing clarity

on these processes may give firefighters the most accurate evaluation of their cardiovascular health and may save a citizen's life or their own.

Background

Today's fire service is steeped in tradition and moving into an era of high physical fitness standards continues to be a challenge for some firefighters. During the last 30 years, these physical fitness standards have vacillated between a simple push-up and sit-up evaluation to requiring personnel to perform specific job-related skills while wearing bunker gear, such as a stair climb, pulling a fire hose, tool carry, and victim rescue. While these physical fitness standards may have met the mark 30 years ago, today's updated requirements are needed due to proven line of duty fatalities related to cardiovascular deaths.

The most up to date physical standards, along with other health and wellness requirements, are further expanded upon in the Comprehensive Occupational Medical Program for Fire Departments NFPA (2022) standard 1582, which identifies the thirteen essential job tasks that must be completed. Due to these job tasks, strength, and cardiovascular requirements of the position, NFPA 1582 has identified that firefighters meet a measurement of 12 using the Metabolic Equivalent of a Task (MET's) evaluation in order not be counseled, placed into a prescribed fitness program, or restricted from duty (2022). The above mentioned METs of 12 is a scale used to identify the required energy for firefighting activities. This MET's score is derived from a VO2 measurement that evaluates the amount (volume) of oxygen that a body uses during exercise (WebMD, 2023). The problem with this VO2 measurement calculation is that NFPA (2022) 1582 standard outlines the use of "an appropriate maximal or submaximal protocol" (p. 23). While these protocols are similar in nature the submaximal protocol has been linked to an 11% error rate that "overestimate[s] aerobic capacity in less fit individuals and underestimate[s]

it in more fit individuals" (Doleful et al., 2015, p. 143). Identifying the highest level of accuracy is of the utmost importance as an accurate VO2 measurement provides an accurate MET score that ensures firefighters are fit enough to perform their job tasks and aware of the associated metabolic syndromes related to a lower MET score.

Significance of the Study

Last year, 94 firefighters made the ultimate sacrifice and died in the line of duty (USFA, 2022). The number of firefighter deaths related to stress and overexertion continues to be the primary cause of job-related deaths, and in 2022, 39.4% of these fatal injuries were caused by stress/ overexertion and 35.1% of those were caused by a heart attack. Year after year, the majority of firefighter deaths are due to the same cause, yet the fire service still struggles to provide accurate and mandatory physicals and standards for these personnel. This struggle is only magnified by the fact that a majority of fire departments (72%) lack the required programs to maintain health and wellness programs (National Volunteer Fire Council [NVFC], 2021). If the fire service continues to ignore the need for comprehensive, thorough, and accurate health and wellness assessments, they will continue to suffer additional deaths each year.

The significance of this study supports the U.S. Fire Administration's strategic plan by specifically supporting the ability to strengthen the culture of health and wellness by improving responder safety and survival by identifying the most accurate VO2 testing process (USFA, 2019). In addition, the study addresses one of the National Fire Academy's program outcomes by addressing the "technical and adaptive challenges" (National Fire Academy [NFA], 2023, p. 8) associated with the education and incorporation of an accurate VO2 measurement process. As progressive fire service agencies move forward with mandatory physicals, job evaluations, and cardiovascular VO2 assessments, the challenge of accuracy becomes of the utmost importance.

Some fire service agencies are using predictive VO2 measurements to evaluate cardiovascular health that are based on a predictive sub-maximal evaluation versus maximal VO2 measurements. Research has identified that the use of The Fire Service Joint Labor Management Wellness-Fitness Initiative (WFI) sub-maximal calculation has resulted in an overestimation of one MET, which may overestimate a firefighters' cardiovascular health and even their fit for duty assessment (Drew-Nord et al., 2011). This overestimation may be the tipping point for an individual moving below the 12 MET standard that is associated with various metabolic syndromes that must be evaluated by a knowledgeable physician (NFPA, 2022).

This research supports what has been identified by the *21st Century Fire and Emergency Services white paper, critical issue D, initiative 4*: "Ensure ongoing physical fitness and wellness requirements are standardized, adopted, and used within every department" (The Center for Public Safety Excellence [CPSE] & International City/County Management Association [ICMA], 2020, p. 17). The needed research and data will look to identify the most accurate VO2 measurement process to ensure firefighters feel they are receiving the most comprehensive evaluation of their cardiovascular health. Ensuring the most accurate VO2 measurement for firefighters will allow them to be accurately measured against the NFPA MET's standards and possibly reduce line of duty deaths.

Problem Statement

The problem is that some firefighters are accepting a subpar evaluation of their VO2 score that has been associated with an 11% error rate that overestimates aerobic capacity (Doleful et al., 2015). This is a major problem, as an accurate VO2 score and measurement is identified by the NFPA (2002) standard 1582 as a job-related standard, health and wellness evaluation, and marker for cardiac related casualties. Allowing for a predictive method of testing

a firefighters VO2 results may provide a false narrative that these individuals are assuming they have met the associated MET score of 12 as identified in NFPA standard 1582. While a substandard application and model of measuring VO2 is published by The Fire Service Joint Labor Management's Wellness- Fitness Initiative (WFI), this report identified sources of errors related to age prediction, maximal heart rate, and heart rate responses due to various medical issues and medications (International Association of Firefighters [IAFC], 2018). The research and evaluation is needed to identify if a predictive or direct measurement of VO2 is needed to ensure firefighters are prepared to complete their job tasks, maintain a high level of personal health and wellness, and monitor/evaluate their fitness plans.

Purpose Statement

The purpose of this research is to explore firefighters' perspectives as it relates to a predictive or direct measurement model used to calculate a VO2 score and provide firefighters with the most accurate and impactful evaluation of their cardiovascular health. Providing an accurate VO2 calculation model or gold standard will ensure firefighters are receiving the support they need to ensure job related standards and overall health and wellness.

Research Question(s) or Hypothesis

The research questions will identify if the firefighters feel a difference in a predictive versus a direct measurement VO2 max process and if they are concerned with accurate results.

RQ1: What are firefighters' perceptions or perspective (pick one) about workload from the predicted VO2 max test process in relation to workload required during a direct measurement model?

RQ2: Does the predictive VO2 test process make firefighters feel like they are being accurately tested?

RQ3: Are firefighters concerned about the most accurate evaluation of their cardiovascular health?

Summary

Chapter 1 provides an introduction and background on the predictive sub-maximal and maximal VO2 calculations that are being used to calculate a MET's score. Chapter 2 will review existing literature related to the current processes that are currently being used to calculate VO2 measurements. Chapter 3 will identify the research method that will be used to evaluate both predictive sub-maximal and VO2 max calculations. Chapter 4 will outline the result of the completed research. Chapter 5 will provide conclusions on the VO2 testing and future recommendations.

CHAPTER 2: LITERATURE REVIEW

Introduction

The theoretical framework will identify if literature denotes a difference in a predictive or direct measurement model used in VO2 calculations. The current literature tends to support the concept that predictive measurement models are associated with quantitative errors and overestimation and under estimation of VO2 calculations (Doleful et al., 2015). While the literature tends to support the fact that the quantitative measurement of the predictive VO2 evaluation model is not as accurate as a direct measurement process, the literature appears to lack the qualitative evaluation by firefighters. Scrutiny will be applied to various VO2 measurement models, including national standards and academic articles that focus primarily on firefighter VO2 testing.

Existing Literature

Today's firefighters are required to perform activities in extreme environments that challenge their mental acuity, physical boundaries, increase their exertional heart rate 84-100% and escalate their peak oxygen uptake to 63-97% (Cho et al., 2022). While technological advances may improve their effectiveness and efficiency during some of their operations, the individual's physical prowess is still a crucial element of these job-related tasks. The review of literature will focus on national standards and academic review.

