UNDERSTANDING AND ADDRESSING HEALTH DISPARITIES AMONGST EASTERN FIREFIGHTERS USING CARDIOMETABOLIC RISK SCORES

by

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ABSTRACT

Cardiac events have remained the leading cause of on-duty deaths among US firefighters for the past five decades. PURPOSE: The purpose of this study was to assess the prevalence of cardiometabolic risk (CMR) and examine racial differences between White non-Hispanic and minority firefighters in Eastern North Carolina, specifically the Pitt County area. An adaptation of a predictive CMR model equation was developed to form a composite risk score using data accessible from local firefighters' annual fitness assessment conducted through East Carolina University's Cardiovascular Health Assessment Program. By utilizing comprehensive annual fitness assessments, this study aims to address the existing gap in regional data. While research on firefighter health is growing, there is a clear need for more studies focused on the specific population of firefighters in Eastern North Carolina, considering the unique environmental challenges they face. Understanding the impact of cardiometabolic health is crucial for developing effective interventions and improving their overall wellbeing. Eastern North Carolina minority firefighters are expected to have a higher relative risk for cardiovascular disease compared to their White non-Hispanic counterparts. To understand the relationship between cardiometabolic risk (CMR) and sudden cardiac death (SCD), this study examines health disparities faced by firefighters in Eastern North Carolina, with a focus on addressing CMR to better understand the predispositions of SCD. METHODS: 183 career firefighters (38 ± 9 yrs) participated in this study. Group comparisons were made between White non-Hispanic firefighters ($n = 150$) and minority firefighters ($n = 33$). CMR composite scores were calculated for firefighters using established cardiometabolic indicators: diagnosed cardiovascular diseases, hypertension medication use, dyslipidemia medication use, diabetes status, tobacco abuse, android gynoid ratio, and metabolic equivalence. An independent samples t-test was conducted to evaluate group differences. RESULTS: The independent samples t-test showed no statistically significant difference in CMR scores between Minority and White non-Hispanic firefighters, t (1.423), $p = 0.138$, with a negligible effect size (Cohen's $d = 2.21$). White non-Hispanic firefighters had a slightly higher mean CMR score ($M = 4.21$, $SD = 2.24$) compared to Minority firefighters ($M = 3.63$ $SD = 2.07$). Levene's test confirmed equal variances across groups. CONCLUSION: Contrary to initial predictions, no significant racial differences in CMR were observed among firefighters for the sample population in Eastern North Carolina. Rather, individual health indicators—particularly lipid profiles—emerged as primary contributors to CMR.

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List of Abbreviations

Code of Federal Regulations (CRF)

Coronary Heart Disease (CHD)

Cardiovascular Disease (CVD)

Cardiometabolic Disease (CMD)

Cardiometabolic risk (CMR)

Diastolic Blood Pressure (DBP)

Dual-energy x-ray absorptiometry (DEXA)

East Carolina University (ECU)

International Association of Fire Fighters (IAFF)

International Association of Fire Chiefs (IAFC)

low-density lipoproteins (LDL)

Major adverse cardiac event (MACE)

North Carolina Department of Labor (NCDOL).

National Fire Protection Association (NFPA)

Occupational Safety and Health Administration (OSHA)

Physical activity (PA)

Physical Activity Guidelines (PAG)

Systolic Blood Pressure (SBP)

Chapter I: Introduction

Cardiovascular disease (CVD) is the leading cause of on-duty deaths of firefighters, with 35% of fatalities being linked to SCD (NFPA 2023). Research and literature validated the correlations between metabolic syndrome, cardiovascular disease, obesity, and a sedentary lifestyle among firefighters (Bode et al. 2021, 2021; Ras et al., 2022). The job title portrays the harsh environment and hazardous exposures they encounter on a regular basis. This occupation extends further into strenuous physical and endurance training needed to de-escalate emergencies of varying circumstances (Bhojani et al., 2018; Dobson et al., 2013). Many northern and western states have conducted most of the literature, research, and interventions performed on firefighters, which have left eastern North Carolina as an outlier, creating a gap of knowledge for a region known for higher morbidity rates and is often referred to as the “Stroke Belt.” Added stress, demand, and lack of routine or coverage have many departments not prioritizing and enforcing annual assessments, fitness standards, and health. Early detection, through testing and assessment, can lead to treatment that can be lifesaving. Annual risk assessment consisting of a lipid panel, anthropometric measures, and stress testing with physician review will be performed on local fire departments through the Cardiovascular Health Assessment Program offered to the community by East Carolina University’s (ECU) Human Performance Lab (HPL). The data collected will be analyzed and compared to the NFPA Standard 1952 Category B criteria for Metabolic syndrome to distinguish the correlation associated with health risk/predisposition to incident and injury through the use of CMR scoring. CMR scores are as high or higher than those of neighboring regions. Ongoing efforts to adequately address these issues are needed to see meaningful reductions in health disparities among eastern firefighters.

