Firefighter Body Composition

Benjamin S. Stone

Los Alamos Fire Department, Los Alamos, New Mexico

Certification Statement

I hereby certify that this paper constitutes my product, that where the language of others is set forth, quotation marks so indicate. Appropriate credit is given where I have used the language, ideas, expressions, or writings.

X______________________________ 1/9/2022

Abstract

This applied research project aims to use evaluative research with a mixed methodology to study the current procedures available to body composition data from firefighters. Fitness levels across the firefighting community can span from fit to morbidly obese. The correlation of obesity with chronic and acute health problems is strong, leading to an epidemic amongst the fire service. The reduction of firefighter obesity leads to a reduction of time lost due to injury and medical events. The current fire service suggested measuring technique for body composition assessment is the skin fold test (SKF). However, new technology may offer improved accuracy. The problem is that the different body composition measurement methods have not been widely studied in the firefighter population. The purpose of this study is to provide insight into the various body composition measurement techniques. This evaluative, mixed methodology study will review the current procedures used by the Los Alamos Fire Department (LAFD) to assess body composition. The research questions will compare data and perceptions of bioelectric-impedance (BIA) with the body mass index (BMI) chart and skin-fold measurements (SKF). The procedures will include comparing the measurements and perceptions found with BIA, SKF, and the BMI chart. The evaluations will occur at the Los Alamos National Laboratory wellness center and be conducted by a certified exercise physiologist. The findings for the research showed that individual firefighters could see several percentage points variance in their measurements, while the mean of the group showed no statistically significant differences. The recommendation of this study is to add the bio-electric impedance scan into LAFD’s yearly fitness evaluation, then reassess the department’s perceptions after a larger population is assessed.

Keywords: firefighter, body fat, fitness, body composition, LODD.

Table of Contents

CERTIFICATION STATEMENT 2

ABSTRACT 3

TABLE OF CONTENTS 4

INTRODUCTION 6

BACKGROUND AND SIGNIFICANCE 8

Los Alamos Firefighter Health 8
History of Firefighter Health 13
Current Firefighter Health Standards 16
Skinfold Testing 17
Bioelectrical Impedance 18
Hydrostatic Weighing 18
Dual Energy X-ray Absorptiometry 19
Future of Firefighter Health 19

SIGNIFICANCE 20

LITERATURE REVIEW 20

Body Fat in Firefighters 22
BMI Chart 24
Skinfold Test 26
Bioelectric Impedance Testing 28

METHODOLOGY 30

Procedures 30
Body Fat Testing Methodology 32
BMI Chart. 32
Skinfold Test 33
BIA Testing 34
Survey Methodology 35
Limitations 36

RESULTS 36

DISCUSSION 42

RECOMMENDATIONS 45

REFERENCES 48

APPENDIX A 53

APPENDIX B 55

APPENDIX C 56

APPENDIX D 57

APPENDIX E 64

Introduction

Firefighting is an industrial sport that requires fitness levels compared to professional athletes. Firefighters use a mixture of technically challenging movements associated with high-intensity firefighting, which requires that they frequently utilize anaerobic metabolism. According to Sokoloski et al. (2020), athletes engaging in strenuous activity may use anaerobic energy for nearly 50% of the total metabolic energy used during the event (anaerobic -45%; anaerobic a-lactic- 24.9% anaerobic lactic- 29%). The use of anaerobic metabolism in athletes has been well documented through peer-reviewed research (Sokoloski et al., 2020; Winter et al., 2010). Concurrently, there is a benefit from using the oxidative system during high-intensity interval training (HIIT) (Sokoloski et al., 2020). The role of body fat plays a significant role in the oxidative system and anaerobic respiration (Köroglu, 2021). Since firefighting activities can often span 120 minutes or more, body fat as an energy source is critical. The critical factor to consider is the concept of diminishing gains. Firefighters need a healthy amount of body fat. Excessive amounts of fat reduce their longevity while increasing injury and chronic health conditions (Marciniak et al., 2021).

Excess body fat in firefighters negatively affects their performance, livelihood, and longevity in the fire service. Firefighters wear heat-protective fire equipment, self-contained breathing apparatus and carry many tools into every fire. The combined weight of this equipment is typically around 50 pounds (Marciniak et al., 2021), which causes increased inhalation resistance, heat stress, and the use of the SCBA stresses the cardiovascular system (Bode et al., 2021). In addition to the pressure on the cardiovascular system, firefighting demands intense muscle strain, as they carry equipment, climb ladders, move patients, and crawl through an immediately dangerous to life and health (IDLH) environment (Bode et al., 2021). Numerous studies have found that firefighters require a high level of physical fitness to meet the demands of an emergency scene (Bode et al., 2021; Sokoloski et al., 2020; Winter et al., 2010). Every year the National Fallen Firefighters document over 100 line of duty-related deaths, with 452 occurring due to cardiac events over the last ten years (Norris, 2021). Albert et al. (2000) suggested that excess weight was a primary factor in the mismatch of fitness and the high-energy requirements of firefighting, contributing to the epidemic of cardiovascular events in the service.

Firefighting is a dangerous job that demands a great deal of physical fitness, including aerobic metabolism, anaerobic metabolism, and physical strength. Studies have found that firefighters increase their risk of cardiovascular disease as their body fat and body mass (BMI) increase (Norris, 2021). As these measures increase, so does the risk for several diseases, including diabetes, coronary artery disease, hypertension, and changes in serum blood levels (Albert, 2009; Risavi & Staszko, 2016). In addition to the systemic health issues related to increased body fat, there is ample documentation of an increased risk of musculoskeletal injuries in overweight firefighters (Cornell & Ebersole, 2021; Köroglu, 2021) as every unit increase in body fat results in a 5–9% increase in lost time (injury/million working hours; Smee et al., 2019). Body fat plays a significant role in firefighters' ability to do their jobs and perform to retirement successfully (Sergi et al., 2021). Minimal improvements in firefighters' body fat percentage may be associated with a significant reduction in the myocardial metabolic risk factors (Sergi et al., 2021). The addition of technology to improve body fat measurement leads to the problem statement: It is unknown which body fat measurement method provides the most accurate, cost-effective, and efficient assessment of a firefighter's body composition.

The purpose of this study is to investigate different body fat measurement methods; this study will provide insight into the preferred body composition method that provides accurate, reliable, and valuable information as a means for assessing a firefighter's overall fitness. This applied research project aims to use evaluative research with a mixed methodology to study the current procedures available to collect body composition data from firefighters. The existing approaches include the body mass index (BMI) chart, skin-fold caliper measurement, bio-impedance scans, and dual-energy x-ray absorptiometry (DXA) (Campa et al., 2021). This researcher will collect qualitative and quantitative data from ten firefighters to compare BMI charts, skin-fold caliper measurements, and bio-impedance scan procedures then gather the firefighter's perceptions on the three tests. Using output measurement, this study will compare measurements from bioelectrical impedance analysis (BIA), Skinfold testing (SKF), and traditional BMI charts. The data provided will gain insight into how body composition is measured, potentially improving practices within fire department health and safety offices, and how firefighters meet National Fire Protective Association (NFPA) 1582 standards (Association, 2007).

The research questions for this applied research project are:

RQ1: How accurate is the BMI chart compared to bioelectric impedance scans?

RQ2: Is there a significant difference in SKF between the two testers?

RQ3: Is there a significant difference between SKF and bioelectric impedance scans for assessing body composition?

RQ4: What are the firefighter perceptions of accuracy of body composition interpretation and results?

Background and Significance

Los Alamos Firefighter Health

Los Alamos Fire Department (LAFD) is located on the 109 square miles Pajarito Plateau on the southern edge of the Jemez Mountains of Northern New Mexico. The community sits at an elevation of 7300 feet, allowing for separation from the desert southwest climate, providing four distinct seasons. LAFD is on a proverbial island atop the plateau, with the closest mutual aid being over 40 miles away. The population of Los Alamos is nearly 18,000 during the evenings and closer to 30,000 during the day (LAFD, 2020). The fluctuation in population is due to the community's top employer, the Los Alamos National Laboratory (LANL). LANL is the nation's premier nuclear research facility that also works in atomic energy, technology, chemistry, space exploration, and a myriad of additional research. The diversity of research that LANL conducts provides LAFD with a complex response system that taxes responders daily.

The County of Los Alamos frequents the nation's list of bests, being named among the best places to live, the fittest, the highest number of millionaires, and the highest educated (LAFD, 2020). Many of these attributes are due to the world-renowned reputation that the county has received due to the groundbreaking work that LANL conducts. LANL workers make up most of the population during the day, many of whom commute from Santa Fe, Albuquerque, and Colorado. LANL and its contractors make up the largest employer in Los Alamos and are amongst the largest in New Mexico. In addition to research, LANL is the primary benefactor to LAFD, which functions under a cooperative agreement that allows the county fire department to provide emergency services to the laboratory campus (LAFD, 2020). The LANL contract is the primary reason LAFD is not a mixed volunteer agency and has 140 members paid fire department. The LANL contract benefits LAFD in many ways, including access to LANL medical physicians and fitness staff to aid firefighters in staying compliant with physical mandates.

LAFD is a 140-member fire department serving out of five fire stations strategically located throughout LANL and the community. LAFD firefighters are prepared to respond to events ranging from minor medical to extremely technical radiological releases. In addition to laboratory response, LAFD provides hazardous materials response, wildland firefighting, structural firefighting, high angle/technical rescue, terrorist response, and community emergency medical services (EMS) (LAFD, 2020). LAFD response includes a tiered paramedic response system, with a minimum of one paramedic being dispatched to every call and additional paramedics being dispatched based on patient acuity. LAFD approaches preparedness by conducting nearly 20 hands-on drills yearly, participating in tabletops, and conducting after-action reports (LAFD, 2020). These actions have created a strong relationship with LANL based incident response commanders (IRC) while preparing LAFD firefighters to remediate most emergencies.

LAFD follows fitness standards that the NFPA outlines, and their firefighters participate in four annual health and fitness assessments. The preliminary tests are phase 1, phase 2, and microfit. Phase 1 is a comprehensive medical evaluation that includes a blood panel, vital signs, x-rays, pulmonary function tests, electrocardiogram, vision, and hearing tests. This set of tests is conducted with trained medical technicians. In addition to phase 1, firefighters participate in a microfit. The microfit is conducted by exercise physiologists (EP) at the LANL wellness center (gym). The test consists of a skinfold measurement, bicycle heart rate test, sit and reach, pushups, and bicep strength test.

The skinfold measurement follows the Anthropometry Procedure Manual (Kamal, 2006) and involves measuring the upper chest, triceps, abdomen, and thigh sites. The second component is the submaximal bicycle heart rate variability test that measures metabolic equivalents (METS). During this test, the EP places a heart rate monitor on the participant, who proceeds to pedal at progressive resistances (e.g., 50 to 200 Watts) until their heart rate reaches 80% of age-predicted heart rate max (220-age). For the push-up test, the firefighter is instructed to complete as many repetitions as possible until their form breaks or become so fatigued that they cannot perform another repetition. The v-sit-and-reach test has the firefighter sit with their legs fully extended, their ankles dorsiflexed, and their feet 12 inches apart. From there, they are instructed to reach as far as they can between their legs while folding at the low back and keeping everything else perfectly still. The upper-body strength test is a maximal voluntary isometric contraction performed by the biceps at 90 degrees of elbow flexion. During this test, the firefighter is instructed to pull as hard as possible for 5 seconds on a straight bar attached to a force transducer via a cable/rope system.

The test data is input into the computer system, and the Firefighter is given an overall fitness score. That score is reviewed during the phase 2 physical. Once phase 1 and microfit are completed, phase 2 is scheduled with a nurse practitioner or physician's assistant. Phase 2 reviews the phase 1 findings, microfit results, and a physical evaluation.