National Standards

The NFPA outlines a multitude of performance standards that support the fire service. These NFPA standards vary from a firefighter's standard qualifications or deployment models to the standards in NFPA 1582, which outline the Comprehensive Occupational Medical Program for Fire Departments. NFPA (2022) 1582 identifies that firefighters shall have their aerobic

capacity tested annually using a maximal or submaximal protocol. The 1582 requirement outlines this aerobic capacity to be measured by a MET score and recommends a MET score of 12. A MET score is calculated using a VO2 measurement that educates individuals on their fitness level and assists them in identifying the appropriate exercise program to increase one's fitness level (IAFC, 2018). While the MET score is identified in the literature, the commonly used "submaximal assessments that can be used to determine a firefighter's aerobic capacity: the WFI sub-maximal treadmill and the WFI sub-maximal Stepmill assessment" (IAFC, 2018, p. 4) are used to provide the predictive VO2 calculation that converts to a MET's score. This WFI process requires the determination of an individual's Body Mass Index (BMI) (Appendix A-Figure A1), and the Target Heart Rate (THR) calculation to individualize results (Appendix A-Figure A2).

VO2 testing varies and can be completed using indirect / predictive models or direct models. Indirect calculations "estimate a person's aerobic capacity based off their heart rate, their distance covered, and or their time of trial when using a certain protocol" (Kour Buttar et al., 2019, p. 25), whereas a direct model will "measure an individual's expired gases to analyze their pulmonary ventilation, inspired oxygen, and their expired carbon dioxide. Direct measures accurately determine an individual's maximum oxygen consumption by breath-by-breath analysis" (Kour Buttar et al., 2019, p. 25). In order to understand the VO2 definitions and calculation (VO2=ML/KG/MIN), one must be familiar with the VO2 definitions and calculation; VO2 (V=Volume, O2= Oxygen), also consider VO2 Max (V=Volume, O2=Oxygen, Max = maximal), ML (milliliters), KG (kilograms), MIN (minutes). This calculation identifies the volume of oxygen (ML) times the relative body weight (KG) of an individual times the use of oxygen in one minute (MIN), which identifies how much oxygen one's body can consume; this

test is typically performed on a treadmill in a laboratory setting for the most accurate results or modified to use in a predictive model. As recommended by NFPA (2002) standard 1582, firefighters should meet a 12 MET standard, which is obtained by dividing a VO2 score divided by 3.5; Example, a VO2 score of 42 divided by 3.5 equals 12 (MET's) or "1 MET =3.5 ml of O2/kg/min" (Drew-Nord et al., 2011, para. 3).

Academic Review

Historical academic literature and more recently updated articles have identified that predictive VO2 testing results in a misrepresentation of true VO2 measurements and the associated MET score. Research has identified that predictive VO2 processes over predict a VO2 max by approximately 10-20% based on the protocol (Aguiar et al., 2018), with the lowest overestimation of "5.4% for men and 11.8% for women" (Petelczyc et al., 2023, p. 6). Providing accurate results is critical for firefighters to understand their fitness level so they can modify their exercise habits and have a true picture of their health. With the number one contributor of sudden cardiac death being attributed to low levels of physical fitness, meticulous processes should be used to evaluate a VO2 measurement (Dicks et al., 2019). Providing firefighters with accurate testing and evaluation processes to ensure they are fit to do the job and minimize cardiac related events is necessary.

Predictive VO2

Predictive studies have identified that 36% percent of the sampled firefighters would be categorized incorrectly as being fit for duty, which ultimately corresponds to the overall life safety of a firefighter (Klaren et al., 2014). The previous statement supports the fact that a predictive VO2 process may misclassify a firefighter into a fit for duty area, which may result in a firefighter serving beyond their work capacity when their life may be at risk. Firefighters

depend on these evaluations to determine if they have the appropriate level of fitness to complete their jobs safely.

Additional review of predictive VO2 testing conducted by Hale et al. (2022), resulted in the overestimation of VO2 scores by 13.7% for the majority of the study, and a study conducted by Doleful et al.'s (2015) identified that 11% of the predictive results overestimated aerobic capacity in less fit firefighters. There was also a moderate correlation that identified that a "submaximal treadmill protocol underestimated true VO2max in 72.4% of the firefighters by as much as 21% and overestimated the true VO2max by as much as 30.6%" (Hale et al., 2022, p. 9). These overestimations and underestimations continue to be documented by various research articles using different VO2 testing processes (stair mill, stationary bike, ramp protocol, and step method), and they continue to identify that these predictive "equations significantly over- and under-predict the VO2max of young adults, respectively" (Aguiar et al., 2018, p. 42). While Aguiar et al. focuses specifically on firefighters, the correlation of predictive processes has been researched in civilian populations using a predictive and in-line model involving the Bruce Protocol and cardiopulmonary exercise testing (CPET); this research has identified that the predictive Bruce Protocol was not able to evaluate true capacity and ultimately overestimated it (Moreira da Rocha Neto et al., 2019). While some firefighters and fire service administrators prefer the indirect or predictive models due to the reduced cost of equipment, training of personnel and reduced processing of individuals to complete these tests, these models are associated with a lower level of exertion that allows sedentary and obese people to pass these tests (Kour Buttar et al., 2019); while the indirect or predictive models may appear business friendly, firefighters and fire service administrators must provide the highest level of evaluation for firefighters to ensure their safety.

Direct VO2 Testing

Various research has identified that the use of a direct VO2 measurement model is associated with increased accuracy, with a direct VO2 max being "the most important physiological measurement in defining functional capacity of an individual[s] aerobic power" (Moreira da Rocha Neto et al., 2019, p. 363). The direct measurement VO2 max process has been identified as the gold standard, as it allows individuals to push their physiological limits, have their individual results evaluated, and understand their cardiovascular work capacity (Wiecha et al., 2023). While the direct VO2 testing process requires the use of standardized equipment (stair climber, treadmill, ergometer), trained technicians, a direct measurement VO2 testing machine and is ultimately more expensive due to personnel costs, the results are more accurate (Habibi et al., 2014). Providing the most accurate results for firefighters should be at the forefront of fire service administrators and health and wellness staff alike. Many researchers continue to support the use of an indirect or predictive model to calculate a VO2 or measurement based on the reduced cost and mass testing philosophies, but the results continue to identify that the direct measurement model is preferred over an indirect model and is the only way to directly measure VO2 (Koutilanos et al., 2013). In the end, a direct measurement VO2 max model cannot be replaced or considered interchangeable with an indirect or predictive equation (Wiecha et al., 2023).

Synthesis of the Existing Literature

The existing literature supports and identifies numerous options for VO2 measurement processes for firefighters. While these options are designed to be scalable based on agency size, financial constraints, and ease of operation, the most comprehensive process should be considered in order to identify the most accurate VO2 measurement and associated MET score.

These options focus on the indirect (predictive) calculations, direct measurement, and VO2 max testing; VO2 max testing can be measured using indirect or direct calculations. The literature continues to identify that the indirect measurement models lack the accuracy of direct models and points out discrepancies that misclassify fit for duty firefighters, underestimates and overestimates VO2 scores, and allow sedentary people to pass these tests. The direct measurement process continues to be the gold standard used to evaluate a VO2 or VO2max score.

While the literature identified the error rates associated with indirect testing and the strengths associated with direct testing, a shortcoming of the literature did not identify if the 12 MET requirement for firefighters should be standardized to include only a direct measurement model. Identifying the use of direct measurement model would only appear to provide the most accurate VO2 calculation and therefore provide the most accurate MET score.

Summary

Literature assisted in understanding that there is a MET's standard for firefighters that is based on a VO2 calculation that evaluates cardiovascular function. This MET's score is derived from a VO2 calculation using an indirect (predictive) measurement model or a direct measurement model; the indirect models are associated with notable errors and are linked to misrepresenting an individual's fit for duty status and VO2 measurement. These indirect measurement models continue to be used by fire service agencies as they require less equipment, personnel, and less financial impact. While the research identified that the indirect methods are associated with VO2 errors, the literature did not identify if the direct measurement model used to calculate VO2 scores was preferred by firefighters who require and accurate assessment of their cardiovascular endurance. Continued research will need to be conducted to identify if an

indirect or direct model of VO2 calculation provides similar results in achieving the 12 MET standard for firefighters.