Chapter II: Review of Literature

This review of literature will examine the regulation that governs firefighters' health standard, examine the unique characteristics of the job and the cardiovascular demands of firefighter profession, and evaluate modifiable and non-modifiable risk factors associated with sudden cardiac death. It will further explore the relevance and adequacy of current fitness standards recommended by the National Fire Protection Association and investigate the use of cardiometabolic risk scores to understand and address health disparities, particularly amongst minority firefighters in Eastern North Carolina. Through this comprehensive analysis, the study aims to identify gaps in current practice and highlight opportunities to enhance firefighter health to recognize key risk factors that influence their well-being.

Regulation

Fire stations in rural areas of Eastern North Carolina are considered public sector organizations that operate within a municipality, county, state, nation, and district. Federal regulations do not have authority over State, municipal, or volunteer fire departments, which are governed by state and local governments responsible for their own occupational safety and health programs, which are approved by the North Carolina Department of Labor (NCDOL). The Occupational Safety and Health Division has adopted the United States Code of Federal Regulations (CRF) for or related to fire brigades in North Carolina. Still, since the fire stations are state-regulated, the CFRs are not all-inclusive. NCDOL adheres to selected CRFs and enforces its own Administration Codes, which contain state-specific labor laws, statutes, and regulations issued by the NCDOL (Occupational Safety and Health Administration, 2024). The standards that are inspected are as follows: General Industry (hazardous waste operations and emergency response, personal protective equipment general requirements, respiratory protection, portable fire extinguishers, fire brigades, access to employee exposure and medical records, hazard communication), Construction (hazardous waste operations and emergency response, fire protection), State specific (hazardous materials), North Carolina General Statue (N.C. General Statues 95-173 through 95-218 – identification of toxic or hazardous substances), and recordkeeping (recording and reporting). According to the standards outlined above, the fire service has traditionally emphasized the maintenance of personal protective equipment over the well-being of the personnel who rely on those tools to provide life-saving services. Firefighters face arduous tasks that demand significant physical and mental exertion, which can have a detrimental impact on their overall well-being and ability to perform effectively. It is important to acknowledge the potential consequences of these challenges and take steps to safeguard the long-term health and the efficacy of emergency response services by shifting the focus to prioritize the health and safety of emergency responders. In 2020, the NFPA conducted a Service Needs Assessment Survey involving 2,969 fire departments with an 11% response rate. The survey revealed that over half of the participating departments had unmet needs for structural fire training, and 21% of them did not conduct annual testing or inspection of their PPE. While 77% of the departments engaged in fire prevention preparedness and mitigation training, only 37% were responsible for code enforcement (NFPA, 2021).

The standards requirements of 29 CFR § 1910.156(b)(2) - (c)(3) specify the physical capabilities, training, and education expectations for fire brigade employees. According to these standards, the Chief ensures firefighters receive appropriate training and education quarterly, tailored to their roles in the fire brigade. Additionally, the Chief must ensure that firefighters have the physical ability to perform during fire brigade emergencies or training and that firefighters with known heart disease, epilepsy, or emphysema provide a physician's certificate of fitness to participate in such activities (United States Department of Labor, 2024). OSHA and NCDOL ensure that municipal fire station employees' health and safety by enforcing requirements set by statutes, standards, and regulations. The regulations undergo periodic program inspections, typically scheduled every 2-3 years. Filed complaints, reported accidents, or fatalities may also prompt inspections. These mandates influence funding obtained to maintain and run the fire station. The regulatory framework and cultural norms within fire stations are shaped by the combined influence of the NCDOL, OSHA, and NFPA. The NFPA is an accredited, independent nonprofit organization with published standards and codes supported by research and educational integrity. Through its publications, NFPA offers educational course materials for instructional and training purposes. NFPA serves as a universally acknowledged standard within all fire organizations, providing valuable references and guidance.