Phase 2 is completed at LANL occupational medicine, under the direction of the medical director. The LANL assigned nurse practitioner, physician assistant, or physician will conduct a physical evaluation that follows Department of Transportation standards and review the findings from phase 1 and microfit. Once the evaluations are completed, the practitioner will recommend "fit for duty" or "not fit for duty," and the medical director will confirm their decision. If the Firefighter is not fit for duty, they will be given a work plan to complete to return to duty. In addition to the yearly fit for duty exams, LANL occupational medicine provides immunizations, psychiatric care, clinic time for return-to-work approvals, and drug testing. LANL occupational medicine also accommodates the medical needs of the entire laboratory population. Once approved as fit for duty, the Firefighter is authorized to complete the final two fitness evaluations, the pack test and the Criterion Task Test (CTT).

In late winter each year, LAFD conducts a red card pack test for all response personnel. The Pack test, or work capacity test, assures that all firefighters are physically able to meet the minimum fitness requirement associated with response to a wildfire incident as described in the NWCG standard for wildland fire position qualifications (NWCG, 2020). There are three levels of capabilities under the NWCG standard: arduous, moderate, and light. LAFD requires that all personnel attempt the arduous test, which requires an above-average endurance and exceptional conditioning (NWCG, 2020). The pack test consists of a three-mile walk on level terrain and is completed while wearing a 45-pound pack with a 45-minute time limit (NWCG, 2020). Once complete, the Firefighter will be red card qualified and considered a deployable asset to a wildfire incident. LAFD firefighters work in an urban-wildland interface and are encouraged to obtain their red cards, but they are not required to pass this physical test only participate. The final test that LAFD firefighters take is the CTT.

The CTT consists of five stations and must be completed within 6 minutes and 59 seconds. LAFD firefighters must complete and pass the CTT yearly in the fall. The CTT is a nationally recognized firefighter task-based fitness test (Saari et al., 2020) completed while wearing full bunker gear and a self-contained breathing apparatus (SCBA). The test begins with a 45-pound high-rise hose pack; the Firefighter takes the hose pack and climbs three flights of stairs. The pack is placed on the ground, and then the Firefighter reaches outside the drill tower to haul a 45-pound hose roll up the tower's exterior. The Firefighter will then descend the stairs and begin the Keiser apparatus moving 160-pound steel beam five feet with a nine-pound sledgehammer. The following is a hose pull, using a one ¾" hose, advancing 75 feet. The final step is a firefighter rescue, moving 175-pound mannequin 100 feet. The CTT is the last LAFD fitness qualification process completed yearly. Overall, LAFD firefighters perform well and pass the examinations.

LAFD has encountered medical issues that it has not previously faced in recent history. In addition to the minor injuries that frequently occur during training and on fire scenes, the LAFD has had several firefighters with cardiac events, back surgeries, and severe knee injuries. These events left one Firefighter on permanent disability and several serving in administrative duties for over six months to recover from injuries. With daily staffing of 37, losing just a few firefighters to injury or illness causes excessive overtime for the remainder of the staff to try and cover. General firefighter wellbeing has been a hot topic in the fire service due to the number of yearly line of duty deaths. The issue of firefighter health begins with fitness.

History of Firefighter Health

Firefighter physical fitness has been a hot topic in the fire service for decades, often being an afterthought within the culture, which is highly guarded and is frequently isolated from external influences. The fact that firefighters face dangerous, physically demanding incidences is well known, yet many will ignore the distinct correlations between being overweight and injury, disease, and death. The typical firehouse routine became a place where firefighters would spend their time trying to rest and eat, with the thought that they had to be well-rested and fed in case they encountered a fire. This thought process placed firefighters into a situation where they were overeating and sedentary. Firefighter fitness problems were then compounded when fire prevention, building construction, and fire engineering reduced the number of fires, subsequently reducing the physical demand of the job. It wasn’t until the late 1990s’ that firefighter fitness became an accepted need. It was then that representatives from labor boards, management teams, and industry leaders began developing and implementing industry best standards to try and reduce firefighter injuries and deaths related to fitness.

Firefighter fitness programs began to emerge about three decades ago, beginning with the National Fallen Firefighters Foundation, the International Association of Firefighters, and the National Volunteer Fire Council. The fitness movement was fueled by studies focused on defining firefighters' physical and psychological threats. The findings included increased cardiovascular disease, stroke, cancer, and post-traumatic stress disorder. Winter et al. (2010) suggested that cardiovascular disease and coronary artery disease are leading causes of death amongst firefighters. A study conducted with the Dallas Fire Department in 2008 detected hypertension, hyperlipidemia, high triglycerides, high glucose levels, and increased hemoglobin A1c among their firefighters (Winter et al., 2010). These are markers found in overweight individuals and may lead to early cardiac death and musculoskeletal injuries. Additionally, each of these markers is prevalent in individuals with higher body fat levels. Medical insight and research into the causes of firefighter fatalities pushed fire service leaders to seek change.

In 1896 the NFPA was created as a self-funded nonprofit organization that devoted its work to eliminating firefighter line of duty deaths and injuries. NFPA initially began reviewing and recommending firefighter fitness requirements in 1974 with the release of NFPA 1001, the Standard on Professional Qualifications for Firefighter (Loflin, 1989). The NFPA 1001 suggested the minimum qualifications to become a firefighter; these recommendations, however, were rarely implemented, primarily due to departments not knowing about the standards or a lack of resources to enforce them (Loflin, 1989). The NFPA then began to work on the Fire Service Occupational Safety and Health standard, later becoming NFPA 1500 (Loflin, 1989). NFPA 1500 became the national standard for firefighter safety and included recommendations for personal protective equipment. The standard for Firefighter Medical requirements (NFPA 1582) was released in 1992, nearly 100 years after the creation of NFPA (Association, 2007; Leffer & Grizzell, 2010). This document fell under the responsibility of the Fire Service Occupational Safety and Health Committee. NFPA 1582 has been revised several times since its inception; updates occurred about every three years and sought to implement the guidance provided by fire department physicians (Association, 2007; Leffer & Grizzell, 2010). It wasn't until 2003 that the International Association of Fire Chiefs (IAFC) and the international association of Firefighters (IAFF) joint labor-management team pushed NFPA to implement NFPA 1583, the Standard on Health-Related Fitness Programs for Firefighters (Association, 2000). The purpose of NFPA 1583 is to set the minimum requirement for a fire department to establish a firefighter health-related fitness program (Association, 2000).

In 2004 the National Fallen Firefighters Foundation (NFFF) introduced the 16 firefighter life safety initiatives. These initiatives were developed during a life safety summit to address the requisite cultural changes within the fire service to minimize the number of preventable firefighter fatalities. The industry-led to the Everyone Goes Home program, adopting the 16 Firefighter Life Safety Initiatives. Initiative number six is medical and physical fitness. This standard requires the development and implementation of a national medical and physical fitness standard that can be equally applicable to all firefighters and that can be adjusted to the duties that they will be required to perform. The summit participants suggested that among all the line of duty deaths (LODD), significant reductions could be made through the foundation of medical surveillance and physical fitness programs. The cruciality of this initiative is due to the estimated 737,000 firefighters that serve in the United States that do not have a program to maintain their essential health and fitness needs (everyone goes home).

Current Firefighter Health Standards

NFPA 1582 is the standard that provides fire chiefs with the knowledge to ensure that their firefighting staff can perform to the community's requirements. NFPA 1582 provides a detailed list of medical and physical examinations requirements that fire chiefs should implement for every new hire and continuously each year through a firefighter's career. The current standard includes information for medical providers to conduct a comprehensive medical evaluation that consists of a blood panel, cancer screening, vital signs, x-rays, pulmonary function tests, electrocardiogram, vision, and hearing tests. The NFPA 1582 standard also recommends that fire chiefs provide initial and periodic fitness evaluations. Fitness evaluations fall into NFPA 1583, the Standard for Health-Related Fitness Programs.

Periodic physical fitness evaluations are critical in any industry where labor-intensive work is an essential job task. Firefighting is a labor-intensive job with a personal fitness requirement that extends beyond the individual, affecting the team, customers, and the community. This responsibility drives an increased need to be fit. NFPA 1583 suggests that the Firefighter's fitness assessment comprises five components: flexibility, muscular endurance, strength, body composition, and aerobic capacity. Aerobic capacity is tested by measuring VO_2max, the industry-standard metric used to measure aerobic power. The SKF uses calipers to measure the firefighters' body composition. Force gauges are used to measure muscular strength. Most components of the fitness evaluation have started to take advantage of technology to provide for improved accuracy when measuring. Aerobic capacity uses heart rate monitors, digital resistance gages, and computer software to calculate VO_2 max accurately. Force gauges can be analog or digital. However, digital gauges have been found to improve accuracy. One of the components lagging behind the technology is body fat measurement. The current standard still suggests a skinfold caliper measurement of body fat.

There are multiple methods to measure or estimate body fat in a firefighter; the BMI chart, SKF, BIA, hydrostatic weighing, and DXA. The BMI is a calculation and graph used to estimate a person's overall body composition. The measure is based on the person's weight in kilograms divided by the height in meters and estimates the amount of fat in a body. Although the BMI chart does not measure fat directly, BMI is moderately correlated with the amount of fat found on the body (Appendix A).

Skinfold Testing

The SKF measurement is a technique used to estimate the amount of subcutaneous fat on the body. The measure involves using a caliper device to lightly pinch the skin and subcutaneous fat in several locations. This is a quick and inexpensive method to gather body fat data. However, this process takes a high level of skill and training to garner accurate results. Skinfold programs recommend that the test be done frequently and by the same person to reduce differences due to interrater reliability for the best results. These details provide for average body fat. Several protocols are available for the SKF procedure; many utilize three to eight pinch locations and test each spot several times to improve accuracy.

LAFD currently uses the three-fold Jackson and Pollock testing protocol. The Jackson-Pollock formula is not a direct assessment of subcutaneous fat percentages, rather a measurement of relative body density. The body density measurement is then used to provide a relatively accurate body fat percentage. The Jackson-Pollock method has been widely accepted due to a generalized calculation that can be accurately implemented through a vast range of populations.

The Jackson-Pollock body density measurement is converted to body fat percentage using the Siri equation. The Siri equation estimates body fat percentages based on a given body density.

$$\text{Density} = 1.10938 - (0.0008267 * (\text{Sum of 3 measurements})) + (0.0000016 * (\text{Sum of 3 measurements}^2) - (0.0002574 * \text{age})$$

Jackson-Pollock Equation

$$\text{Percent Body Fat} = (485 / \mathbf{DENSITY}) - 450$$

Siri Equation

Bioelectrical Impedance

BIA is a procedure that assesses an individual's body composition. BIA is a non-invasive assessment that involves the placement of electrodes on the individual's foot and hand. Different models of BIA devices will utilize one side of the body or both sides. The test works by sending an electrical pulse from the hand to the foot. This device measures how the electrical signal is impeded as it passes through different tissue types. Tissues such as blood and hemoglobin conduct electricity quickly, where muscle, fat, and bone slow the electrical impulses at different rates. This allows the programming to estimate the individual's body fat, bone density, hydration levels, and in some cases, inflammation. The BIA has become a standard tool used in many civilian health and wellness programs. BIA measurements are easier to implement and require less practice and ongoing training to be accurate.

Hydrostatic Weighing

Hydrostatic weighing is considered one of the most accurate ways to estimate body fat percentages. Hydrostatic weighing uses the Archimedes principle of displacement, which states that the buoyant force placed on a submerged object equals the fluid displaced by the object (CITE). This method determines the percentage of body fat found in an individual. The density of fat varies from that of bone and muscle, changing the displacement of water. The person that carries more body fat will be more buoyant and weigh less underwater. Alternatively, individuals with more muscle mass will weigh more underwater. The hydrostatic weighing procedure begins with assessing the individual's dry weight, then evaluating them. The participant will be placed on a special scale and lowered into the water. The participant will then remove all the air in their lungs and hold their breath underwater while their weight is measured. This test is completed over three attempts, with the results being averaged to provide the result.