CHAPTER 3: METHODOLOGY

Research Design

This chapter will summarize the methodology used to review and plan for the appropriate type of research; quantitative, qualitative, and a mixed methods approach was considered. Quantitative research focuses on establishing statistically significant conclusions based on analyzing results numerically while qualitative research focuses on arriving at a theory by observing behaviors along with interviews, and a mixed methods approach combines quantitative and qualitative research methods (Lowhorn, 2007). After a thorough review of qualitative and quantitative research methods, the generic qualitative research method was selected. This qualitative method looks to verify from a firefighter's perspective the findings existing literature already supports quantitatively; a predictive VO2 protocol has been linked to an 11% error rate that "overestimate[s] aerobic capacity in less fit individuals and underestimate[s] it in more fit individuals" (Doleful et al., 2015, p. 143). These error rates are continuously identified in the literature, yet the qualitative portion as seen from the firefighter's point of view is missing. The qualitative method will seek to identify the firefighter's familiarity with VO2 testing and associated MET requirements, differences in the processes, strengths and weaknesses, cardiovascular expectations, work capacity, and their opinion on what is the better measurement tool.

The research is focused on providing clarity for firefighters and their agency administrators beyond the quantitative differences associated with predictive versus in-line measurement of VO2 testing. This research strives to identify the direction that individuals and agencies should take to measure an individual's VO2 and associated MET score in an optimistic approach to meet the NFPA 12 MET standard and reduce the annual fatalities associated with

cardiovascular-related line of duty deaths. The research hopes to provide fire service personnel with an accurate measurement of their health for job related success and life beyond the fire service. In the end, the research is committed to a supportive model that will "ensure ongoing physical fitness and wellness requirements are standardized, adopted, and used within every department" (CPSE & ICMA, 2020, p. 17), and to "strengthen the culture of health and wellness [by] improve[ing] responder safety and survival" (USFA, 2019, Goal 2).

Population and Sample Size

South Metro Fire Rescue (SMFR) consists of approximately 800+ employees that include three major areas that report to the fire chief: Emergency Services, Internal Services, and Community Services. The following personnel are required to complete a VO2 / MET's test every year: line firefighters and rotational office positions (650 personnel), including firefighters, paramedic / firefighters, engineers, lieutenants (suppression and emergency medical services), captains (suppression and emergency medical services), battalion chiefs (suppression and emergency medical services), district chiefs and certain personnel from the fire marshal's office.

The research is focused on the positions that are required to complete the annual VO2 / MET evaluation. Line positions account for the majority of the individuals who complete the VO2 test, but the fire marshal's office will be offered the ability to complete this research too. These positions are required to complete the annual VO2 test, as they may have to wear a self-contained breathing apparatus (SCBA) during an emergency call. In addition to wearing an SCBA, Line personnel are expected to perform strenuous actions on the fireground that include but are not limited to forcible entry, search and rescue, hose line deployment, ventilation operations, and salvage and overhaul.

Sample Size

The sample size will vary based on the number of individuals that volunteer to complete the multi-tiered research process. The initial goal / sample size is aimed at 10–15 individuals and/or saturation of data. The sample size and associated data may struggle to accurately gather a comprehensive review of certain ages, genders, and ranks due to various individual concerns or abilities. Due to the differences in age, life, outside influences, and previous commitments, the initial thought is that younger individuals will volunteer their time to complete the required research at a greater level than older individuals. This may result in data that favors one age group over another and limits the ability to evaluate the difference between age groups and ranks. The sample size may further struggle to accurately represent the female gender based on the number of females who volunteer to participate in the research; SMFR's female ratio is 5.28%, which is well in line with the data that identifies that "5% of all career firefighters are women" (United States Fire Administration [USFA], 2023, p. 1). While the sample size is based on the number of volunteers and their ability to complete the research, an optimistic outlook will be used to reach out to volunteers to gather an appropriate sample size that provides relevant data.

Instrument(s)

Interviews will be conducted individually following the first and second and VO2 testing evaluation. The interviews will take place at SMFR's Headquarters facility in the gym or at the Joint Service Facilities gym. These interviews will include qualitative questioning that includes a review of their recent completion of an in-line and predictive VO2 test and their associated feedback.

Three forms were completed by the volunteers to account for the various stakeholders to ensure accountability and forthrightness. A consent form was created to ensure the volunteer was aware of the reasons for the research questions, the method used to process the information, confidentially, participation, and withdrawal (Appendix B). A *Release of Liability* form was completed by the volunteers to ensure they understood that SMFR would not be responsible for a possible injury or death before or after their participation in the VO2 testing process (Appendix C). Finally, the participant completed the questions during the interview. All three of these forms were reviewed by academic scholars at Columbia Southern University to ensure validity and reliability. The following questions will be asked of the 15 volunteers / participants.

Interview Questions Day 1

1: What is your current position at South Metro Fire Rescue?

2: Age and gender?

3: How many years have you been in the fire service (includes all fire based- career related time)?

4: To what extent have you had your extreme cardiovascular endurance tested on the fireground?

1: How would you compare this VO2 test to this work capacity on the fireground?

5: How did you feel at the end of the VO2 test?

6: To what extent did this test challenge your cardiovascular endurance?

Interview Questions Day 2:

1: To what extent have you had your extreme cardiovascular endurance tested on the fireground?

1: How would you compare this VO2 test to this work capacity on the fireground?

2: How did you feel at the end of the VO2 test?

3: To what extent did this test challenge your cardiovascular endurance?

4: Why do you think South Metro Fire Rescue (SMFR) requires a VO2 / METS evaluation?

1. Are you familiar with the NFPA 1582 MET requirements? If so, list the ones you are aware of.

5: To your knowledge, what are the differences between a predictive VO2 measurement process and an in-line measurement process?

6: In your opinion, what are the strengths and weaknesses of a predictive VO2 measurement process versus an in-line measurement process?

7: Why do you believe that cardiovascular health should be measured for firefighters?

8: If you received a low VO2 score and associated MET's score during annual testing, would you modify your lifestyle?

9: In your opinion, does a predictive or in-line VO2 process closely mirror your previous cardiovascular work capacity?

10: How did your work capacity compare between the in-line measurement process versus the predictive process?

11: In your opinion, how do you think SMFR should provide you with the most accurate measurement of your personal VO2 measurement and associated METs score?

Research Process

The research process began by identifying if the researcher had the support of SMFR, specifically the Wellness Bureau. Support of the Wellness Bureau is needed, as portions of the research require very specific equipment and personnel trained in the use of their equipment to measure an individual's VO2 measurement and associated MET. SMFR's Health and Wellness Bureau agreed to support the researcher via email and in person but did require that participants complete a release of liability form.

Once SMFR committed to the project, the researcher emailed SMFR's line firefighters, and the fire marshal's office to recruit volunteers for the research project. In order to gather a broad data spectrum, the researcher focused on selecting a group of 10-15 individuals who covered various age groups, ranks, and genders if possible. If more than 15 participants agreed to participate in the research the number of volunteers would have to be minimized as SMFR only had the capacity for 15 individualized research tests.

VO2 Research

The selected individuals agreed to participate in two days of testing. Each day required participation from SMFR's Wellness Bureau and the participants. Participants were to follow general guidelines each day. They should only participate after having a normal sleeping pattern the day before the VO2 tests (it was recommended not to complete VO2 testing after coming off shift) and should wear similar exercise apparel each day. If the participant performed a warmup prior to VO2 testing, the same warm-up should be completed on both tests. A minimum of 48 hours was needed between the tests with a maximum window of 14 days to complete the testing.

Facility Guidelines

Participants will complete the required VO2 testing and follow-up interviews at SMFR's headquarters in the Wellness gym. This facility houses various physical fitness equipment and serves as the primary fitness center for SMFR's wellness and rehabilitations facility for firefighters. Evaluation will be monitored by a SMFR Wellness coach who is trained in the use of the treadmills' operation and the associated VO2 testing processes and equipment.

VO2 Equipment

Participants will use the Woodway treadmill (4Front model) during the VO2 testing process to evaluate cardiovascular resistance. These treadmills are provided in every fire station

for physical training and have been used for approximately five years for VO2 testing. The Facilities Bureau ‘in coordination with the Wellness Bureau’ schedules preventative maintenance and/or repair to ensure equipment operability.

Participants will use the KORR Medical technologies Inc. CardioCoach Original during the direct VO2 measurement process while completing their VO2 test on day one. The CardioCoach’s specifications are outlined in Appendix D. The CardioCoach is calibrated prior to VO2 testing by the Wellness staff to ensure accuracy and validation during VO2 testing. The CardioCoach will be operated by a trained and competent staff member who routinely completes approximately 200 VO2 testings each year using this exact equipment.