The NFPA 1582 standard delineates an occupational medical program intended for implementation within fire departments. Its objective is to mitigate the risk and burden of fire service occupational morbidity and mortality. The standard elaborates further on a wide array of medical conditions, criteria of medical conditions, associated risk factors, special provisions, potential restrictions, and affected job tasks (s) that could be evaluated to optimize the health and safety of personnel. By doing so, it seeks to enhance the health, safety, and efficacy of firefighters, thereby safeguarding the lives and property of the public.

Characteristics of the Job

Firefighters are categorized as blue-collar workers because they engage in manual labor and skilled trades. The job encounters high risks of accidents or exposure to harmful substances, which often lead to higher rates of work-related injuries and illnesses (NCDOL, 2024). Firefighters must make fast and accurate decisions in emergencies, including extinguishing fires and searching for and rescuing victims while wearing heavy and uncomfortable personal protective equipment. Cognitive function and cardiorespiratory fitness are essential to complete their duties. Therefore, firefighters need cognitive function, aerobic capacity, and muscular endurance to perform their tasks safely and successfully. However, while firefighters are on duty, various job-related tasks can negatively affect cognitive function, and if not physically sound, they may encounter life-threatening circumstances/events.

Given the occupational specificity of firefighting and the ongoing necessity for optimal health and fitness, the elevated incidence of cardiovascular disease-related fatalities among firefighters is a matter of concern. Firefighter candidates undergo a demanding recruitment process consisting of a background check, drug screen, psychological evaluation, respiratory clearance, medical examination, human performance physical evaluation, and physical ability assessment test. The candidates also attend a training academy where they learn the basics of the job, which can last up to 25 weeks. Academy training combines course education and physical strength and conditioning to prepare them for the job. Considerable efforts are dedicated to achieving specific fitness and health standards during a rigorous hiring process. For example, all recruits must undergo training to ensure they are "fit for duty" as firefighters. The focus of physical fitness training is on improving cardiorespiratory fitness, strength, endurance, and overall health, which would also improve body composition regarding body mass index, body fat percentage, and waist circumference (Andrews et al., 2019; Bode et al., 2021; Choi et al., 2016; Clark et al., 2002; Ode et al., 2014; Sergi et al., 2023). Research indicates that new firefighters generally improve their physical fitness and health upon completion of training (Andrews et al., 2019; Sokoloski et al., 2020). Enforcing proper safety standards and regulations can reduce the risks of SCD. However, once firefighters begin their duties, these standards and levels of health and fitness often decline due to being overshadowed by other job responsibilities.

Sudden Cardiac Death

In 2022, heart disease claimed the lives of 702,880 individuals, accounting for one in every five deaths or roughly one death every 33 seconds. Among these fatalities, 371,506 were attributed to coronary heart disease. Annually, an estimated 805,000 individuals in the U.S. experience a heart attack, with approximately one in five being silent heart attacks (CDC, 2024).

On-duty SCD is defined in the Hometown Heroes Survivors Benefits Act of 2003, which was decreed by the president and enacted Public Law 108-182. The law presumes that if a public safety officer dies as the direct and proximate result of a heart attack or stroke, that officer shall be presumed to have died as the direct and proximate result of a personal injury sustained in the line of duty — if the firefighter was engaged in nonroutine, stressful or strenuous physical activity while on duty and if the firefighter became ill within 24 hours after engaging in such activity (*PLAW-108publ182.Pdf*, n.d.). In 2023, 89 firefighters died from heart attacks, strokes, aneurysms, or traumatic injuries while on duty or within 24 hours of duty. The year prior, 2022, the fatality count was the second highest by one death since 2013, with 97 on-duty deaths (NFPA).

Evidence indicates that SCD is highly preventable. NFPA 1582 standard has addressed modifiable risk factors associated with SCD. SCD, being the leading cause of death for firefighters, is known among the fire industry. Studies have identified CMR factors as attributable causes of morbidity and mortality in this population.