Dual Energy X-ray Absorptiometry

DXA is a newly FDA-approved method to measure body fat. This procedure for this method is simple and requires only that the individual lay in front of the DXA machine for around 20 minutes. The DXA uses two x-ray beams to scan the body and measures bone density, body fat percentages, lean mass percentages, and total body composition. The scan can also identify weak spots in the muscle and bone and identify rheumatoid arthritis, thyroid issues, and inflammatory diseases. The DXA is the most accurate body fat measurements (Bilsborough et al., 2014). In recent years, the DXA scan has started to be used for fitness and body fat measurement. Still, this method has rarely been integrated into firefighter fitness evaluations due to the time and financial commitment needed. DXA and impedance devices provide a technological basis for the future of measuring firefighters' body fat and overall health.

Future of Firefighter Health

Historically, body fat has been underutilized as a critical indicator of firefighter fitness. BMI charts were a methodology that started a trend that allowed firefighters to improve their understanding of body composition and how fat affected their capacity to work. As time progressed, departments began using SKF to enhance body fat estimations. The evolution of technology has provided multiple avenues for firefighters to improve their total fitness through measuring body fat. These new technologies are not well accepted into the firefighting culture.

The future of body fat analysis lies in using technology to obtain the most accurate data possible. This change is critical, as a few percent difference in body fat may be the difference in survival for a firefighter. The next section of this study will review the research and literature supporting each body fat measurement procedure discussed in the background.

Significance

This study holds significance to the Los Alamos Fire Department, is linked to the Executive Fire Officer Curriculum, and further meets the strategic goals of the United States Fire Administration. The synergy of the NFFF Firefighter Safety Initiatives and the NFPA 1583 standard build a strategic plan for fitness and wellness implementation across the country. These standards allow fire chiefs to promote fitness amongst responders while providing improved safety for their community. The LAFD will benefit from this study by understanding the effect of firefighters' body fat on preparedness and the preferred method to collect information. The potential gain reduces latent cardiac issues and injuries related to excessive body fat levels. The National Fire Academy R-0306 Executive Analysis of Fire Service Operations in Emergency Management program teaches Executive Fire Officers the importance of response readiness and the complications during an emergency. Measuring firefighter body fat falls into the NFPA 1583 standards, the NFFF initiative six (medical and physical fitness), NFFF initiative eight (technology), and the EFO program topic through assessing and assuring the readiness of responders to meet the physical demands of firefighting. The current standards that NFPA has implemented present a unique challenge to the fire service, as they strive to reduce the number of health-related line of duty deaths.

Literature Review

Firefighters across the United States are required to maintain exceptional physical fitness to provide for the safety and wellbeing of their fellow firefighters and their communities. This standard aside, recent studies have placed firefighters at an average or below average physical fitness level compared to their peers in the civilian world (Poston et al., 2011). A firefighter with below-average fitness and overweight is incompatible with a firefighter's requisite physical demands. Firefighting tasks include working in respirators, thermally intense environments, wearing heavy equipment, and reduced range of motion due to their equipment. The consequence is a dynamic issue where there is a mismatch of high-energy demand and excess body weight, causing a significant increase in the probability of catastrophic cardiovascular and cerebrovascular incidents. The evidence supporting this claim is extensive, with cardiac and cerebrovascular events equating to more than 49% firefighter deaths (Poston et al., 2011).

Firefighters are required to respond to an assortment of emergency events. Emergencies that firefighters respond to require a standard fitness level that equates to professional and tactical athletes. Fitness requirements have been a hotly debated subject within the fire service for years, and until recently, there was no standardized method to assess overall fitness levels (Loflin, 1989). However, the NFPA introduced their interpretation of firefighter fitness standards; these standards are not required. The fire department leadership can adopt the standard or abandon the standard for alternate paths (Loflin, 1989). The body of research on firefighter fitness focuses on cardiorespiratory capacity, directly correlated with the performance of the 14 firefighter essential job tasks (Appendix B) (Bode et al., 2021). There is a significant need to fully understand each fitness component, including how body fat percentages affect the health and injury potential of the firefighter.

Researchers have recently realized the effects of excessive body fat on firefighter fitness. For example, Nogueira et al. (2015) suggested a distinct correlation between body composition and cardiorespiratory fitness. Cornell et al. (2021), and Bode et al. (2021) added that increased body fat could lead to cardiovascular disease and many chronic diseases. Cornell et al. (2021) go further to correlate increased body fat with increased sudden cardiac death following autonomic nervous system activation during emergency responses. Through accurate body fat measurement, fire departments will better understand firefighters' cardiovascular risk and capacity to perform the 14 firefighter essential job functions.

Body Fat in Firefighters

Obesity has become an international epidemic, and as the world's population becomes less active, the average percentage of body fat has increased (Adair & Lopez, 2020). In the United States, studies have found that nearly 50% of all deaths have body fat-related chronic disease patterns, which include diabetes, kidney disease, morbid obesity, lipidemia, and hypertension (Adair & Lopez, 2020). Additionally, there has been an annual increase of body fat-related illness and death of nearly 3% on average (Adair & Lopez, 2020). Deaths related to increased body fat percentages are above the epidemic threshold, causing the average life expectancy of an American to stall for the first time in several decades. Body fat factors affect many Americans, including firefighters. Some studies place over 30% of firefighters as obese, with more than 50% being overweight, surpassing the averages of the average American (Mathias et al., 2020). Body fat is a predictor of a multitude of outcomes, to include chronic disease, injury, and longevity.

In addition to body fat percentage being an indicator of chronic health issues, it has also been correlated with a multitude of injuries, including lower back, shoulder, and knees (Jahnke et al., 2013a; Kuehl et al., 2013). Furthermore, every unit increase in BMI results in a 5–9% increase in lost time (injury/million working hours) in U.S. firefighters (Smee et al., 2019). Shoulder and lower back injuries are among the most prevalent reported grievances reported by firefighters. Merrigan et al. (2020) studied upper-body fitness assessments, using body composition and push-to-pull-exercise ratios to determine if body composition affected shoulder strength and stability. They found that shoulder injury prevention can be achieved by increasing the muscular strength of the ancillary shoulder, in conjunction with a significant decrease in body fat percentages. Lower back injuries account for 50% of early retirements due to injury (Mayer et al., 2012).

Mayer et al. (2012) conducted a study on 83 firefighters in which they compared body fat, muscular endurance (back, core), and perceived lower back pain. They found that muscular endurance in the back and core was 27% lower in firefighters considered obese or morbidly obese, with slightly lower percentages from those who were overweight (Mayer et al., 2012). The research provided evidence that as firefighters' body fat percentage increases, so does their risk for musculoskeletal injuries (Mayer et al., 2012; Pelozato de Oliveira et al., 2021). Concurrently, the research found that the severity and frequency of injury increased as the body fat percentage increased (Mayer et al., 2012; Pelozato de Oliveira et al., 2021). When combined with chronic health conditions, injury prevention adds to the critical nature of understanding increased body fat on a firefighter's longevity and general health. Body fat significantly affects how well a firefighter can do their job and how long they can do it. By accurately measuring body fat percentages, fire departments can help their responders improve their general health while reducing the potential of injury and providing an enhanced response capability to their community. Several methods are used to collect body fat percent ages such as the BMI chart, SKF, bioelectric impedance, and dual-energy x-ray absorptiometry. Each of these methods has pros and cons associated with their use.

BMI Chart

The BMI chart estimates an individual's body composition based on height and weight. The individual's measurements are then compared to the baseline average measurements of an average individual. Much like any other scientific data, the BMI chart is based on a simple bell curve, with averages being derived from the peak of the curve. Some extremes will have high or low BMI calculations, which are the chart's outliers. Having a good BMI does not necessarily determine if an individual is healthy, as many individuals with normal BMIs still exhibit the same symptomology as the morbidly obese. Studies have shown that diet and exercise are still necessary, even if an individual establishes a normal BMI (Appendix A) (Bode et al., 2021).

The BMI chart has been used in the fire service as a baseline to provide firefighters with an understanding of their general mass versus the average. Firefighters classified as obese by the BMI are up to five times more likely to be hurt on duty than firefighters with an average weight (Smee et al., 2019). Additionally, for every BMI point increase, the firefighter is 5-9% more likely to see an increase in lost time due to injury (Smee et al., 2019). Although BMI has been directly linked to injury rates, its validity has been questioned. This method has pros and cons that fire departments should consider before implementation.

The BMI chart is an inexpensive method to estimate a firefighter's body composition. The scale and chart are easily accessible on the internet, and they take very little training to use appropriately because the scale is derived from the individual's height and weight. Concurrently, individuals can determine their own BMI using the same chart with a bathroom scale. With cost being a primary concern of most fire departments, the BMI option appeals to the bottom line. Although inexpensive and easy to use, the BMI chart is not a direct measurement of adiposity.

The BMI reflects body mass, which differs from body fat, as the term mass includes muscle in addition to fat.

Researchers have shown that the BMI chart does not accurately depict an individual’s body fat percentages (Ode et al., 2014). Several instances of this phenomenon have been cited in peer-reviewed literature. Examples include normal body weight individuals with an average BMI on the chart with excessive body fat and are at risk for obesity-related disease processes (Ode et al., 2014). Studies have shown that the BMI underestimates body fat in firefighters, with nearly 33% misclassifications as overweight and an additional 13% being falsely classified as obese (Smee et al., 2019; Ode et al., 2014). Tactical athletes typically have high body weight, with low body fat, i.e., bodybuilders or tactical athletes, and will be incorrectly indicated as obese or morbidly obese on the BMI chart (Ode et al., 2014; Smee et al., 2019). Although the BMI can accurately categorize firefighters with a mass of over 30, the chart frequently misclassified muscular and lean firefighters as morbidly obese (Ode et al., 2014; Smee et al., 2019). Often, firefighters fall into the tactical athlete category and will be deemed obese when using the BMI scale due to their increased muscle mass compared to a civilian of equal size (Ode et al., 2014). Firefighters have criticized the BMI chart due to its inability to distinguish between muscle mass and fat mass. The use of body fat percentage measurement that can separate the muscle from fat provides for higher accuracy (Smee et al., 2019). In addition to measuring muscle vs. fat mass, the BMI is inappropriate when measuring age-related changes to body composition, as it fails to account for differences in mass related to aging (Smee et al., 2019). The SKF offers additional insight into body composition and is currently the accepted method for measuring a firefighter’s body fat by the NFPA (Association, 2000).

Skinfold Test

SKF is a measurement technique to estimate the body fat on the body. The assessment uses a caliper tool to pinch the skin and subcutaneous fat in several body locations. The measurements can use from three to ten places for the pinch, and accuracy increases with the number of sites being assessed (Naylor, 2021). Although relatively accurate, there are a lot of variables with this method that may skew test results, such as the exact location that the skin pinch takes place, inter-rater reliability, and individual factors such as hydration (Naylor, 2021). Recent studies have suggested that the SKF is best utilized when comparing consecutive results assessed over a span of time (Müller et al., 2013). In this sense, the induvial can compare assessments and trend their body fat percentages. The current NFPA standard addressing firefighter body fat measurements suggests the use of SKF due to several advantages of this tool. One of the main factors to consider when measuring body fat is how accurate the measurements are.

SKF accuracy may vary compared to other systems such as bioelectric impedance and DXA. Müller et al. (2013) conducted a comprehensive study on female athletes, comparing the SKF with bioelectric impedance testing, discovering that the SKF did not accurately represent body fat. The mean values of body fat were not statistically different ($p=0.08$). However, the researchers found a trend that the bioelectric impedance testing yielded between one and two percent differences in body fat due to the SKF being incapable of measuring fat storage other than in the subcutaneous tissue (Müller et al., 2013). Naylor (2021) also studied the Air Force ROTC tactical athletes, comparing the current Air Force circumference testing methodology, BIA, and SKF. The current process for ROTC members is to take circumference measurements in several areas of the athlete’s body, then compare them to a standardized chart, similar to the

BMI. Naylor (2021) found that the BIA and SKF yielded statistically different results expanding on Smee et al. (2019), finding that SKF often overestimates lean mass and underestimates fat mass compared to DXA scanning.