Day 1- Direct Measurement

Participants will report to the SMFR’s Wellness gym on the day of their test and confirmation of the participants' release of liability will be confirmed. The in-line VO2 max test requires the volunteer to run on the treadmill until they can no longer continue, or they choose to stop. The formula used during the calculations will be the following: VO2 max (ml/kg/min); VO2 (V=Volume, O2= Oxygen), also consider VO2 Max (V=Volume, O2=Oxygen, Max = maximal), ML (milliliters), KG (kilograms), MIN (minutes). This calculation identifies the volume of oxygen (ML) times the relative body weight (KG) of an individual times the use of oxygen in one minute (MIN), which identifies how much oxygen one's body can consume; this test is typically performed on a treadmill in a laboratory setting for the most accurate results or modified for use in a predictive model. As recommended by NFPA (2022) standard 1582, firefighters should meet a 12 MET standard which is obtained by dividing a VO2 score divided by 3.5; example, a VO2 score of 42 divided by 3.5 equals 12 (MET’s) or “1 MET =3.5 ml of O2/kg/min” (Drew-Nord et al., 2011, para. 3).

Participants will be weighed on a scale, and their weight will be converted from pounds to kilograms. Once weighed, they will be encouraged and permitted to perform a warm-up prior to their test. After their warm-up is completed, they will be fitted with an appropriately sized heart rate monitor and VO2 mask. After being fitted with the required equipment, a wellness representative will coach them through the VO2 measurement process and answer any questions. Once they are ready, the wellness representative will begin the Gerkin protocol on the treadmill (Appendix A- Figure 3**),** while consistently monitoring the participant's VO2 score. During this time, the CardioCoach operator will provide updates to the candidate as to when they meet the following VO2 / MET's score: 10METS, 11 METS, 12METS, etc. Once the participant chooses to stop, their time and score will be documented for reference. A brief interview will be conducted after the volunteer has rested for at least five minutes; this abbreviated interview will ensure the researcher gathers pertinent information following the initial test, so it may be compared with the second VO2 test and interview questions.

Day 2- Indirect / Predictive Measurement

Participants will report to the SMFR's Wellness gym on the day of their test and confirmation of the participants' release of liability will be confirmed. The predictive VO2 test requires the volunteer to run on the treadmill "until the participant's heart rate exceeds the [Target Heart Rate] THR rate for 15 seconds, or the subject exhibits the medical criteria for early termination" (IAFC, 2018).

The formula used during the calculations will follow the WFI calculations: "Use the formula provided below with the treadmill time in minutes (TT), and body mass index (BMI) to estimate VO2; VO2 max (ml/kg/min) = 56.981 + (1.242 x TT) – (0.805 x BMI)" (Appendix A-Figure 3).

Participants will be weighed on a scale and their weight will be converted from pounds to kilograms. Once weighed, they will be encouraged and permitted to perform a warm-up prior to their test. After their warm-up is completed, they will be fitted with an appropriately sized heart rate monitor. After being fitted with the required equipment, a wellness representative will coach them through the VO2 measurement process and answer any questions. Once they are ready, the Wellness representative will begin the Gerkin protocol on the treadmill (Appendix A Figure 3), while consistently monitoring the participants' heart rate. During this time, the operator will provide updates to the candidate as to when they reach their THR for at least 15 seconds. Once the participant meets their THR for 15 seconds, the test will be stopped and their time and VO2 score will be documented for reference. The predictive VO2 test stops when the participant reaches 85% of their predictive VO2 score. A brief interview that is focused on test two will be conducted after the volunteer has rested for at least five minutes; the abbreviated interview will ensure the researcher gathers pertinent information following this second test, so it may be compared with the first VO2 test and interview questions.

The last and final interview will be conducted after approximately 10 minutes of participant rest and will contain the questions outlined under Instruments. The interview results will be reviewed and organized by the researcher to identify common responses from the participants. These results will be then organized into various Excel spreadsheets to allow for pattern recognition and ease of data inquiry.

Ethical Considerations

The ethical considerations for this research have become apparent due to the researcher's organizational position at SMFR and the willingness of volunteers to participate in the research.

These two challenges were addressed to ensure honest, truthful, and fair research was completed that supports the morality of the fire service and upholds the values of SMFR.

There can be an inclination for employees to feel obligated to volunteer when a manager or supervisor asks for volunteers. Volunteers were reassured verbally and in writing that their participation was not tied to any supervisor / subordinate relationship and that there was not any work relationship during this process. In order to ensure ethical actions, the researcher created an interview consent form that outlined that none of the researcher's directions, answers, or interactions during the research would affect their employment. This form was signed by the researcher and participant (Appendix B).

Participation in the study was voluntary, and personnel were not compensated for their off-duty time to complete the evaluation. SMFR requires line personnel and fire investigators to complete a VO2 test annually; SMFR allowed the research VO2 max test to count towards their annual 2024 requirement. The guidelines for the VO2 test were included in the consent form as was the participation / withdrawal process. The confidentiality clause was included on the form to ensure volunteers that their personal information would be protected, and any information collected besides age, gender, rank, and years of service would be managed to ensure the volunteers' privacy and confidentiality. The collected data will be stored in a secured location accessible only to the researcher and retained for a period of four years, at which time the data will be destroyed.

Summary

In Chapter 3, the researcher identified that a generic qualitative research approach would be used. This approach will attempt to identify if the firefighters completing the VO2 tests are concerned about using the most accurate process to measure their cardiovascular endurance.

While the population of SMFR exceeds 600 personnel that complete an annual VO2 / MET's test, the sample size is focused on 10-15 volunteers and/or data saturation. The instrument used will include a qualitative interview that occurs on day one and day two of the VO2 test. The qualitative documentation required the creation and approval from Columbia Southern University staff to ensure validity and reliability of the consent form and qualitative questions; SMFR required that a release of liability be completed for the volunteers. The research process identified the need for support from SMFR's Wellness Bureau. Once approval was obtained from SMFR, the researcher emailed the line personnel and fire marshal's office to recruit volunteers. The VO2 testing took place in the Wellness gym and required the volunteers to participate in two days of individual testing. The overall testing window and interview process is estimated to be completed in 14 days. The ethical considerations were considered and reinforced with documentation to ensure trust and confidentiality throughout the process.

CHAPTER 4: STUDY RESULTS

Introduction- Demographics of the Participants

The study began after selecting the participants who volunteered to participate in the research process. The initial outreach for volunteers only recruited eight line firefighters, but a second email request resulted in an additional five volunteers for a total of 13 line firefighter positions. While participant recruitment included portions of the fire marshal's office, there were no volunteers from this bureau. The following outlines the demographics of the personnel who participated in the study:

Demographics of Participants

Participant #:	**Gender**	**Age Range**	**Rank**
Participant #1	Male	30-40	Lieutenant
Participant #2	Male	50-60	Engineer
Participant #3	Male	30-40	EMS Lieutenant
Participant #4	Male	50-60	Firefighter
Participant #5	Male	40-50	Captain
Participant #6	Male	20-30	Firefighter
Participant #7	Male	50-60	Battalion Chief
Participant #8	Male	20-30	Firefighter
Participant #9	Male	20-30	Firefighter
Participant #10	Male	30-40	Paramedic / Firefighter
Participant #11	Male	30-40	Paramedic / Firefighter
Participant #12	Male	40-50	Paramedic / Firefighter
Participant #13	Male	30-40	Lieutenant

While a variety of participants was represented across most ranks and age groups, there was lack of participation from certain positions, age groups, and females. This may be due to various concerns that will not be addressed in this research. The research moved forward by creating a sign-up process to efficiently schedule personnel for two separate VO2 testing days.

The research moved forward in an effort to identify if the firefighters feel a difference in a predictive versus a direct measurement VO2 max process and if they are concerned with accurate results.

RQ1: What are firefighters' perceptions or perspective (pick one) about workload from the predicted VO2 max test process in relation to workload required during a direct measurement model?

RQ2: Does the predictive VO2 test process make firefighters feel like they are being accurately tested?

RQ3: Are firefighters concerned about the most accurate evaluation of their cardiovascular health?