Modifiable and Non-modifiable Risk Factors

Understanding the risks of heart disease is the first step toward heart health. An individual's risk is influenced by various factors that can be changed through lifestyle choices (modifiable), as well as those that are inherently fixed and unchangeable (non-modifiable). CVD risk factor assessment can be used to provide exercise professionals with more information regarding the overall health and well-being of a person. The identification of risk factors can help identify an individual's need for medical clearance due to comorbidities, which can then be used to develop exercise prescriptions, lifestyle modifications, and education to help reduce CVD. Risk factors are conditions or behaviors that increase the likelihood of developing a disease, and these risk factors may vary from person to person. Preventing heart disease begins with recognizing risk factors and taking steps to reduce them. Non-modifiable risks include age, sex, race, and family history, while modifiable risk factors include physical inactivity, hypertension, dyslipidemia, tobacco abuse, and obesity/overweight. Each risk factor increases the likelihood of developing chronic diseases, such as but not limited to heart disease and type II diabetes. The more risk factors you have, the greater your overall risk (AHA, 2013).

One modifiable cardiovascular risk factor is the use of tobacco. The Framingham study revealed that for every ten cigarettes smoked per day, cardiovascular mortality increased by 18% in men and 31% in women (Mahood et al., et al. 2014). According to the World Health

Organization, 22% of the world's population are tobacco users, with men having higher rates of smoking compared to women. Tobacco abuse is the single greatest preventable cause of disease and premature death in America. One year after tobacco cessation, the risk of CHD decreases by 50%. Within 15 years, the relative risk of dying from CHD for an ex-smoker is matched to that of a lifetime non-smoker. However, those who continue to smoke after a myocardial infarction have a 22% greater risk of death and a 50% greater risk of reinfarction compared to those who quit smoking.

Another modifiable risk factor is physical inactivity. Physical activity (PA) is a behavior defined as any bodily movement produced by the contraction of skeletal muscles that results in an increase in caloric requirements over resting energy expenditure (ACSM, 2022). Being physically active is often equated to meeting the Physical Activity Guidelines (PAG) for Americans, which are suggested to the general public by the U.S. Department of Health and Human Services. The PAG released in 2018 recommends at least 150 minutes to 300 minutes of moderate-intensity or 75 minutes to 150 minutes of vigorous-intensity or a combination equivalence of moderate and vigorous-intensity aerobic physical activity every week for adults and two to three days of muscle strength training a week. However, most of the adult population in the U.S. spends most of their waking time performing light to moderate physical activities or is predominantly sedentary. Sedentary behavior is any waking behavior characterized by an energy expenditure of 1.5 METs while sitting, reclining, or lying (Piercy et al., 2018). Approximately half of the adult population meets the PAG for aerobic activity, while only a quarter fulfill both the aerobic and muscle strengthening PAG (Piercy et al., 2018; CDC, 2022). Metabolic equivalents (METs) are a standardized method to quantify the absolute intensity of various behaviors and activities. METs compare the demands of a physical task with the aerobic capacity of the person performing the task. Among adults, light intensity PA is defined as 1.6-2.9 METs, moderate as 3.0-5.9 METs, and vigorous as 6 METs (Ainsworth et al., 2011; ACSM, 2022). According to NFPA 1582, firefighters should have a work capacity of at least 12 METs to perform the physical demands of the job. Numerous studies have shown that a large percentage of U.S. firefighters fail to meet the physical requirements necessary for their demanding profession. Although many programs are legally not punitive in design, meaning that if the exercise requirement is not met, there will be no repercussions or punishment. Established connections between aerobic capacity, muscular strength, muscular endurance, and body composition are associated with job performance and the reduction of CVD risk.