Furthermore, the findings suggested that technicians using the textbook technique during SKF evaluation may find variances of ±3.5% from the athlete's actual body fat measurement. Variances in measurement outcomes could be a potentially critical factor in a firefighter's wellbeing. Consider a firefighter with a 27.5 (slightly overweight) SKF result; the potential of a plus or minus 3.5% places them with a range of 24% (healthy) to 31% (obese). Although accuracy may be an issue, there are several benefits to the SKF.

One of the major draws to the SKF is the cost. The testing does have some costs associated with its use as the calipers can range from a few dollars to several hundred. In addition to the price of the calipers, fire departments may elect to use computer programs or apps to conduct their testing, which is an additional cost. The benefits go beyond a lower price, with improved accuracy over the BMI chart. The SKF is considered moderately accurate and is accepted as a standard within the fire service (Association, 2007). The accuracy of the SKF, when compared to using the BMI chart, is achieved through additional measurements. The SKF goes beyond height and weight by including subcutaneous fat stores in several body areas. The benefits of the SKF are two-fold, affordability and accuracy. Along with the benefits of the SKF are the negatives.

The SKF has several benefits, such as cost, it also has several challenges that firefighters should consider. The firefighter may run into inaccurate measurements due to inter-rater reliability, amount of skin due to weight loss, size of the calipers, hydration, and evaluator experience. These considerations can be accounted for through multiple measurements, averaging the findings to improve accuracy. The SKF provides a semi-accurate assessment of a firefighter's body fat percentage. Combined with an overall fitness assessment, it yields the desired outcomes of informing firefighters of their potential risk for cardiac-related events. Although the skinfold evaluation improves accuracy over the traditional BMI chart, other tools provide firefighters with enhanced data. BIA testing goes beyond measuring subcutaneous fats and claims to include visceral fat, resting metabolism, and muscle mass.

Bioelectric Impedance Testing

Assessing body composition is important to determining a firefighter's optimal fitness levels, specifically when controlling for their training regimen and work functions. BIA testing can accurately determine an individual's various masses. Each biological tissue type emits a complex set of signals depending on the tissue layout, body structures, physiological status, and hydration. The tissue signals can be measured when an alternating electrical signal is introduced. The BIA method interprets the various characteristics of the body's tissues, offering a non-invasive overview of body fat versus muscle mass (Singh et al., 2018). BIA testing provides many applications to the healthcare industry, spanning from disease diagnosis, resting metabolism, body composition assessment, and injury analysis (Singh et al., 2018). There are two main BIA techniques: two or four electrode methods. The primary differences in each testing methodology are: BMI does not distinguish fat-free mass from fat mass, SKF only distinguishes fat-free mass from fat mass, and BIA can break down fat-free mass and fat mass into subcategories such as skeletal muscle mass, total body water, and visceral fat.

The body comprises two sets of mass, the fat-free body composition, and the fat mass. The fat-free body composition includes skeletal muscle, bone, and water. The fat mass acts as an insulator for electric current, and the fat-free body composition is the conductor due to the main component being water. The bioelectric impedance testing is used to evaluate the individual's fat mass, fat-free mass, BMI, resting metabolism, and systemic body water (Singh et al., 2018). The data received can be used to comprehensively understand an individual's body composition while also providing insight into overall fitness, nutrition, disease process/progression, injury monitoring, and general wellbeing (Singh et al., 2018). Impedance measurements give firefighters insight into their general health that is not achieved through BMI measurement or SKF, making the test a versatile and informative tool. A top priority of any measurement device is to understand the accuracy of the evaluation. BIA testing is an easy, fast, and non-invasive test that can provide reliable measurements of a firefighter's body composition. The BIA testing has minimal intra- and inter tester variability. Additionally, the results of this test are almost instantaneous, only taking the time needed to print. The BIA test results are immediately reproducible with less than a 1% error rate (Achamrah et al., 2018). The BIA equipment takes up minimal space and requires very little training to administer. Most of the currently available equipment provides the user with directions to assist their test. Administering the assessment in this manner has the benefit of reducing user anxiety about being in their underwear during the test, as they can be left alone in the room. The cost of the equipment varies depending on the capabilities of the system. The prices may span from a few hundred to several thousand. The BIA equipment is also easily moved between locations, making it more accessible to larger fire departments that span large distances. Fitness staff can package the equipment and bring it to the individual station to perform testing.

The limitations to the BIA include primarily related to human behaviors and the use of predictive equations. The primary limitation for the BIA system is the assumption that the firefighter has a fixed hydration level (Achamrah et al., 2018). Studies that have addressed the issue of hydration have found mixed results; some present data that hydration may change body fat readings by several percentages, while others have found very little change (Campa et al., 2021; Müller et al., 2013; Storer et al., 2014). In addition to water consumption for hydration, factors such as diuretics (caffeine) may play a minor role in overall hydration, although science again does not agree on this factor. In obese, severely obese, and morbidly obese patients, the predictive calculations and body water distribution play a significant role in the inaccuracy of the test. The BIA will typically underestimate fat mass with obese patients (Achamrah et al., 2018).

Methodology

This evaluative, mixed methodology study will evaluate current procedures of how LAFD assesses firefighter body composition. This type of research is conducted to evaluate a program or system. The process implemented by researchers is a type of applied research that has the potential to have a real-world effect. This study will review the procedures implemented to measure firefighters' body mass to update processes to meet the needs and desires of LAFD firefighters. The study will also include a mixed methodology. The mixed-methods approach provides a rich understanding of the data by including qualitative and quantitative data. Through mixing methods, research receives a complete and synergistic data set. Evaluative research requires a robust data set to achieve the intended goal of supporting process improvement, and a mixed-method approach achieves that goal.

Procedures

The research for this project started in July 2021 with a literature review at the Learning Resource Center National at Fire Academy (NFA) in Emmitsburg, Maryland. Research continued upon completing the Executive Analysis of Fire Service Operations in Emergency Management (RO306). Resources from the National Fire Protection Association, University of

New Mexico Library, The Grand Canyon University Library, and a Google Scholar Key Word search (Appendix C) were reviewed. Materials subject to review were published materials in print and electronic forms, books, periodicals, journals, and expert interviews.

Various measurement tools can be utilized to understand body fat measurements, such as SKF, BIA testing, and the BMI chart. The literature review provided the latest research on each of the tools available to the fire service. Additionally, a focused attempt was made to include peer-reviewed data beyond the fire service. Body fat analysis is used in many sports and organizations, and failing to consider this data may have omitted critical aspects of the industry best practices when measuring body fat percentages. The research methodology for this applied research project follows the prescribed procedures as learned in the Grand Canyon University Doctoral Program and the National Fire Academy Executive Fire Officer curriculum.

Firefighter confidentiality will be a primary concern while completing this applied research project. Firefighters will be issued an alphanumeric number, i.e., FF1, FF2, etc. No identifiable information will be collected, such as date of birth, name, or rank. The researcher will only collect demographic data pertinent to the research; the Firefighter' age, weight, and height will be collected. Participants will be required to sign a release waiver and acknowledge that they received the privacy policy for this project. All information collected will be protected, secured, and treated as private healthcare information for the duration of the research project. Data will be stored in the researcher's computer until one year beyond completing the Executive Fire Officer Program. Then, all data will be erased. All hard copies of documents will also be destroyed one year after course completion.

PRETEST DIRECTIONS.

Participants will receive pre-test instructions (Appendix D)

- Exercise- Firefighters will be requested to refrain from exercising for 12 hours before the testing process.
- Food intake- Firefighters will be requested to refrain from eating for 12 hours before testing.
- Hydration- Firefighters will be requested to hydrate following their typical routine the day before the test. On the morning of the test, they will be asked to limit their fluid intake.
- Caffeine- Firefighters will be asked to minimize their caffeine intake the morning of the test.

Body Fat Testing Methodology

The testing will be scheduled while the Firefighter is on duty with their battalion chief. The participants will be tested with each aspect of the study randomly; BMI chart, SKF 1, SKF 2, bio-impedance test. Each test's results will be documented into an excel spreadsheet for further evaluation. Upon completing the body fat testing, the participant will complete a short survey on their experiences and perceptions of the testing process.

Certified EPs who will conduct the body fat testing have been trained in each collection method and currently conduct all physical fitness assessments for LAFD. All information collected will be entered into an excel spreadsheet created by the researcher. The EPs will assign the participant their alphanumeric identifier, collect their height, weight, and age, and enter them into the spreadsheet. The EPs will reference the BMI chart and document the BMI into the spreadsheet. The EP will then proceed to the SKF component.

BMI Chart.

The EP will collect the body mass data from the InBody scan. The InBody requests that the Firefighter enter their height and measure their weight. The InBody will then use the x, y-axis of the adult BMI chart (Appendix A). The BMI number identified on the chart will be documented in the excel spreadsheet for the Firefighter being tested (Appendix A).

Skinfold Test

The EP will use skinfold calipers (Harpenden, Slimglide, Lange) and the recording spreadsheet. Jackson-Pollock body density measurement will be taken from 3 different standard anatomical sites around the body. The EP will test on the right side of the Firefighter's body. The sites used will be the chest, abdomen, and quadriceps. The EP will pinch the Firefighter's skin at the appropriate location to separate the adipose tissue from the muscle. The calipers are applied at a right angle, 1 cm below the pinch site. The reading will be obtained in mm. The measurement for each of the three locations will be taken two times, and each result will be documented in the spreadsheet. The second EP will repeat the test, and the results will be recorded. To avoid having one EP influence the other, one tester will be out of the room while the other tester takes their measurement. The order in which they measured skinfolds on the same subject will be randomized and counterbalanced. The SKF will follow the International Standards for Anthropometric Assessment (2001) outlined in the procedures section.

- **Chest:** The pinch is taken at a point between the axilla and nipple as high as possible on the anterior axillary fold. A horizontal skinfold raised on the chest above the 10th rib at the point of intersection with the anterior axillary line
    - A diagonal pinch across the chest.
- **Abdomen:** The pinch is taken 5 cm adjacent to the umbilicus (belly button), to the right side.
    - The vertical pinch is made at the site, and the calipers are placed just below the pinch. Be careful not to put the caliper or fingers inside the navel.
- **Quadricep**: The mid-point of the anterior (front) surface of the thigh, midway between the patella (kneecap) and inguinal fold (crease at the top of thigh).

- A vertical pinch is taken. This measurement is typically taken with the subject sitting, and the knee bent at right angles. If there is difficulty lifting a fold of skin, it may be easier with the leg extended or with the thigh supported from below by the subject.

BIA Testing

The EP will use the InBody 570 BIA device using the following steps.

1. Enter the Firefighter's height, weight, gender, and age.
2. Firefighters will wear fitness apparel: shorts and a t-shirt. They will be given the option to wear just undergarments. The Firefighter will be left alone in the room and can wear what makes them comfortable.
3. Before the scan, the firefighters will be given a cleaner wipe that they will use on their hands and feet.
4. Position the Firefighter onto the equipment.
    a. When holding the hand electrodes, make sure your thumbs are covering the thumb electrodes and hold the palm electrodes with the rest of the hand.
    b. Bare feet must be in contact with the electrodes.
    c. Make sure to place the heel on the circular (rear sole) electrode.
    d. Then, place the sole on the elliptical (front sole) electrode surface
    e. The proper body posture is a normal standing position with the arms and legs extended.
    f. The Firefighter should remain relaxed and avoid straining or moving the body during the analysis.
5. Once the Firefighter completes the scan, the E.P. will enter the data into an excel spreadsheet.