Research Results

A generic qualitative research method was used to analyze the perceptions or perspectives that firefighter's have about the VO2 testing processes. The research focused on the comparison between a VO2 max evaluation or in-line evaluation, and a predictive VO2 evaluation or in-direct evaluation. This research required firefighters to not only test their physical abilities but also their mental capabilities in an environment that required the use of specialized equipment and a trained operator to administer the VO2 test. Following the rigorous testing, the volunteers completed numerous interview questions following Day 1 and Day 2

testing. After reviewing the answers in the interview there were numerous themes that appeared.

The following themes were identified from the majority of the volunteers during this process:

Themes Developed from the Research

Theme	**Participant response**
Extreme cardiovascular endurance on the fireground	Involved multiple assignments, job related tasks, hose evolutions, and the use of bunker gear and SCBA.
VO2 max comparison and opinions	Less work than compared to the fireground. Is focused on running/cardio and lacks other muscle involvement.
VO2 predictive comparison and opinions	Does not compare to work on the fireground. Not even close to cardiovascular capacity and simply considered a warm-up.
Strengths and Weaknesses	Predictive process was easier to complete due to not wearing a mask and was less stressful but lacked accuracy. In-line allowed the ability to push oneself but was stressful.
Cardiovascular measurement and importance	Cardiovascular measurement identified as important due to job related tasks. Identified as the top two killers of firefighters.
Work capacity compared	In-line was harder to maintain and neared maximum physical output. Predictive was markedly easier with less effort.
VO2 accuracy	In-line measurement provided accurate data. In-line process relatable to fireground stressors.

Theme 1: Extreme Cardiovascular Endurance on the Fireground

To establish a baseline of what firefighters considered extreme cardiovascular endurance on the fireground, the participants were asked to describe an event when they had this occur. The interviewees related experiences that involved multiple assignments that were tasked in succession with compound movements. The assignments required the use of bunker gear, SCBA while being on air, and the challenges of being in an austere environment with limited visibility and thermal insults. The majority of volunteers related these cardiovascular challenges to fireground activities that included: climbing stairs, charged hose line evolutions, search and rescue, overhaul operations, and the mental stressors associated with not only training scenarios but actual fireground activities. Multiple participants identified areas during training scenarios and actual calls where they "had to stop" their operations or "felt as if they couldn't catch a full breath". This theme outlined the critical cardiovascular endurance required on the fireground.

Theme 2: VO2 max Comparison and Opinions

The participants were asked to compare the VO2 max test with their extreme cardiovascular endurance on the fireground. The majority of the volunteers identified that this test required less work than the fireground and was more focused on running / cardio and lacked the use of other muscles that are required on the fireground. Participants identified that while the test focused on cardio predominately, the mental stressors were relatable to the fireground due to job related requirements and the use of a mask during the VO2 max evaluation. A few of the volunteers also identified that toward the end of the VO2 max evaluation their "lungs felt taxed" and they were "slightly fatigued". This theme identified the comparison of the VO2 max to the volunteer's extreme cardiovascular endurance on the fireground.

Theme 3: Predictive Comparison and Opinions

The participants were asked to compare the predictive test with their extreme cardiovascular endurance on the fireground. The majority of the volunteers identified that this test did not compare to work on the fireground and was not even close to the cardiovascular capacity required on the fireground and was only considered a warm-up. When participants compared the predictive VO2 process to the fireground, phrases and terms were used that included “I was more winded during my warm-up”, “I was just getting stretched out”, and “This one’s nothing!” This theme identified the comparison of the predictive VO2 test to the volunteer’s extreme cardiovascular endurance on the fireground.

Theme 4: Strengths and Weaknesses

The participants were asked to identify what the strengths and weaknesses were when comparing a predictive VO2 assessment versus an in-line measurement process. The majority of the volunteers identified that the strengths of the predictive process included no mask requirement, reduced anxiety, and that the test “was easier to administer”. The majority of the volunteers identified that the strengths of the in-line process included the ability to accurately measure an individual’s personal VO2 versus relying on the heart rate. The majority of the volunteers identified that the weaknesses of the predictive process were related to an estimated VO2 score versus an individualized score. The weaknesses identified for the in-line process focused on the fact that participants had to wear a mask during the test and that this test contributed to “stress” and increased anxiety. This theme identified the candidates’ strengths and weaknesses of the predictive and in-line VO2 testing processes.

Theme 5: Cardiovascular Measurement and Importance

The participants were asked why cardiovascular health should be measured for firefighters. The majority of the responses focused on a firefighter's ability to complete job related tasks not only on the fireground, but during "lift assists, vehicle extrications, wildland calls" and other daily physical demands of the job. Specific individuals mentioned that cardiovascular health should be measured as firefighters "are looked upon differently and expected to be fit", and if "you can't perform skills because you are out of shape, you won't be able to perform fine-tuned skills when needed." The participants were asked if they would modify their lifestyle if they received a low VO2 score; participants stated that a low VO2 measurement would prompt them to pursue "different workouts, high intensity interval training, and a change in diet." This theme identified why the candidates believe cardiovascular measurement should be completed and the importance of this measurement.

Theme 6: Work Capacity Compared

The participants were asked to compare the associated work capacity between the in-line measurement process and a predictive process. The majority of responses identified that the in-line process was "much harder to maintain" and even considered by some to be "double as hard as the predictive process." The predictive process was identified as being a "warm-up" and even considered "10% of the VO2 max evaluation." The theme identified that the bulk of the participants considered the in-line process to be harder than the predictive process.

Theme 7: Accuracy

The participants were asked how they think SMFR should provide them with the most accurate measurement of their personal VO2 measurement and associated MET's score. Most of the participants stated they believe that the VO2 max measurement should be used as it provides

"individual and exact results." The volunteers also stated that the VO2 max was associated with a process that "truly evaluates metabolic processes in the body" and "keeps us on the safer side" during firefighter related operations.

Summary

The research process used a generic qualitative research methodology to analyze the perceptions or perspectives that firefighters had about the VO2 testing processes. The 13 participants who volunteered to participate consisted of line-related firefighter positions. While outreach was sent to the fire marshal's office, there were no volunteers from this bureau. The demographics consisted of various ranks and age groups but only included males; no females volunteered to participate in the research.

The seven themes identified in the research allowed the participants to describe their extreme level of cardiovascular endurance, compare their VO2 max with previous experiences, compare predictive VO2 with their previous experiences, discuss strengths and weaknesses, identify why cardiovascular measurement is important, compare VO2 capacity, and identify their need for accuracy. Chapter 5 will provide a summary of the data, discuss limitations, implications, recommendations, and a conclusion.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

Summary of the Results

The research focused on identifying the workload required for firefighters to perform cardiovascular related activities and the real-world evaluations and measurement of VO2 processes. The research was aimed at exposing firefighters to the VO2 max evaluation and a predictive VO2 process. Once the firefighters were exposed to both processes, they were able to compare these exercises for strengths, weaknesses, and accuracy.

The original research question sought to identify a firefighter's perception regarding the workload associated with a VO2 max / direct measurement test. The themes from the research identified that firefighters felt that the VO2 max was more focused on running and cardio and lacked the use of other muscles required for fireground activities. While the VO2 max test focused on cardio, it stimulated job stressors as it requires the use of a mask during the evaluation, which was compared to using an SCBA. While the volunteers identified that the test focused on cardio, the process also had the participants sweating, breathing hard, and feeling taxed and fatigued after completion of the test. While the test may have only evaluated cardio as described, the firefighters related this cardiovascular exertion as being similar to fireground activities.

The second research question of the study asked firefighters if they felt that the predictive VO2 test made them feel like they were being tested accurately. The themes from the research identified that the participants felt that the predictive VO2 test was easy and barely pushed them out of their warm-up prior to the test being completed. After completing both the VO2 max and predictive VO2 process, participants predominately identified that the predictive process was not as accurate as the VO2 max.

The third research question asked firefighters if they were concerned about receiving the most accurate evaluation of their cardiovascular health. After each participant performed multiple days of individual testing and received their associated VO2 measurement, associated MET, and evaluated their own work capacity they predominantly agreed that the VO2 max evaluation provided them with the most accurate evaluation. The data each participant received followed the previous predictive literature, which reinforced that the submaximal protocol has been linked to an 11% error rate that "overestimate[s] aerobic capacity in less fit individuals and underestimate[s] it in more fit individuals" (Doleful et al., 2015, p. 143); numerous fit individuals had their VO2 scores underestimated by up to 3.9 METs, while the less fit individuals received an overestimated score of up to 1.6 METs. While some of the participants appeared to want the predictive process to be the most accurate, the data identified that the in-line process provided superior accuracy and the participants leaned toward this standard.