Fitness Standard for Firefighters

The International Association of Fire Fighters and International Association of Fire Chiefs have attempted to combat physical fitness and wellness issues with the Fire Service Joint Labor Management Wellness Fitness Initiative, which is a non-punitive medical and fitness program that is made up of five main components: medical evaluation, physical fitness, rehabilitation and injury prevention, behavioral health, and data collection. A meta-analysis based on active-duty career firefighters within exercise interventions that focused on the effects of exercise on validated outcomes of health and/or one or more components of physical fitness found that firefighters in departments meeting WFI criteria were less likely to be obese, more likely to meet endurance capacity standards for firefighting, and had higher estimated VO2 max (Andrews, K. et al. 2019). However, studies have found that fewer than 20% of US municipal fire departments routinely engage in fitness programs and annual fitness assessments (Durand et al., 2011). They emphasized the importance of not only maintaining fitness standards but also providing support and resources for firefighters to improve their overall health (WIF, 2018). According to the National Nutrition and Health Examination Survey and National Health Interview Survey utilized by the Centers for Disease Control, approximately 41.9% of U.S. adults are classified as obese. From 1999 to March 2020, US obesity prevalence increased from 30.5% to 41.9%, and severe obesity also increased from 4.7% to 9.2% in the same period (CDC, 2022). In June 2013, the American Medical Association House of Delegates voted to recognize obesity as a disease state requiring treatment and prevention efforts. Among the surveyed population, first responders make up a portion of those who face the same battle with obesity. The NFPA surveyed US firefighters, and 37% of career firefighters struggle with obesity, alongside 60% of volunteer firefighters (NFPA 2023). Specifically, over 70% of U.S. firefighters are overweight or obese, which exceeds the national average for adults (NFPA, 2005; Wilkinson, 2014). Research has shown that disease can make an individual susceptible to comorbidities, work-related injuries, and decreased quality of life (Choi et al., 2010-2016; Dobson et al., 2012; Moffatt et al., 202; Storer et al., 2014). Atherosclerotic cardiovascular diseasen is characterized by plaque buildup in the arterial walls. It encompasses related conditions such as aortic atherosclerotic disease, peripheral artery disease, CHD, and cerebrovascular disease (AHA, 2024). Fasting blood glucose, TC, LDL-C, TG, and low HDL-C were more likely to be silently present and interact to increase the risk synergistically (Moffatt et al., 2021).

Although exceeding normative weight values poses a challenge, it is equally crucial to consider one's body composition (Dobson et al., 2013; Calfas et al., 2000; Andrews et al., 2019). Although body fat endures a negative reputation, fats and lipids play a critical role in the body's overall function. Fats are needed for anaerobic metabolism, energy expenditure, and reserve. Lipids perform various functions, such as the structure of a cell membrane, to help with the absorption or transfer of enzymes, vitamins, or hormones. Fats and lipids are essential; 3-5% of fats are needed in males, and 8-12% of fats are needed in females for proper bodily function. Excess adipose tissue is the non-essential fat that accumulates in the body and, if not proportionate to body height and weight, can be detrimental to one's health. Body composition is a measure used to determine an individual's fat and fat-free mass. Body composition is composed of essential and non-essential fat. Essential fat is defined as the fat needed for normal bodily function, whereas non-essential fat is defined as excess adipose tissue. High body fat percentage is an indicator of cardiometabolic health risks.

It is also crucial to consider the location of body fat. Body composition gives greater detail and provides validity of tissue distribution. Fat accumulation around the lower section, which is closer to the hips, thighs, and buttocks region, is commonly termed the Gynoid region for its pear-like shape. Fat accumulation around the midsection, which is central and closer to the abdomen, is commonly termed the Android region for its apple-like shape. This weight distribution around the body's vital organs within the midsection is more detrimental to an individual's health. A way to determine an individual's weight distribution is to measure their waist circumference. Waist measurements are an indicator of health risk since abdominal obesity has been linked to an increased risk of cardiometabolic syndrome and other health disparities. Measuring the waist at the narrowest part of the torso (at the umbilicus) provides a measure that can be compared with that of other men and women to determine the risk category from very low to very high (ACSM). Central adiposity: Higher WC is associated with increased prevalence of metabolic abnormalities and CHD risk and was deemed a better predictor of the risk of coronary heart disease than BMI. (Li et. al. 2017; Alboqai et. al. 2009). To avoid these issues, it is crucial to maintain a normative weight and monitor caloric intake while also staying active (Strauss et al., 2021). Combining waist circumference with BMI or body fat percentage can help classify the risk of obesity that makes an individual predisposed to disease risk of illness, such as type 2 diabetes, hypertension, and cardiovascular disease.