Survey Methodology

A survey instrument was developed in Microsoft Word (Appendix E) and distributed through Google Forms for this project. The study population will consist of participants in the measurement component of this study. The sample will be determined by the number of volunteers for the study. Each of the participants in this study will complete the survey upon completing their body fat measurements. The survey questions are based on the information obtained from the literature review. Once the questions were completed, six peer reviewers, Chief Officers at LAFD, the LANL medical director, and the EPs examined the survey for construct validity. The reviewers conferred and determined that the study answered the research questions and met the intended construct. Additionally, a pilot survey was conducted with three LAFD chief officers; the chiefs were asked to review the survey for functionality and conduct a grammar/spelling check. The reviewers agreed that the survey was complete and acceptable for this research. The survey will be completed once the participating Firefighter completes their body fat evaluations.

The survey will be used to gauge the participants in the study. The survey will be a paper form that the participants will complete when they finish their body fat assessment. The population will be the 14 firefighters participating in the research. The survey is kept 100% anonymous; no time will the researcher know the Firefighter's identity completing the study. The survey will be ten questions in length and consist of open-ended questions that the firefighters will be able to share their feelings and perceptions of the different testing methods. The survey results will be sorted, classified, and reported in the findings section.

Limitations

Primarily, the sample size is limited to LAFD firefighters due to the access requirements of the National Laboratory. The Laboratory requires that individuals entering the health/fitness building hold a top-secret "Q" clearance and be up to date on required laboratory training. These requirements eliminate the potential of adding outside fire personnel into this study. Therefore, the sample size of this study is small, reducing the statistical power. Concurrently, the current research on this subject is limited within the United States, to include the NFA EFOP ARP library. This limitation affected the amount of data included in the literature review. Finally, the time constraint of six months to complete the program reduced the research time. Additional time may have resulted in a more extensive data set and more accurate findings. As presented, the limitations of this study allow the project to continue and data to be collected.

Results

The research was conducted in December 2021 at the Los Alamos National Laboratory, Occupational Health Fitness center. The researcher requested participation from 37 LAFD employees; 14 volunteered and completed the body mass testing and survey. The 14 participants equate to a 38% percent participation rate. The participants completed a questionnaire on their current fitness activities. All the participants exercise greater than four days per week, have recently scored greater than 12 Mets, and are considered fit. The study requested that ten employees participate, and this number was surpassed. The data received during testing was input into excel, and statistics were run on the findings. The remainder of the section will be broken into each research question.

The first research question is: how accurate is the body fat index chart compared to bioelectric impedance scans? The data received was broken down using the accepted body fat percentage classifications (Appendix A).

The BMI chart placed four firefighters in the low-risk category (green), eight into the overweight category (orange), and two into the class 1 obesity category (red). When compared to the bioelectric impedance device (BIA), 12 firefighters were considered healthy or below weight (green), and two were overweight (orange). No firefighters were deemed to be obese using the BIA measurements. The difference in some cases is significant; were others there, the two readings are within a few percentages of each other. FF2 shows the most significant difference in readings, having an overweight BMI of 26.9 and a BIA of 11%. Alternatively, FF13 has a BMI of 30.4 and a BIA of 28.3. In the case of FF13, the BMI score places them into a high-risk category for long-term health problems, while the BIA places them in a lower risk category.

Table 1.

A depiction of the body mass index (BMI) and bioelectrical impedance (BIA) data for 14 subjects.

	FF1	FF2	FF3	FF4	FF5	FF6	FF7	FF8	FF9	FF10	FF11	FF12	FF13	FF14
BMI	25.8	26.9	25.4	29.5	27.1	26.4	32.7	21.9	17.1	22.8	25.7	25.2	30.1	24
BIA	16.6	11	23.1	26.9	15.5	15.5	21.6	12.3	17.3	12.5	21.7	19	28.3	13.2

BMI (kg/m2) and BIA (BF)

FF = firefighter; BF% = body fat percentage; kg = kilograms; m = meters.

The second research question investigates whether a significant difference in SKFs occurs between rater one and two. The data for this question were averaged, and a paired t-test was used to analyze the data. The mean shows no significant difference between the two means: $t(13)= 0.489$; $p=0.63$. The estimation plot, displaying individual data points, suggests considerable variation between the SKFs conducted by the two raters. The most marked difference is 4%, and the minor difference is 0.2%.

Table 2.

A depiction of the rater one and rater two BF% measurement data for 14 subjects, with the difference.

	FF1	FF2	FF3	FF4	FF5	FF6	FF7	FF8	FF9	FF10	FF11	FF12	FF13	FF14
Rater 1	18.2	12.6	22.1	23.6	15.5	20.2	14.6	11.6	16.9	18.6	14.6	17.4	19.3	9.7
Rater 2	21.2	12.3	18.8	19.6	12.6	14.9	15.5	12.5	17.1	15.6	15.7	18.4	22	13.5
Difference	3	0.3	3.3	4	2.9	0.9	0.9	0.9	0.2	3	1.1	1	2.7	3.8

MEASURED IN BF%.

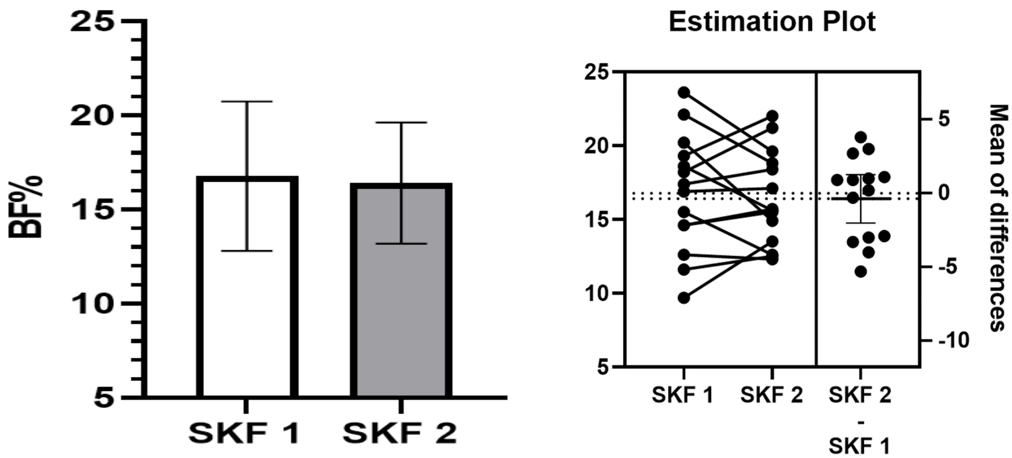

Figure 1: The group means for body fat percentage (BF%) stemmed from two SKF measurements assessed by two separate raters (left). In addition, the estimation plot (right) displays individual data points for the 14 subjects.

The third research question investigates the difference between SKF and bioelectric impedance scans for assessing body fat percentage. The data was tested using a paired t-test, revealing no statistically significant differences between the means; t(13)=1.583; p=0.15. The estimation plot, displaying individual data points, suggests that some firefighters had considerable variability between the SKFing and the BIA test. The most significant difference found was FF13, showing a 7.65% difference, while the closest reading was FF8 with a 0.25% difference.

TABLE 3. A display of body fat percentage (BF%) data as measured by two SKF assessments and a BIA assessment. Average SKF denotes the mean of rater 1 and rater 2. N = 14.

	FF1	FF2	FF3	FF4	FF5	FF6	FF7	FF8	FF9	FF10	FF11	FF12	FF13	FF14
Rater 1	18.2	12.6	22.1	23.6	15.5	20.2	14.6	11.6	16.9	18.6	14.6	17.4	19.3	9.7
Rater 2	21.2	12.3	18.8	19.6	12.6	14.9	15.5	12.5	17.1	15.6	15.7	18.4	22	13.5
Average SKF	19.7	12.45	20.45	21.6	14.05	17.55	15.05	12.05	17	17.1	15.15	17.9	20.65	11.6
BIA	16.6	11	23.1	26.9	15.5	15.5	21.6	12.3	17.3	12.5	21.7	19	28.3	13.2
Difference	3.1	1.45	2.65	5.3	1.45	2.05	6.55	0.25	0.3	4.6	6.55	1.1	7.65	1.6

- FF = firefighter

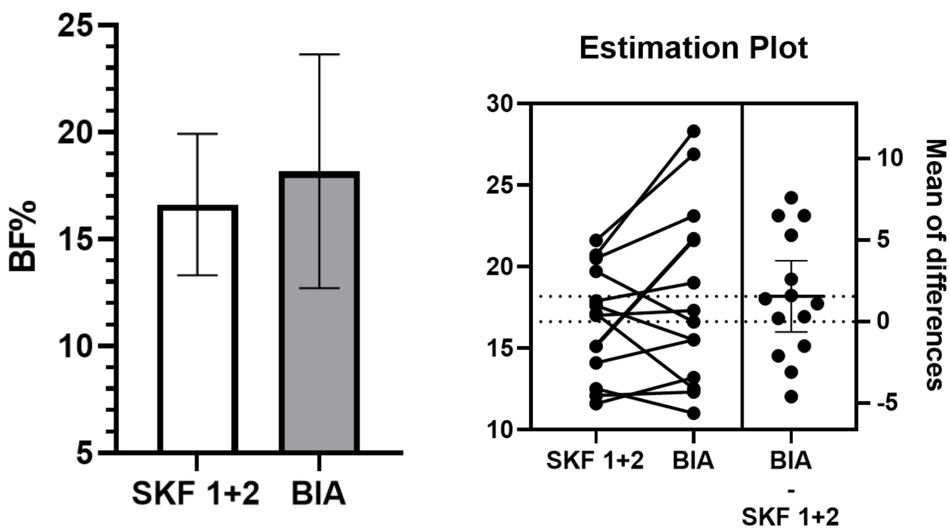

FIGURE 2: The group means for body fat percentage (BF%) stemmed from two SKF measurements assessed by two separate raters (left) next to the BIA scan. In addition, the estimation plot (right) displays individual data points for the 14 subjects.

Research question four is qualitative and will use the survey to answer: what are the firefighter’s perceptions of accuracy of body composition interpretation and results? This research question uses the 11 survey questions to identify perceptions of each of the three body composition tests. The first survey question assessed the perceptions of LAFD firefighters on the BMI chart. Of the 14 firefighters, 12 stated that the BMI chart is unreliable, inaccurate, and fails to account for variables that affect general health. One Firefighter did not share an opinion, and one Firefighter stated that the BMI chart was an excellent way to track overall body mass. The perceptions of the BMI chart are predominantly negative, leading to question two. Using a five-point Likert scale, spanning from very bad to very good, what is your opinion of the accuracy of the BMI chart. Nearly 79% of the firefighters found that this assessment modality is bad or very bad, with the remaining assessments being neutral. The following several questionnaire questions are based on the SKF.

The third questionnaire question requests the Firefighter's opinion of the skin fold assessment. This question received about 50% positive and 50% negative responses. Four of the answers stated that the test could be accurate, depending on the rater. Nine firefighters noted that the test was inaccurate, while all 14 said SKF improved on the BMI chart. One of the significant factors identified in the literature reviews was the perceptions of interrater reliability. Question four asked the firefighters their perceptions of the measurement techniques used by the raters. The questionnaire found that 12 of the 14 perceived the raters as using different techniques, citing that the raters would pinch varying amounts of skin and fat or use slightly different locations. The remaining two firefighters stated that the raters used similar techniques. Finally, question five rated the SKF using a five-point Likert scale, spanning very bad to good. Two firefighters rated the test as bad, 11 selected neutral, and one selected good. Their answers provided a 79% neutral rating for the SKF. The final component of the study is the bioelectric impedance test.