Conclusions Based Upon Your Results

The research identified themes that can be applied to the fire service that will contribute to firefighter health and wellness, further the knowledge of VO2 processes, identify the importance of this measurement, and how it will be useful to the firefighting profession.

Application in the Field

The themes in the research identified that firefighters experience extreme cardiovascular requirements on the fireground that challenge their mental and physical abilities. These challenges were also simulated during the VO2 max portion of the testing where participants described being "spent, winded, reaching near max capacity, depleted, exhausted, and [even] feeling like [their] vision was narrowing." While these descriptions may seem extreme, they are experienced on the fireground and the VO2 max simulated this work capacity. To support

firefighter health and wellness, the use of appropriate measurement processes should be used in VO2 testing. These processes can be completed in a supervised and controlled environment that provides firefighters with an accurate measurement of their VO2 max and associated MET score.

Further Existing Knowledge

The research focused on comparing a VO2 max evaluation using an in-line measurement and a predictive VO2 process using the WFI process via the Gerkin protocol. To further knowledge for firefighters, educational opportunities and experiences should be provided so firefighters are aware of the differences between in-line and predictive VO2 processes. The research identified that most of the participants were unaware of the MET requirements identified in NFPA 1582. There was also a lack of knowledge related to the associated metabolic syndromes linked with a decline in METs and the increase in heart disease, stroke, and type two diabetes. Providing this knowledge will arm firefighters with a clear vision of their health and the dangers associated with a MET's score below 12.

Why is this important?

The important theme related to the research is that less fit individuals METs scores were overestimated and fitter individuals MET's were underestimated. While the underestimation of fitter individuals does not correlate to any real adverse results, it skews the individual's personal results and goals due to inaccuracies. This underestimation continues to miscategorize these personnel and does not give them their true MET score, which may move them into MET category below 12; MET categories below 12 are associated with negative metabolic syndromes, which interfere with NFPA's (2022) 1582 essential tasks and increases the risk for cardiovascular disease, hypertension, and hyperglycemia. An additional negative implication is that less fitter individuals overestimated MET scores may provide a false sense of wellness and

more importantly allow an unfit firefighter to continue to respond to emergency calls while they should be considered not fit for duty.

Limitations

The research resulted in various limitations that included specific processes, and participant sample size. These limitations may adversely affect interpretation of the results or the ability to recreate or compare results with other firefighting agencies. These limitations are expanded below.

Processes

The processes used in this research required specific equipment and defined processes. This included the use of a Cardiocoach VO2 max testing machine and associated equipment to perform in-line VO2 measurements. Additionally, the use of a Woodway treadmill was required to complete the Gerkin protocol; some agencies may prefer to use a different cardiovascular protocol that requires other forms of equipment. While SMFR has the equipment and personnel trained in its use, some agencies may not have the equipment or trained personnel to complete a similar test.

Sample Size

The sample size used in the research was relatively small and lacked diversity in rank, age, and lacked any females in the research that may be needed to compare data with other organizations. While research outreach was sent to over 6oo+ individuals, there was a small group that agreed to participate. Based on the small sample size, the interpretation and use of the data may not be applied to other organizations of different size or volunteer agencies.

Implications and Recommendations to the Field

The lessons learned from the research identified areas that can be put into practice to ensure firefighters receive the most accurate evaluation of their VO2 measurement. The problems identified in the research and the recommendations for SMFR and other fire service agencies are expanded on below.

Putting in into practice

The research identified that firefighters are concerned about the most accurate evaluation of their cardiovascular health and that they preferred the VO2 max over the predictive process. To support this preference, agencies should consider evaluating and moving into a VO2 max using an in-line process to measure an accurate and job related VO2 score. Putting these evaluation processes in operation will provide an individual with an accurate VO2 score. A true VO2 score and associated MET score will allow personnel to strive for a high level of fitness for fire ground activities and to better support their life after the fire service.

Problems

The problems associated with providing an in-line measurement process are related to equipment, trained personnel, and the time to process these evaluations. To provide the equipment and personnel, budgetary needs will have to be addressed and supported. These budgetary needs may exceed planned expenditures which will result in short and long-term financial implications. Scheduling will also have to be accounted for to ensure firefighters and support staff are allowed the time to adequately evaluate and coordinate individuals through a comprehensive VO2 max process. Scheduling will also need to consider initial and repeat VO2 testing to ensure follow-up and constant reevaluation.

Recommendations

To provide firefighters with a VO2 score that supports their personal health and wellness goals and provide them with an accurate MET's score, it is recommended to continue or to transition to a VO2 max process using in-line measurement. This process will provide accurate results to measure a firefighter's ability to complete the 13 essential job functions and associated 12 MET requirement identified by NFPA (2022) 1982. When moving from a predictive process to a VO2 max it will be associated with various financial, cultural, and personnel challenges. This transition will provide firefighters with the most accurate measurement of their VO2 and associated MET score. Agencies owe it to their employees to provide them with the most accurate VO2 process and associated MET score.

Recommendations for Future Research

The research identified that there are numerous protocols and exercises that may be used to evaluate a VO2 max process. The Gerkin was chosen as its one of the protocols used to administer the WFI protocol, and it was the most logical choice to compare the same exercise protocol to one that SMFR already uses. The challenge with the Gerkin was that it is focused on running; multiple participants identified that the Gerkin was simply cardio and that it "lacked other body mechanics [and was] monostructural." Future research may look to use the alternative protocol approved by WFI that uses a step mill to complete the process; the Step mill may incorporate more body mechanics as identified by the participants. Using a VO2 max process on a step mill may be easily attained by following the WFI protocol, but by using the CardioCoach to measure an accurate VO2 and associated MET score.

Future research recommendations should include the use of bunker gear, SCBA and incorporation of the 13 essential job functions associated with NFPA's 12 MET requirement.

Providing job specific equipment and skills will provide firefighters with a more realistic evaluation of their personal health and wellness. The incorporation of job-related skills will address what participants identified as missing; participants felt that both the VO2 max and predictive processes missed the challenges on the fire ground related to moving charged hose lines, wearing SCBA, using multiple muscles, and moving from task to task quickly.

Conclusion

The research focused on identifying the perceptions or perspectives of firefighters and their evaluation of a VO2 max process versus a predictive process that measures their VO2 results and associated MET score. The themes identified by the participants stated that the VO2 max test was focused on running predominately, simulated job stressors due to the use of a mask and left them feeling winded and tired. The participants stated the predictive formula only served as a warmup was not as accurate as the VO2 max. The participants were concerned about receiving accurate VO2 results and predominately agreed that the VO2 max was the most accurate, as it simulated job stressors, keeps firefighters on the safe side, and is comparable to working in SCBA. The importance of this research is related to what literature has identified previously: a predictive VO2 process overestimates less fit individuals VO2 scores. This overestimation puts firefighters in an unacceptable space where their overestimated VO2 measurement and overestimated MET score put these responders on the wrong side of cardiovascular compromise. The hope is that the research will ensure agencies provide firefighters with the highest level of VO2 testing, so they can be physically prepared and trained for a life-threatening career.