Impact on Minorities

Cardiometabolic risk (CMR) factors, including obesity, hypertension, diabetes, cardiovascular disease, and metabolic syndrome, have a disproportionate impact on racial and ethnic minority populations. These disparities are particularly concerning for firefighting given the physically demanding nature of the profession and its critical role in public safety. Minority firefighters, especially those serving in rural or underserved communities, face unique stressors and health burdens that may elevate their risk for adverse cardiometabolic outcomes. Poston et al. (2014) conducted a landmark analysis of health disparities among racial and ethnic minority firefighters, revealing that minority firefighters had significantly higher body mass index (BMI) and body fat percentage (BFP) compared to their White, non-Hispanic counterparts. Specifically, minority firefighters were 59% more likely to be classified as obese (AOR = 1.59, 95% CI: 1.16 – 2.18), highlighting the disproportionate burden of cardiometabolic risk factors among different racial groups. The study also found that minority firefighters reported significantly more poor physical health days, and those serving in minority-dominated communities experienced the highest frequency of these poor health days. The implications of these findings are significant because elevated cardiometabolic risks not only threaten individual health but also compromise occupational readiness and safety. Moreover, the intersection of occupational stress, environmental exposures, and structural inequities, such as limited access to preventive care or culturally appropriate health resources, may further exacerbate these disparities among minority firefighters.

Cardiovascular and Metabolic Risk Calculators

Several tools have been validated for calculating cardiovascular and metabolic risk. The Framingham Risk Score was developed by the National Heart, Lung, and Blood Institute based on data from the Framingham Heart Study from 1948, which recruited over 5,000 predominantly middle-class white males from Massachusetts to track the development of heart disease (National Heart, Lung, and Blood Institute, n.d.). Since then, FRS has expanded to include risk of cerebrovascular events, peripheral artery disease, and heart failure, predicting the potential risk of CVD within a 10-year timeframe.

The Pooled Cohort Equations were introduced in 2013 by the American College of Cardiology and the American Heart Association as another tool for risk prediction to estimate the 10-year risk of atherosclerotic cardiovascular disease. This risk equation was based on data from multiple, racially and geographically diverse cohorts designed to be sex and race-specific (Karmali, Goff, Ning, & Lloyd-Jones, 2014).

A recent study by the U.S. Fire Administration focusing on firefighters aged 45 or younger found that traditional cardiovascular risk factors such as obesity, cigarette smoking, and hypertension, play a major role in increasing the risk of SCD through the susceptibility to CHD and left ventricular hypertrophy (LVH)/cardiomegaly. Although SCD is most commonly observed in middle-aged firefighters (aged 45 and older) with CHD, younger individuals are not exempt, especially when several risk factors are present. Among the risk factors, obesity is a key contributor to CVD, as it elevates other risk markers, including high cholesterol, high blood pressure, and elevated blood sugar. CMDS were originally designed to predict the onset of diabetes and the 10-year risk of major adverse cardiovascular events. The CMDS performs similarly, if not better than, the traditional Framingham Risk Score (FRS) and Pooled Cohort Equations (PCEs), which are used to estimate 10-year CVD risk (Table 1). These scoring systems have significantly advanced risk stratification for both cardiovascular and metabolic conditions by enabling more precise risk estimation and lifestyle-based interventions for early prevention and/or reduction of CMR.

Chapter III: Methods

Study Environment

The Cardiovascular Health Assessment Program is a community outreach program performed in the Human Performance Laboratory (HPL) at East Carolina University. Established in 1982, four local fire agencies have partnered with the HPL for physical examinations and assessments during their hiring process (talent acquisition) and continuous evaluation and screening of employees throughout their tenure. The participants' identities were anonymized, and the data obtained approval from the Institutional Review Board (IRB). Participants were active-duty career firefighters between 2023 and 2024. While many firefighters have had multiple evaluations in the HPL, this study used only the data from the most recent visit. Annual cardiovascular risk assessments vary between the four local fire agencies. Greenville Fire Rescue offers the risk assessment every three years for employees under the age of 40, every two years for those ages 40 – 49, and every year for those employees 50 years and older. Washington and Winterville Fire & Rescue perform risk assessments every year during their corresponding birth month. While many firefighters have had multiple evaluations in the HPL, this study used only data from the most recent visit.