The bioelectric impedance was assessed using two questions. The sixth question evaluated firefighter perceptions of the bioelectric impedance test. Of the 14 firefighters, 100% felt that BIA was superior to the BMI chart and SKF. Several cited that this test removed the human element of testing, improved accuracy, and provided consistency. Additionally, 70% found that the amount of the information supplied by the scan was far superior to the other testing modalities. Question seven assessed the BIA scan using a five-point Likert scale, spanning very bad to good. The firefighters were nearly unanimous, with 13 of the 14 ratings the BIA as good or very good. One Firefighter did not rate the scan and stated that he would need additional information. The eighth question asked which test the firefighters preferred when choosing from the BMI, SKF, and the BIA. The 14 firefighters agreed that their preference was the BIA.

The final three questions of the survey delved deeper into how the firefighters perceived components of the test, including comfort levels, understanding of the importance of body composition, and the future of measuring body composition at LAFD. Question nine asked the firefighters if they felt uncomfortable during any test portion. Seven of the firefighters stated they were uncomfortable during the SKFing, citing being in their underwear in front of the rater, being touched by the rater, and pain associated with the pinch for the test. The remaining seven stated no to the question. Question ten provides information on how the firefighters perceive accuracy when conducting body composition testing. All 14 responses indicated that body fat, composition, and muscle determine overall fitness.

Additionally, half of the responses stated that the accuracy of the information is essential when maintaining fitness. The firefighter’s perception of accuracy indicated that they needed more information than the BMI chart and SKF provided. The final question asked the firefighters why they suggested BIA for future use at LAFD. The answers were very similar, suggesting improved data accuracy, consistency, removal of rater bias, reduced pain, touchless, more information, and ability to track muscle mass. The consensus of the final answer confirms their recommendation to continue using the BIA scan during LAFD fitness evaluations. The following section will discuss the qualitative and quantitative results.

Discussion

The BMI chart is inexpensive and easy to use. The low cost benefits the fire service due to constant budgetary requirements. The problem with the BMI chart is that it is unreliable as a measurement tool, specifically in populations that are considered fit or muscular (Ode et al., 2014; Smee et al., 2019). Firefighters fall into the category of tactical athletes and will frequently be deemed as obese according to the BMI chart (Ode et al., 2014; Smee et al., 2019). This phenomenon occurs due to firefighters having a higher-than-average muscle composition, causing a divergence from the “normal” population (Ode et al., 2014; Smee et al., 2019). The current study supports the literature review. The BMI readings differed significantly from the SKF and the bioelectric impedance scan. According to the height and weight measurements, nine firefighters were considered unhealthy or obese. The SKF revealed that 12 firefighters of the 14 were evaluated healthy, and two were overweight. The study’s findings confirm the findings of Ode et al. (2004) and Smee et al. (2019) that in the tactical athlete, the BMI chart is not accurate due to differences in body composition. In addition to the quantitative results from the study, the firefighters held a predominately negative perception of the BMI chart as a method of measuring fitness or body mass.

The SKF is a reliable and relatively accurate assessment of body fat. Naylor (2021) found that the SKF may have several variables that skew the findings, such as inter-rater reliability, location of the pinch, and individual factors. Müller et al. (2013) suggested that accuracy would increase when the same rater conducted the skin fold assessment several times over a few months. The Müller et al.(2013) study found that the mean values were not statistically different;

however, in several cases, the athletes had significant differences in measurements. Naylor (2021) confirmed the Müller et al. (2013) study, finding that the means may not be statistically significant. Yet, the individual has several percentage points differences, both in interrater reliability and when compared to BIA. The current study confirmed these findings. The firefighters of this study showed no statistical difference in the means. However, many of them did show substantial differences in inter-rater reliability and between tests. The mean comparison of SKF to BIA alludes to the tests being similar to rate a firefighter's body composition. The individual data points matter in the case, as it is possible that LAFD would observe statistically significant changes in the mean through a larger data set. While looking deeper into the numbers, it is evident that the SKF interrater reliability and comparison to BIA may vary based on unknown variables. There is insufficient evidence to equate the variances to a single variable or set of variables.

The firefighters' perceptions of the SKF provide additional insight into this debate. The firefighters were split on if they approved of this method and most preferred it to the BMI chart. They felt that the SKF could yield accurate results, dependent on the rater. Although the interrater reliability is not statistically significant, 86% of the firefighters felt that the raters used different pinch techniques or locations. A neutral rating on the five-point Likert scale echoed the Firefighter's perception of interrater reliability. Combining the qualitative and quantitative data provides a mixed view of the SKF. Many felt that there were human-based discrepancies that should be considered. The perceptions of accuracy were underpinned by the mean of the test providing relatively accurate results. The final component of this study is a review of the BIA test.

The BIA test provides information to firefighters that can aid in nutrition, injury monitoring, wellbeing, and body composition. Singh et al. (2018) suggested that the BIA offers athletes benefits not available with the BMI chart or SKF. The BIA is a non-invasive, touch-free, accurate evaluatory tool (Achamrah et al., 2018). Additionally, the BIA removes several variables, such as interrater reliability, reducing time, and non-invasive (Singh et al., 2018). Studies using the BIA have shown reproducible results with less than a 1% variance in readings, compared to a plus or minus 3% with SKF (Achamrah et al., 2018). Singh et al.'s (2018) findings were supported in the qualitative component of the study. When surveyed, the 14 firefighters found that the BIA offered a comprehensive overview of their body composition, resting metabolic rate, body fat analysis, body muscle analysis, and segmented composition analysis. Additionally, the survey results suggested that the firefighters appreciated removing the human element of SKF. The removal of the human component included interrater reliability, discomfort from the pinch test, and the discomfort of being in undergarments in front of the evaluators.

This researcher's analysis of the findings is that the firefighters in this study felt that a comprehensive understanding of their body composition was necessary to maintain the required health standards. The BMI chart, the SKF, and BIA all have varying histories within the fire service. As information and data become commonplace within the fire service, it is prudent for fire service leaders to consider that as technology advances, so should how it is used. There is a saying in the fire service: "firefighters hate two things; the way things are and change." This study suggested a separation from this aphorism, as the firefighters studied the desire to utilize updated technology and accept the change. The divergence from a norm and acceptance of difference shows a potential shift in the culture driving the implications for LAFD.

The implications of LAFD are complex. The current standard that LAFD follows includes policy and procedure. This study supports the need for LAFD and LANL to expand to a larger population, improving validity. The current policy and practice are that LAFD combat firefighters complete their microfit evaluations to include the SKF. The Medical Director approves this testing modality with oversight of the program, the Fire Chief, and the Labor team. Research implications indicate that LAFD, the Wellness Center, and LANL occupational medicine should consider revising policy and procedure to accommodate the use of updated technology. Updating the policies and practices will involve meeting all the stakeholders' requirements while keeping the firefighter's needs as the primary goal. The benefits of including the BIA test into the fitness policy and procedures are related to this study's findings. First, the BIA is accurate, consistent and removes the potential errors associated with the human element. Second, the SKF and BMI chart provides inconsistent data and fails to meet today's firefighters' perceived needs. It is prudent to consider that this study had a small sample size that may not accurately represent the entire population of firefighters within LAFD or the greater population of the fire service. Considering the lack of sample size leads to this study's recommendations.

Recommendations

Within the fire service, significant attention has been focused on managing chronic health conditions, specifically those related to the line of duty deaths. Heart attacks, diabetes, and stroke remain prominent disease processes with this focus. The fire service has suggested that ongoing health evaluations to include fitness exams be a component of a firefighter's annual requirements. Yet, it is widely acknowledged that chronic health conditions continue to be leading causes of death and disability. This study explores the potential benefits of expanding current fitness evaluations to include evolving technology such as BIA. The recommendations of this study will further explore the purpose of this study; to provide insight into the various body composition measurement techniques. The three-fold recommendation; the first will concentrate on the Los Alamos Fire Department, the second concentrate on a comparative analysis of populations, and the last will focus on the nation's fire service.

Recommendation 1.

This recommendation is that LAFD continues this study, expanding it to include the entire department. The department should work with occupational medicine to incorporate the BIA into the yearly physical fitness evaluation. This change would then increase participants to over 100, improving accuracy, consistency, and perceptions.

Recommendation 2.

Complete recommendation one, then complete a comparative analysis of LAFD firefighters to the general population of LANL. This will better describe the distribution of unhealthy firefighters to the general population. This information will further illuminate the limited nature of the BMI chart while concurrently assuring that the most appropriate body composition assessment is recommended for future use in the firefighter population.

Recommendation 3.

The final recommendation is to report the LAFD population findings to national firefighter trade magazines. Writing the results to national trade magazines may aid other departments in effecting change within their populations.

LAFD and the nation's fire service must continue to evolve, adapt, and overcome the problem of meeting the evolving demands of fire ground operations. It is not acceptable for firefighters to be considered out of shape, obese, or worse. Similar to many things in the world, accuracy matters, and data should drive change. This study shows that LAFD firefighters are prime for change, accept data, and know about the risk associated with excess body fat. This critical juncture is where firefighters receive change, and data is supportive of the change that LAFD should act.

References

Achamrah, N., Colange, G., Delay, J., Rimbert, A., Folope, V., Petit, A., Grigioni, S., Déchelotte, P., & Coëffier, M. (2018). Comparison of body composition assessment by DXA and BIA according to the body mass index: A retrospective study on 3655 measures. *PLoS One*, *13*(7), e0200465. https://doi.org/10.1371/journal.pone.0200465

Adair, T., & Lopez, A. D. (2020). The role of overweight and obesity in adverse cardiovascular disease mortality trends: an analysis of multiple cause of death data from Australia and the USA. *BMC medicine*, *18*(1), 1-11.

Albert, C. M., Mittleman, M. A., Chae, C. U., Lee, I.-M., Hennekens, C. H., & Manson, J. E. (2000). Triggering of sudden death from cardiac causes by vigorous exertion. *New England Journal of Medicine*, *343*(19), 1355-1361.

Albert, D. (2009). *An investigation into the prevalence and risk factors of occupational musculoskeletal injuries in firefighters in the Durban Metropolitan Fire Department*

Association, N. F. P. (2000). NFPA 1583 Standard on health-related fitness programs for fire fighters. *National Fire Protection Association, Quincy, MA*.

Association, N. F. P. (2007). Standard on Comprehensive Occupational Medical Programs for Fire Departments.

Bilsborough, J. C., Greenway, K., Opar, D., Livingstone, S., Cordy, J., & Coutts, A. J. (2014). The accuracy and precision of DXA for assessing body composition in team sport athletes. *Journal of sports sciences*, *32*(19), 1821-1828.

Bode, E. D., Mathias, K. C., Stewart, D. F., Moffatt, S. M., Jack, K., & Smith, D. L. (2021). Cardiovascular Disease Risk Factors by BMI and Age in United States Firefighters. *Obesity*.

Campa, F., Toselli, S., Mazzilli, M., Gobbo, L. A., & Coratella, G. (2021). Assessment of body composition in athletes: A narrative review of available methods with special reference to quantitative and qualitative bioimpedance analysis. *Nutrients*, *13*(5), 1620.

Cornell, D., Noel, S. E., Zhang, X., & Ebersole, K. T. (2021). Influence of Body Composition on Post-Exercise Parasympathetic Reactivation of Firefighter Recruits. *International Journal of Environmental Research and Public Health*, *18*(1), 339. https://doi.org/10.3390/ijerph18010339

Cornell, D. G., Stacy L, & Ebersole, K. T. (2021). Functional Movement Quality of Firefighter Recruits: Longitudinal Changes from the Academy to Active-Duty Status. *International Journal of Environmental Research and Public Health*, *18*(7), 3656.

Kamal, S. A. (2006). Manual for obtaining anthropometric measurements. *The-NGDS-Pilot Project-e-Publication, University of Karachi, Karachi, Pakistan, version*, *9*(11).

Köroglu, Y. (2021). The Effects of Respiratory Muscle Training on Aerobic, Anaerobic and Respiration Parameters. *African Educational Research Journal*, *9*(2), 405-417.