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Appendix A

Wellness- Fitness Initiatives Fitness Protocols

Figure A1

Body Mass Index (BMI) Calculation

IAFF/IAFC WELLNESS-FITNESS INITIATIVE
Fitness Protocols

Table 1. Body Mass Index (BMI) Conversion Table. BMI = Weight (kg) / Height $(m)^2$ or BMI = 703 x Weight (lbs) / Height $(inches)^2$

BMI	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
HEIGHT	BODYWEIGHT (Pounds)																														
58" (4'10)	96	100	105	110	115	119	124	129	134	138	143	148	153	158	162	167	172	177	181	186	191	196	201	205	210	215	220	224	229	234	239
59" (4'11)	99	104	109	114	119	124	128	133	138	143	148	153	158	163	268	173	178	183	188	193	198	203	208	212	217	222	227	232	237	242	247
60" (5'0)	102	107	112	118	123	128	133	138	143	148	153	158	163	168	174	179	184	189	194	199	204	209	215	220	225	230	235	240	245	250	255
61" (5'1)	106	111	116	122	127	132	137	143	148	153	158	164	169	174	180	185	190	195	201	206	211	217	222	227	232	238	243	248	254	259	264
62" (5'2)	109	115	120	126	131	136	142	147	153	158	164	169	175	180	186	191	196	202	207	213	218	224	229	235	240	246	251	256	262	267	273
63" (5'3)	113	118	124	130	135	141	146	152	158	163	169	175	180	186	191	197	203	208	214	220	225	231	237	242	248	254	259	265	270	278	282
64" (5'4)	116	122	128	134	140	145	151	157	163	169	174	180	186	192	197	204	209	215	221	227	232	238	244	250	256	262	267	273	279	285	291
65" (5'5)	120	126	132	136	144	150	156	162	168	174	180	186	192	198	204	210	216	222	228	234	240	246	252	258	264	270	276	282	288	294	300
66" (5'6)	124	130	136	142	148	155	161	167	173	179	186	192	198	204	210	216	223	229	235	241	247	253	260	266	272	278	284	291	297	303	309
67" (5'7)	127	134	140	146	153	159	166	172	178	185	191	198	204	211	217	223	230	236	242	249	255	261	268	274	280	287	293	299	308	312	319
68" (5'8)	131	138	144	151	158	164	171	177	184	190	197	203	210	216	223	230	236	243	249	256	262	269	276	282	289	295	302	308	315	322	328
69" (5'9)	135	142	149	155	162	169	176	182	189	196	203	209	216	223	230	236	243	250	257	263	270	277	284	291	297	304	311	318	324	331	338
70" (5'10)	139	146	153	160	167	174	181	188	195	202	209	216	222	229	236	243	250	257	264	271	278	285	292	299	306	313	320	327	334	341	348
71" (5'11)	143	150	157	165	172	179	186	193	200	208	215	222	229	236	243	350	257	265	272	279	286	293	301	308	315	322	329	338	343	351	358
72" (6'0)	147	154	162	169	177	184	191	199	206	213	221	228	235	242	250	258	265	272	279	287	294	302	309	316	324	331	338	346	353	361	368
73" (6'1)	151	159	166	174	182	189	197	204	212	219	227	235	242	250	257	265	272	280	288	295	302	310	318	325	333	340	348	355	363	371	378
74" (6'2)	155	163	171	179	186	194	202	210	218	225	233	241	249	256	264	272	280	287	295	303	311	319	326	334	342	350	358	365	373	281	389
75" (6'3)	160	168	176	184	192	200	206	216	224	232	240	248	256	264	272	279	287	295	303	311	319	327	335	343	351	359	367	375	383	291	399
76" (6'4)	164	172	180	189	197	205	213	221	230	238	246	254	263	271	279	287	295	304	312	320	328	336	344	353	361	369	377	285	394	402	410
77" (6'5)	169	177	186	194	202	211	219	228	236	245	253	261	270	278	287	295	304	312	320	329	337	346	354	363	371	380	388	396	405	413	422
78" (6'6)	173	182	190	199	208	216	225	234	242	251	260	268	277	286	294	303	312	320	329	338	346	355	363	372	381	389	398	407	415	424	433
79" (6'7)	177	186	195	204	213	222	231	240	249	258	266	275	284	293	302	311	320	328	337	346	355	364	373	382	391	399	408	417	426	435	444
80" (6'8)	182	191	200	209	219	228	237	246	255	264	273	282	291	300	310	319	328	337	346	355	364	373	382	391	401	410	419	428	437	446	455
BMI	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50

(IAFC, 2018-a)

Figure A2

Target Heart Rate (THR) Calculations

Table 2. Target Heart Rate (THR) for Respective Age. THR = [208-(0.7*Age)]*0.85

AGE	THR	AGE	THR	AGE	THR	AGE	THR	AGE	THR
18	166	27	161	37	155	47	149	57	143
19	165	28	160	38	154	48	148	58	142
20	165	29	160	39	154	49	148	59	142
21	164	30	159	40	153	50	147	60	141
22	164	31	158	41	152	51	146	61	141
23	163	32	158	42	152	52	146	62	140
24	163	33	157	43	151	53	145	63	139
25	162	34	157	44	151	54	145	64	139
26	161	35	156	45	150	55	144	65	138
27	161	36	155	46	149	56	143	66	138

(IAFC, 2018-b)

Figure A3
Gerkin Protocol

Assessment Guidelines

1. Conduct Pre-Evaluation Procedures.
2. Monitor the participant's heart rate continuously throughout the assessment. The participant straddles the treadmill belt until it begins to move. When the treadmill reaches approximately 1mph, instruct the participant to step on to the belt. Then increase the speed to 3mph at 0% grade.
3. Start the stopwatch when the treadmill reaches 3 mph at 0% grade. Continue with this speed and grade for 3 minutes (steady state).
4. After completing the 3-minute steady state interval, inform the participant that the speed will increase to 4.5 mph. OPTIONAL: Record the participant's rating of perceived exertion (RPE) during the last 5 seconds of each subsequent stage.
5. Advise the participant that the assessment is a series of 1-minute intervals, alternating between speed and percent grade. All subsequent speed increases occur at 0.5mph.
6. At 4:01 minutes, increase the grade from 0% to 2%. At this time, inform the participant that all subsequent grade increases occur at 2% intervals.
7. The assessment will continue until the participant's heart rate exceeds the THR rate for 15 seconds, or the subject exhibits the medical criteria for early termination.
8. Once the heart rate exceeds the Target Heart Rate (THR), note the time and continue the assessment for an additional 15 seconds. Do not make any changes to the assessment speed or grade during this time. If the participant's heart rate remains above the THR for the full 15 seconds, then stop the assessment and proceed to the cool-down phase. Record the total time, including the 3-minute warm-up, at which point the participant exceeds the THR. If the participant's heart rate exceeds the target, but then drops back to the THR or below within 15 seconds, then the assessment should continue. The assessment is not complete until the participant's heart rate exceeds the THR for 15 seconds. If this does not occur within 18 minutes, then terminate the assessment and record the time.
9. Once the assessment is completed, the time is recorded. The participant should perform a cool-down for a minimum of 3 minutes at 3 mph, 0% grade. Continue to monitor the heart rate during the cool-down. Record the recovery heart rate after each minute of the cool-down.

Time	Speed	Grade
0:00 - 0:00	0.0	0
0:00 - 3:00	3.0	0
3:01 - 4:00	4.5	0
4:01 - 5:00	4.5	2
5:01 - 6:00	5.0	2
6:01 - 7:00	5.0	4
7:01 - 8:00	5.5	4
8:01 - 9:00	5.5	6
9:01 - 10:00	6.0	6
10:01 - 11:00	6.0	8
11:01 - 12:00	6.5	8
12:01 - 13:00	6.5	10
13:01 - 14:00	7.0	10
14:00 - 15:00	7.0	12
15:01 - 16:00	7.5	12
16:01 - 17:00	7.5	14
17:01 - 18:00	8.0	14
0:00 - 1:00	3.0	0
1:01 - 2:00	3.0	0
2:01 - 3:00	3.0	0

(IAFC, 2018-c)

Figure A3
Gerkin Protocol- Continued

Submaximal Treadmill Test VO2 Estimation

10. Use the formula provided below with the treadmill time in minutes (TT), and body mass index (BMI) to estimate VO2.[1]

VO2 max (ml/kg/min) = 56.981 + (1.242 x TT) – (0.805 x BMI)

Evaluation Criteria

- Test time (use to estimate VO2 max)
- RPE at specific speed/grade
- Heart rate recovery

Notable Observations (KNEES / BACK)

- Knee alignment (during each test stage)
- Low back curvature (during each test stage)

Reasons to Stop the Test

- The THR is exceeded for 15 seconds
- The THR has not been met after 18 minutes
- The participant asks to terminate the exercise
- The equipment malfunctions
- Medical conditions arise that prohibit completing the assessment