Population

The initial sample included 201 firefighters. After excluding 17 participants due to incomplete data, the final sample included 183 firefighters from the Eastern North Carolina, Pitt & Beaufort County area. Of these, 150 identified as White non-Hispanic and 33 as members of minority groups. The sample also consisted of 10 females and 173 males.

Assessment

To provide a comprehensive risk assessment, we obtained retrospective data retrieved from East Carolina University's Cardiovascular Health Assessment Program database. The data retrieved consisted of a standard blood lipid panel, body composition, rest and exercise vitals, and metabolic equivalents. The standard lipid panel consisted of total cholesterol (TC), triglycerides (TG), glucose (BG), very low-density lipoproteins (VLDL), low-density lipoproteins (LDL), and high-density lipoproteins (HDL). Body composition retrieved consisted of anthropometric measures of height, weight, waist circumference, and dual-energy x-ray absorptiometry (DEXA), which denotes the participant's body fat percentage and android gynoid distribution ratio. Vital measures consisted of systolic and diastolic blood pressure. Aerobic fitness was evaluated through the metabolic equivalence achieved from the submaximal stress test.

The fire departments that were evaluated in the study have a fitness program requiring all personnel to exercise for at least one hour while on duty. Firefighter personnel evaluated currently work 24-hour shifts followed by 48 hours off duty, a common schedule known as the 24/48 schedule. Although firefighters are subject to mandatory overtime for disasters, large emergencies, or to meet minimum staffing requirements. Each firefighter works approximately 10 shifts per month, totaling 56 hours per week on average, accounting for overtime and other duties (Fire/Rescue Department, City of Greenville, n.d.). The overall assessment consists of body composition, pulmonary function test, aerobic fitness, and vision assessment. A licensed medical doctor then evaluated the results from these assessments. Not all components from the assessment were used; only selected variables were collected and analyzed based on the requirements of the data analysis.

Faculty, graduate students, and PhD students from the ECU HPL department conducted the firefighters' annual assessments. The students have been trained, tested, and evaluated through skills evaluation led by certified faculty.

The series in which the assessment was conducted was taken into consideration to obtain valid results, and preliminary evaluations were conducted before the VO2 submaximal treadmill protocol. Subjects were asked before the assessment to wear athletic clothing and shoes. A 'personal history form' was completed before the assessment by the subject, consisting of the subject's health history, and was reviewed by a physician once the subject had completed the entire assessment.

At the beginning of the assessment, a preliminary evaluation was performed. The subject's resting vitals and anthropometric/body composition measures were obtained, which followed the ACSM guidelines and procedures. In regard to this study, only the data was obtained through retrospective collection of hard copies of the firefighters' assessments. All procedures were protocols followed by the ECU Human Performance Laboratory.

Blood pressure (BP) is the force exerted by circulating blood against the walls of the arteries. It is recorded as two numbers. Systolic blood pressure (SBP), the top number, is the pressure of blood pumped out of the heart into the body during the contraction of the heart. While Diastolic blood pressure (DBP), the bottom number, is the pressure between beats when the heart is filling with blood. The American Heart Association is accredited and widely used to categorize BP. Normal BP is defined as a SBP less than 120 mmHg and DBP less than 80 mmHg. Elevated BP consists of a SBP between 120 and 129 mmHg and DBP less than 80 mmHg. Hypertension Stage 1 is diagnosed when the SBP is between 130 and 139 mmHg and DBP is between 80 and 89 mmHg. Hypertension Stage 2 is present when SBP is 140 mmHg or higher or DBP is 90mmHg or higher. A Hypertensive Crisis is a medical emergency where the SBP exceeds 180 mmHg and/or DBP is over 120mmHg, and immediate medical attention is required.

High blood pressure is also known as hypertension, is a serious condition that can silently damage the body over time. Hypertension (HTN) can affect nearly every body system by damaging major organs and blood vessels. Uncontrolled hypertension can lead to narrowed arteries, heart strain, reduced kidney function, and impaired brain function. Uncontrolled HTN can also impact an individual's ADL, such as vision impairment, sexual dysfunction, and cognitive decline as other potential consequences.