LAFD, L. A. F. D. (2020). *Standard of Cover*. https://www.losalamosnm.us/UserFiles/Servers/Server_6435726/File/Government/Departments/LAFD-Fire/Standards%20of%20Cover/Los%20Alamos%20CRASOC%202019%20Final.pdf

Leffer, M., & Grizzell, T. (2010). Implementation of a physician-organized wellness regime (POWR) enforcing the 2007 NFPA standard 1582: injury rate reduction and associated cost savings. *Journal of occupational and environmental medicine*, *52*(3), 336-339.

Loflin, M. E. (1989). NFPA 1500 standard for a fire department OSH program. *Professional Safety*, *34*(4), 15.

Marciniak, R. A., Ebersole, K. T., & Cornell, D. J. (2021). Relationships between balance and physical fitness variables in firefighter recruits. *Work*(Preprint), 1-10.

Mathias, K. C., Bode, E. D., Stewart, D. F., & Smith, D. L. (2020). Changes in firefighter weight and cardiovascular disease risk factors over five years. *Medicine and science in sports and exercise*, *52*(11), 2476.

Mayer, J. M., Nuzzo, J. L., Chen, R., Quillen, W. S., Verna, J. L., Miro, R., & Dagenais, S. (2012). The impact of obesity on back and core muscular endurance in firefighters. *Journal of Obesity*, *2012*.

Merrigan, J. J., Burke, A. A., Fyock-Martin, M. B., & Martin, J. R. (2020). What factors predict upper body push to pull ratios in professional firefighters? *International journal of exercise science*, *13*(4), 1605.

Müller, W., Horn, M., Fürhapter-Rieger, A., Kainz, P., Kröpfl, J. M., Maughan, R. J., & Ahammer, H. (2013). Body composition in sport: a comparison of a novel ultrasound imaging technique to measure subcutaneous fat tissue compared with skinfold measurement. *Br J Sports Med*, *47*(16), 1028-1035. https://doi.org/10.1136/bjsports-2013-092232

Naylor, T. (2021). *Comparing body composition methods for Bowling Green State University's AirFroce ROTC program* [Masters, BOWLING GREEN STATE UNIVERSITY].

Nogueira, E. N. C., PORTO, L. G. G., NOGUEIRA, R. M., MARTINS, W. R., FONSECA, R. M., & LUNARDI, C. C. (2015). BODY COMPOSITION IS STRONGLY ASSOCIATED WITH CARDIORESPIRATORY FITNESS IN A LARGE BRAZILIAN MILITARY FIREFIGHTER COHORT: THE BRAZILIAN FIREFIGHTERS STUDY. *Journal of Strength and Conditioning Research*, *30*(1), 33-38.

Norris, C. W. (2021). *Firefighter Fatalities and Compliance with the National Fire Protection Association (NFPA) 1451 Standard* Walden University].

NWCG. (2020). NWCG Handbook 2.

Ode, J., Knous, J., Schlaff, R., Hemenway, J., Peterson, J., & Lowry, J. (2014). Accuracy of body mass index in volunteer firefighters. *Occupational Medicine*, *64*(3), 193-197. https://doi.org/10.1093/occmed/kqt143

Pelozato de Oliveira, D. I., de Souza Teixeira, B. M., Gomes de Macedo, O., Dos Santos, V., Grossi Porto, L. G., & Rodrigues Martins, W. (2021). Prevalence of Chronic Low Back Pain in Brazilian Military Firefighters. *International Journal of Occupational Safety and Ergonomics*(just-accepted), 1-22.

Poston, W. S. C., 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 & Environmental Medicine*, *53*(3), 266-273. https://doi.org/10.1097/jom.0b013e31820af362

Risavi, B. L., & Staszko, J. (2016). Prevalence of risk factors for coronary artery disease in Pennsylvania (USA) firefighters. *Prehospital and disaster medicine*, *31*(1), 102-107.

Saari, A. I., Renz, G., Davis, P., & Abel, M. G. (2020). The Influence of Age on Firefighter Combat Challenge Performance and Exercise Training Habits. *The Journal of Strength & Conditioning Research*, *34*(9), 2500-2506.

Sergi, T., Bode, K., Hildebrand, D., Dawes, J., & Joyce, J. (2021). Relationship Between Body Mass Index and Health and Occupational Performance Among Law Enforcement Officers, Firefighters, and Military Personnel: A Systematic Review. *Current Developments in Nutrition*, *5*(Supplement_2), 1248-1248.

Singh, G., Anand, S., Lall, B., Srivastava, A., & Singh, V. (2018, 2018). A technical review of various bioelectric impedance methods for health monitoring.

Smee, D. J., Walker, A., Rattray, B., Cooke, J. A., Serpell, B. G., & Pumpa, K. L. (2019). Comparison of Body Composition Assessment Methods in Professional Urban Firefighters. *International Journal of Sport Nutrition and Exercise Metabolism*, *29*(3), 282-288. https://doi.org/10.1123/ijsnem.2018-0040

Sokoloski, M. L., Rigby, B. R., Bachik, C. R., Gordon, R. A., Rowland, I. F., Zumbro, E. L., & Duplanty, A. A. (2020). Changes in Health and Physical Fitness Parameters After Six Months of Group Exercise Training in Firefighters. *Sports*, *8*(11), 143. https://doi.org/10.3390/sports8110143

Storer, T. W., Dolezal, B. A., Abrazado, M. L., Smith, D. L., Batalin, M. A., Tseng, C. H., & Cooper, C. B. (2014). Firefighter health and fitness assessment: a call to action. *J Strength Cond Res*, *28*(3), 661-671. https://doi.org/10.1519/JSC.0b013e31829b54da

Winter, F. D., Seals, N., Martin, J., & Russell, B. (2010). Implementation of the First Wellness-Fitness Evaluation for the Dallas Fire-Rescue Department. *Baylor University Medical Center Proceedings*, *23*(3), 235-238. https://doi.org/10.1080/08998280.2010.11928625

Appendix A

BMI chart

- BMI under 18.5% is underweight.
- BMI of 18.5-24.9 is healthy.
- BMI 25-29.9 is slightly overweight.
- BMI 30+ is obese.
    - Class 1 obese: BMI is 30–34.9.
    - Class 2 obese: BMI is 35–39.9.
    - Class 3 severely obese 40 and above.

HEIGHT \ WEIGHT	95	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235	240	245
5'0"	19	20	21	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
5'1"	18	19	20	21	22	23	24	25	26	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	43	44	45	46
5'2"	17	18	19	20	21	22	23	24	25	26	27	27	28	29	30	31	32	33	34	35	36	37	37	38	39	40	41	42	43	44	45
5'3"	17	18	19	19	20	21	22	23	24	25	26	27	27	28	29	30	31	32	33	34	35	35	36	37	38	39	40	41	42	43	43
5'4"	16	17	18	19	20	21	21	22	23	24	25	26	27	27	28	29	30	31	32	33	33	34	35	36	37	38	39	39	40	41	42
5'5"	16	17	17	18	19	20	21	22	22	23	24	25	26	27	27	28	29	30	31	32	32	33	34	35	36	37	37	38	39	40	41
5'6"	15	16	17	18	19	19	20	21	22	23	23	24	25	26	27	27	28	29	30	31	31	32	33	34	35	36	36	37	38	39	40
5'7"	15	16	16	17	18	19	20	20	21	22	23	23	24	25	26	27	27	28	29	30	31	31	32	33	34	34	35	36	37	38	38
5'8"	14	15	16	17	17	18	19	20	21	21	22	23	24	24	25	26	27	27	28	29	30	30	31	32	33	33	34	35	36	36	37
5'9"	14	15	16	16	17	18	18	19	20	21	21	22	23	24	24	25	26	27	27	28	29	30	30	31	32	32	33	34	35	35	36
5'10"	14	14	15	16	16	17	18	19	19	20	21	22	22	23	24	24	25	26	27	27	28	29	29	30	31	32	32	33	34	34	35
5'11"	13	14	15	15	16	17	17	18	19	20	20	21	22	22	23	24	24	25	26	26	27	28	29	29	30	31	31	32	33	33	34
6'0"	13	14	14	15	16	16	17	18	18	19	20	20	21	22	22	23	24	24	25	26	26	27	28	28	29	30	31	31	32	33	33
6'1"	13	13	14	15	15	16	16	17	18	18	19	20	20	21	22	22	23	24	24	25	26	26	27	28	28	29	30	30	31	32	32
6'2"	12	13	13	14	15	15	16	17	17	18	19	19	20	21	21	22	22	23	24	24	25	26	26	27	28	28	29	30	30	31	31
6'3"	12	12	13	14	14	15	16	16	17	17	18	19	19	20	21	21	22	22	23	24	24	25	26	26	27	27	28	29	29	30	31
6'4"	12	12	13	13	14	15	15	16	16	17	18	18	19	19	20	21	21	22	23	23	24	24	25	26	26	27	27	28	29	29	30

Under healthy weight: BMI <18.5
Healthy weight: BMI 18.5–24.9
Overweight: BMI 25–29.9
Obese I: BMI 30-34.9
Obese II: BMI 35-39.9
Obese III: BMI ≥ 40

WEIGHT / HEIGHT	250	255	260	265	270	275	280	285	290	295	300	305	310	315	320	325	330	335	340	345	350	355	360	365	370	375	380	385	390	395	400
5'0"	49	50	51	52	53	54	55	56	57	58	59	60	61	62	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
5'1"	47	48	49	50	51	52	53	54	55	56	57	58	59	60	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
5'2"	46	47	48	48	49	50	51	52	53	54	55	56	57	58	59	59	60	61	62	63	64	65	66	67	68	69	69	70	71	72	73
5'3"	44	45	46	47	48	49	50	50	51	52	53	54	55	56	57	58	58	59	60	61	62	63	64	65	66	66	67	68	69	70	71
5'4"	43	44	45	45	46	47	48	49	50	51	51	52	53	54	55	56	57	57	58	59	60	61	62	63	64	64	65	66	67	68	69
5'5"	42	42	43	44	45	46	47	47	48	49	50	51	52	52	53	54	55	56	57	57	58	59	60	61	62	62	63	64	65	66	67
5'6"	40	41	42	43	44	44	45	46	47	48	48	49	50	51	52	52	53	54	55	56	56	57	58	59	60	61	61	62	63	64	65
5'7"	39	40	41	42	42	43	44	45	45	46	47	48	49	49	50	51	52	52	53	54	55	56	56	57	58	59	60	60	61	62	63
5'8"	38	39	40	40	41	42	43	43	44	45	46	46	47	48	49	49	50	51	52	52	53	54	55	55	56	57	58	59	59	60	61
5'9"	37	38	38	39	40	41	41	42	43	44	44	45	46	47	47	48	49	49	50	51	52	52	53	54	55	55	56	57	58	58	59
5'10"	36	37	37	38	39	39	40	41	42	42	43	44	44	45	46	47	47	48	49	49	50	51	52	52	53	54	55	55	56	57	57
5'11"	35	36	36	37	38	38	39	40	40	41	42	43	43	44	45	45	46	47	47	48	49	50	50	51	52	52	53	54	54	55	56
6'0"	34	35	35	36	37	37	38	39	39	40	41	41	42	43	43	44	45	45	46	47	47	48	49	49	50	51	52	52	53	54	54
6'1"	33	34	34	35	36	36	37	38	38	39	40	40	41	42	42	43	44	44	45	46	46	47	47	48	49	49	50	51	51	52	53
6'2"	32	33	33	34	35	35	36	37	37	38	39	39	40	40	41	42	42	43	44	44	45	46	46	47	48	48	49	49	50	51	51
6'3"	31	32	32	33	34	34	35	36	36	37	37	38	39	39	40	41	41	42	42	43	44	44	45	46	46	47	47	48	49	49	50
6'4"	30	31	32	32	33	33	34	35	35	36	37	37	38	38	39	40	40	41	41	42	43	43	44	44	45	46	46	47	47	48	49