Table 3. Seconds converted to decimal

Time (s)	Decimal Equivalent	Time (s)	Decimal Equivalent	Time (s)	Decimal Equivalent	Time (s)	Decimal Equivalent	Time (s)	Decimal Equivalent
1	0.02	13	0.22	25	0.42	37	0.62	49	0.82
2	0.03	14	0.23	26	0.43	38	0.63	50	0.83
3	0.05	15	0.25	27	0.45	39	0.65	51	0.85
4	0.07	16	0.27	28	0.47	40	0.67	52	0.87
5	0.08	17	0.28	29	0.48	41	0.68	53	0.88
6	0.10	18	0.30	30	0.50	42	0.70	54	0.90
7	0.12	19	0.32	31	0.52	43	0.72	55	0.92
8	0.13	20	0.33	32	0.53	44	0.73	56	0.93
9	0.15	21	0.35	33	0.55	45	0.75	57	0.95
10	0.17	22	0.37	34	0.57	46	0.77	58	0.97
11	0.18	23	0.38	35	0.58	47	0.78	59	0.98
12	0.20	24	0.40	36	0.60	48	0.80	60	1.00

(IAFC, 2018-d)

Appendix B

Interview Consent form

Interview Consent Form

Identification of Investigators & Purpose of Study

You are being asked to participate in a research study conducted by Nicholas (Nick) Grosch from the National Fire Academy (NFA) and Columbia Southern University. The purpose of this study is to develop a better understanding of a critical issue in the fire and emergency services. This study will contribute to the researcher's completion of their final project for the Executive Fire Officer program.

Research Procedures

Should you decide to participate in this research study, you will be asked to sign this consent form once all of your questions about the study have been answered to your satisfaction. The study consists of two separate VO2 tests and interviews that will be administered to individual participants. Day one's testing includes a direct measurement VO2 evaluation. This is the same test you currently take at South Metro Fire Rescue (SMFR) annually. A brief interview will be conducted after the VO2 test. Day two's testing requires you to complete a predictive VO2 measurement evaluation that will be followed by a more thorough interview. An audio recording of this interview will be used for transcription purposes but will be deleted immediately after transcription is completed and will not be shared with anyone else. You are required to initial your approval for audio recording below.

Time Required

Participation in the study will require two separate scheduled testing windows. The scheduled testing requires at least 48 hours between measurements and should be completed in 14 days. It is recommended that you follow a normal sleep cycle prior to the testing to ensure your best performance. The following time expectations may vary based on your warm-up and associated questions the day of the test. Day one will consist of approximately 10-15 minutes on the treadmill and a brief five-minute interview. Day two will consist of approximately 10-15 minutes on the treadmill and a ten minute interview.

Risks

As with any physical exercise process, there is a risk of injury and/or death. In addition to this consent form, SMFR has required participants to complete a release of liability. The researcher, SMFR, the NFA, and its contractors take no responsibility or liability for the mental or physical actions or limitations during or after the research.

The NFA, Columbia Southern University, and its contractors take no responsibility for the actions or outcomes of the research study.

Benefits

There are no direct benefits to the participant; however, information from this study may benefit you, and other communities, in the future.

Incentives

There are no incentives (financial or otherwise) associated with participation in this study.

Confidentiality

The results of this research will be presented to NFA and Columbia Southern University program faculty and students. The results of this project will be coded in such a way that the respondent's identity will not be attached to the final form of this study. The researcher retains the right to use and publish non-identifiable data. While individual responses are confidential, aggregate data will be presented representing averages or generalizations about the responses as a whole. All data will be stored in a secure location accessible only to the researcher. Upon completion of the study, all information that matches up individual respondents with their answers (including audio recordings) will be destroyed. Final aggregate results will be made available to participants upon request.

Participation & Withdrawal

Your participation is entirely voluntary. You are free to choose not to participate. Should you choose to participate, you can withdraw at any time without consequences of any kind.

Questions about the Study

If you have questions or concerns during the time of your participation in this study, or after its completion, or you would like to receive a copy of the final aggregate results of this study, please contact:

Nick Grosch
Student
National Fire Academy
nick.grosch@southmetro.org

Dr. Justin Heim
Course Manager
Columbia Southern University
Justin.Heim@columbiasouthern.edu

Giving of Consent

I have read this consent form, and I understand what is being requested of me as a participant in this study. I freely consent to participate. I have received satisfactory answers to my questions. The investigator provided me with a copy of this form. I certify that I am at least 18 years of age.

☐ I give consent to be filmed and audio recorded during my interview. _____ (interviewee initials)
☐ I give consent to be audio recorded during my interview. _____ (interviewee initials)

Interviewer Signature		**Date**:	

Interviewee Signature		**Date:**	

Appendix C

Release of Liability Form

THIS IS A RELEASE OF LIABILITY
READ IT CAREFULLY AND COMPLETELY BEFORE SIGNING
WAIVER AND RELEASE OF LIABILITY FOR USE FOR PARTICIPATION IN PHYSICAL FITNESS TRAINING PROGRAMS AT THE SMFR JSF GYM OR HEADQUARTERS FACILITY

I, _____ acknowledge that I have requested permission from the South Metro Fire Rescue District (the "District") to use the District's facilities and equipment as well as the facilities and equipment of any business entity contracted by the District for physical training and conditioning (the "Program") and/or VO2 testing.

Now therefore, in consideration of being permitted to participate in the Program and/or VO2 testing, I state that I understand that such training may be dangerous both physical and mentally and understand that I run the risk of physical injury, both internal and external, temporary or permanent, or the risk of death, and may run the risk of developing mental stress. I agree to abide by all rules of the District and its personnel, the Program, and all instructions of District personnel and Program instructors, and understand and acknowledge that failure to comply with such rules, regulations and instructions may result in my immediate dismissal from the Program and/or VO2 testing. I understand that I have a duty to inspect all equipment before use, and I acknowledge that by using any such equipment or facilities, I have determined that the equipment or facilities are in acceptable condition. If I determine any equipment or facilities not to be in acceptable condition, I will notify the District personnel in charge of the facility and not use the equipment.

1. Assumption of Risk. I have independently reviewed the risks and determined to participate in the Program and/or VO2 testing with full knowledge and acceptance of the risks. Fully understanding these risks, I, my spouse, legal representatives, heirs, and assigns, hereby agree to assume full responsibility and liability for the risk of injury (including death), or property damage which may result from participation in the Program and/or VO2 testing.

2. Release. I, for myself, my spouse, legal representatives, heirs and assigns, hereby waive, release, and discharge the District, its officials, employees, volunteers, attorneys, and agents (hereinafter the "District") from any and all liability to me, my spouse, legal representatives, heirs, and assigns, for any and all losses or damages resulting therefrom, on account of any injury to myself, even injury resulting in death, or to my property, whether caused by negligence of the District or otherwise, which claims, losses, and demands arise during or result directly or indirectly from my participation in the Program and/or VO2 testing.

3. Indemnification. I agree to fully indemnify and hold harmless the District from any and all losses, liabilities, damages, or costs, including reasonable attorney's fees, which may be incurred as a result of injuries to me, the District or other parties or persons, which arise from participation in the Program, whether any such loss or liability was caused by the negligence of the District or otherwise and for any acts or conduct on my part.

4. Extent of Release. The undersigned expressly agrees that this Release is intended to be as broad and inclusive as is permitted by the laws of the State of Colorado. If any portion of this Release is held invalid, the balance shall, notwithstanding, continue in full legal force and effect.

Read, understood, and agreed to on _____, 2023.

USER OF FACILITY / PROGRAM PARTICIPANT:

_____
Signature

_____
Print Name

Appendix D

CardioCoach Specifications

CARDIOCOACH SPECIFICATIONS

Measurement	Oxygen Uptake, expired gas analysis
Test duration	7 – 20 minutes
Dimensions	15" x 15" x 4" (W x L x H)
Weight	7 lbs 14 oz (3.5 kg)
Warranty	1 year manufacturer
Options	Roll cart, carrying case, laptop, software, heart-rate watches, TV monitor.
Outputs	VO_2 Max
	Anaerobic Threshold (AT)
	Peak O_2
	Predicted Peak O_2 (SubMax Test)
	Calories Burned per Hour
	REE/RMR (PLUS and CO_2 unit)
	RER (CO_2 unit)

(Korr, n.d.)