Obese I: BMI 30-34.9 | Obese II: BMI 35-39.9 | Obese III: BMI ≥ 40

Appendix B

NFPA Standard 1001 Standard for Firefighter Professional Qualifications, Essential Job Tasks, and Job Performance Requirements Descriptions:
(1) While wearing personal protective ensembles and self-contained breathing apparatus (SCBA), Performing firefighting tasks (e.g., hotline operations, extensive crawling, lifting and carrying heavy objects, ventilating roofs or walls using power or hand tools, forcible entry), rescue operations, and other emergency response actions under stressful conditions while wearing personal protective ensembles and self-contained breathing apparatus (SCBA), including working in extremely hot or cold environments for prolonged periods.
(2) Wearing an SCBA, which includes a demand valve–type positive-pressure facepiece or HEPA filter mask, requires the ability to tolerate increased respiratory workloads.
(3) Exposure to toxic fumes, irritants, particulates, biological (infectious) and non-biological hazards, and heated gases, despite the use of personal protective ensembles and SCBA.
(4) Depending on the local jurisdiction, climbing six or more flights of stairs while wearing a fire protective ensemble weighing at least 50 lbs. (22.6 kg) or more and carrying equipment/tools weighing an additional 20 to 40 lbs. (9 to 18 kg).
(5) Wearing a fire protective ensemble that is encapsulated and insulated will result in a significant fluid loss that frequently progresses to clinical dehydration and can elevate the core temperature to levels exceeding 102.2°F (39°C).
(6) While wearing personal protective ensembles and SCBA, searching, finding, and rescue-dragging or carrying victims ranging from newborns up to adults weighing over 200 lbs. (90 kg) to safety despite hazardous conditions and low visibility.
(7) While wearing personal protective ensembles and SCBA, advancing water-filled hose lines up to 2 ½ in. (65 mm) in diameter from fire apparatus to occupancy [approximately 150 ft. (50 m)], which can involve negotiating multiple flights of stairs, ladders, and other obstacles.
(8) While wearing personal protective ensembles and SCBA, climbing ladders, operating from heights, walking or crawling in the dark along narrow and uneven surfaces, and operating in proximity to electrical power lines and other hazards.
(9) Unpredictable emergency requirements for prolonged periods of extreme physical exertion without the benefit of warmup, scheduled rest periods, meals, access to medication(s), or hydration.
(10) Operating fire apparatus or other vehicles with emergency lights and sirens in an emergency mode.
(11) Critical, time-sensitive, complex problem solving during physical exertion in stressful, hazardous environments, including hot, dark, tightly enclosed spaces, further aggravated by fatigue, flashing lights, sirens, and other distractions.
(12) Ability to communicate (give and comprehend verbal orders) while wearing personal protective ensembles and SCBA under conditions of high background noise, poor visibility, and to drench from hose lines and fixed protection systems (sprinklers).
(13) Functioning as an integral team component, where sudden incapacitation of a member can result in mission failure or risk of injury or death to civilians or other team members.
(14) Working in shifts, including during nighttime, that can extend beyond 12 hours.

Appendix C

Keyword searches:

FIREFIGHTER BODY FAT

FIREFIGHTER SKF

FIREFIGHTER BIOELECTRIC IMPEDANCE

FIREFIGHTER BMI CHART

TACTICAL ATHLETE BODY FAT

COMPARISON OF BODY FAT MEASUREMENT

BMI VS. SKIN FOLD

SKINFOLD VS. BIA

ATHLETE BODY FAT MEASUREMENT

BODY FAT MEASUREMENT TOOLS

NFPA BODY FAT

OBESITY DISEASES

Appendix D

Testing Schedule

1. Schedule participants with LANL Wellness.
2. Send participants pre-test instructions.
3. Have participants bring athletic shorts.
4. A participant arrives on the day of evaluation.
5. The Participant will go into Room 104 for the informed consent process.
    - They will sign the informed consent
    - They will sign a form to indicate that they followed pre-test guidelines.
    - Last, they will fill out a brief physical activity questionnaire.
6. The subject will enter the break room for testing.
    - They will do InBody and then SKF or vice versa.
        - The researchers will randomize + counterbalance the order of testing.
    - Before the InBody, a researcher will briefly explain the procedure to the subject and will allow them to self-administer the test.
        - Ensure that the subject is wearing minimal clothing (i.e., boxers).
    - Before the SKF, a researcher will briefly explain the procedure before performing the test.
        - Bodyweight will be measured on the Microfit scale.
        - SKF will be measured twice at the chest, ab, and thigh in a cyclical manner.
        - The tester order (LANL 1 or LANL 2) will be randomized + counterbalanced.
        - LANL 1 or LANL 2 will be out of the room while the other is testing to avoid influencing others (e.g., pinching in the same spot).
7. Evaluation is complete. Participant gets dressed.
8. Review of data with LANL 1. 15-20 minutes.
9. Participant completes the survey.

Informed Consent to Participate in a Research Study

Los Alamos Fire Department
Los Alamos National Laboratory Occupational Health
National Fire Academy Applied Research Project
Firefighter Body Fat Measurement
Benjamin Stone
505-500-0008

PURPOSE AND BACKGROUND Benjamin Stone, the EFO Candidate, is researching the accuracy of current body fat measurement practices. The purpose of your participation in this research is to help the researcher identify the most accurate body fat measurement method. You were selected as a possible participant in this study because you are a current LAFD employee.
PROCEDURES If you agree to participate in this research study, the following will occur:

1. The LANL Wellness staff will collect your height and weight.
2. The LANL Wellness will conduct two (2) skinfold caliper tests. The tests will consist of three locations (chest, abdomen, thigh). Two raters will conduct the two tests.
3. The LANL wellness staff will conduct a bioelectric impedance test.
4. Upon completion of the testing, you will receive a short survey.
5. The total time will be less than 30 minutes.

Risks: The risks for this research are the feeling of being uncomfortable, embarrassed and the potential of pain during the skin fold caliper test.
CONFIDENTIALITY The records from this study will be kept as confidential as possible. No individual identities will be used in any reports or publications resulting from the study. All measurements and questionnaire results will be given codes and stored separately from participants' names or other direct identification. Research information will be kept in locked files at all times. Only research personnel will have access to the files, and only those with an essential need to see names or other identifying information will have access to that particular file.
BENEFITS OF PARTICIPATION There will be no direct benefit to you from participating in this research study.
VOLUNTARY PARTICIPATION Your decision to participate in this study is voluntary and will not affect your relationship with the Los Alamos Fire Department or LANL Occupational Wellness. If you choose to participate in this study, you can withdraw your consent and discontinue participation at any time without prejudice.
QUESTIONS If you have any questions about the study, please contact Benjamin Stone by calling 505-500-0008.
CONSENT YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE IN A RESEARCH STUDY. YOUR SIGNATURE BELOW INDICATES THAT YOU HAVE DECIDED TO PARTICIPATE IN THE STUDY AFTER READING ALL OF THE INFORMATION ABOVE, AND YOU UNDERSTAND THE INFORMATION IN THIS FORM AND HAVE HAD ANY QUESTIONS ANSWERED.
If you would like a copy of this form, please inform Wellness Staff or Benjamin Stone.
Signature ________________________________ Date ________________

Research Participant
Signature ________________________________ Date ________________
Researcher

Fitness PAR-Q

The information gathered in this questionnaire will describe the population being studied.

The following questions will ask you about the time you spend doing physical activity. Please answer these questions as accurately as possible.

Question	Response
How many days do you do cardio training activities in a typical week? I.e., Running, biking, stairs, swimming, yoga, sports, etc.	Number of days_____
How many days do you do strength training activities in a typical week? I.e., weight lifting, tactical fitness, bodyweight training, etc.	Number of days_____
How much time do you spend doing fitness activities on a typical day?	Number of minutes _____
During your last micro-fit, what was your MET score?	MET Score _____
Do you typically work out (cardio or strength) when not on duty for the fire department?	Yes_____No_____

MET is the ratio of a person's working metabolic rate relative to the resting metabolic rate. One MET is defined as the energy cost of sitting quietly and is equivalent to a caloric consumption of 1 kcal/kg/hour. It is estimated that, compared to sitting quietly, a person's caloric consumption is four times as high when being moderately active and eight times as high when being vigorously active.

Preparing for Your Assessment

Benjamin Stone, the EFO Candidate, is researching the accuracy of current body fat measurement practices. The purpose of your participation in this research is to help the researcher identify the most accurate body fat measurement method. You will participate in a skin fold analysis, BMI chart review, and a bioelectric impedance (InBody) scan.

For the most accurate results, follow the short steps below. Test results may be skewed if the following guidelines cannot be met.

Contraindications to testing: Pregnancy or pacemaker.
Be prepared for a 30–45-minute test.

Before testing, DO:
Dress in exercise clothing for the test.
Hydrate well the day before the test.
Use the bathroom before your test.
Caffeinate as you usually would.

Before testing, AVOID:
Eating/exercising at least 3 hours before the test.
Consuming alcohol for at least 8 hours before the test.
Use lotion/ointment on your hands and feet the morning of the test.

Were you able to follow these instructions?
Yes____ NO_____
Signature ________________________________ Date ________________
Research Participant
Signature ________________________________ Date ________________
Researcher

Consultation Script

1. Discuss their BMI results
    a. Identify their classification (e.g., normal, overweight, obese, etc.)
    b. Mention that it only includes height and weight and maybe limited because it cannot identify what body weight is comprised of (i.e., fat vs. lean mass)
2. Discuss their SKF BF% results
    a. Identify where they rank according to established norms (e.g., healthy or at risk)
    b. Mention that SKF uses subcutaneous fat thickness to estimate body density. Body fat percentage is then derived from body density.
3. Discuss their InBody results
    a. Identify where they rank according to established norms (e.g., healthy or at risk)
    b. Mention that InBody measures fat mass and muscle mass directly and can measure visceral mass in addition to subcutaneous fat.
4. Do not analyze the segmental data.
    a. Mention that InBody can compare R to L and Upper to Lower.
5. Thank participants for their participation in the study.
    a. Offer additional consultation time after study completion.

Assessment Data

FIREFIGHTER 1										
AGE										
HEIGHT IN										
WEIGHT LBS										
BMI										
SKIN FOLD	**CHEST**	**CHEST**	**CHEST**	**ABS**	**ABS**	**ABS**	**THIGH**	**THIGH**	**THIGH**	**BF %**
RATER 1										
RATER 2										
BIOIMPEDANCE	**BMI**									
Scan										

FIREFIGHTER 2										
AGE										
HEIGHT IN										
WEIGHT LBS										
BMI										
SKIN FOLD	**CHEST**	**CHEST**	**CHEST**	**ABS**	**ABS**	**ABS**	**THIGH**	**THIGH**	**THIGH**	**BF %**
RATER 1										
RATER 2										
BIOIMPEDANCE	**BMI**									
Scan										

Appendix E

Questionnaire.

1. What is your opinion of the body mass index (BMI) Chart for assessing your body fat percentage?
2. What is your opinion of the accuracy of the BMI chart?
    a. Very bad, bad, neutral, good, very good.
3. What is your opinion of the skinfold assessment test for assessing your body fat percentages?
4. Did you feel that there was a difference in measurement techniques between the examiners?
    a. If yes, please describe the differences.
5. What is your opinion of the accuracy of the skinfold assessment?
    a. Very bad, bad, neutral, good, very good.
6. What is your opinion of the bio-electric impedance test for assessing your body fat percentages?
7. What is your opinion of the accuracy of the bio-electric impedance test?
    a. Very bad, bad, neutral, good, very good.
8. What test did you prefer for testing your body fat percentage?
9. At any point in the test, did you feel uncomfortable?
    a. If yes, please describe the experience.
10. Describe your perceptions on how the accuracy of the body fat measurement affects your overall fitness.
11. Given your experience with the testing conducted today, which test would you like to see LAFD use in the future?