Dual energy x-ray absorptiometry (DEXA) is an advanced form of X-ray imaging that measures bone mineral density. The machine uses two different energy levels to distinguish between bone and soft tissue, which can provide additional assessment of body composition. The DEXA can be used as a tool to assess body composition by further distinguishing between lean and fat mass, offering a three-compartment model of bone, fat, and lean mass. The benefits of using this method include efficiency, accuracy, non-invasive, and low-dose radiation. Gallagher et al. indicated in their works that the DEXA-derived body composition correlates with visceral adiposity and cardiometabolic risk, which makes it a reliable tool for assessment instead of traditional anthropometric measures such as waist circumference or BMI.

The DEXA manual which provides guidelines for body fat percentage classifications based on sex. Essential body fat classification is defined as necessary body fat needed to perform normal physiological functions which is categorized as 2-5% body fat for men age and 10-13% body fat for women. Athletes body fat classification is defined as 6-13% body fat for men and 14-20% body fat for women. Fitness body fat classification is defined as 14-17% body fat for men and 21-24% body fat for women. Average body fat classification is defined as 18-24% body fat for men and 25-31% body fat for women. Overweight body fat classification is defined as 25-29% body fat for men and 32-27% body fat for women. Obese body fat classification is defined as ≥30% body fat for men and ≥38% body fat for women.In regard to the classification of body fat percentage, the defined criteria will be listed for 30-39-year-old males and females reflecting the mean age of the sample population.

Android gynoid ratio (A/G) is the measure of body fat distribution, specifically the ratio of fat stored in the abdomen (android) to the hips and thighs (gynoid). It is calculated by dividing the percentage body fat in the android region by the percentage of fat in the gynoid region. For men, the ideal A/G ratios < 1.0 and < 0.8 for women. The higher the A/G ratio is, generally associated with higher visceral fat, which is fat stored around the abdominal organs, which generates an increased risk of cardiovascular and metabolic diseases (Yang et al., 2023).

Lipid and glucose levels were measured through a blood draw, which was completed using standard analytical techniques at either LabCorp Inc. Location or the City of Greenville

Employee Health Clinic. The lab results were provided electronically to the Human Performance Lab. Each subject was instructed to fast before blood sampling. A blood sample was obtained from each participant to measure triglycerides (TG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C). Total cholesterol, low-density lipoproteins, and high-density lipoproteins are categorized as desirable, above desirable, borderline high, high, and very high. High-density lipoprotein cholesterol (HDL-C) are considered the "good fat" because it is associated with a lower risk of heart disease and stroke. Triglycerides are a type of fat (lipid) that circulates in the blood and is the most common type of body fat in the body. They are made up of glycerol and three fatty acids and are categorized as normal, borderline high, high, and very high. Laboratory measurements were performed using standard automated procedures at LabCorp Incorp. ACSM classifications of cholesterol and triglycerides are defined as follows: Low-density lipoprotein cholesterol (LDL-C): <100 mg/dL^{-1} (desirable), 100-129 mg/dL^{-1} (above desirable), 130-159 mg/dL^{-1} (borderline high), 160-189 mg/dL^{-1} (high), ≥190 mg/dL^{-1} (very high). High-density lipoprotein cholesterol (HDL-C): <40 mg/dL^{-1} (low) for men and <50 mg/dL^{-1} (low) for women. Triglycerides: <150 mg/dL^{-1} (normal), 150-199 mg/dL^{-1} (borderline high), 200-499 mg/dL^{-1} (high), ≥500 mg/dL^{-1} (very high).

Metabolic equivalence (METs) is commonly used to compare the physical demands of a task with an individual's aerobic capacity. A MET is defined as the amount of energy expended during one minute of seated rest, which represents a baseline for estimating energy expenditure during physical activity. In terms of oxygen consumption, one MET is equivalent to approximately 3.5 mL/kg/min). According to the analysis from the NFPA 1582, firefighters are expected to demonstrate a minimum aerobic work capacity of 12 METs to meet occupational fitness requirements for firefighting.

Risk scores will be assessed individually for each subject and are based on the risk factors measured during assessment. The risk scores will be calculated by summing the CMRF composite scores without weighing, using the subjects' reference values: medically managed hypertension, elevated resting blood pressure, total cholesterol, glucose, triglycerides, HDL, LDL, tobacco abuse, and android gynoid ratio. These scores will then be applied to the subject and compared to those within the group of firefighters.

Cardiovascular Outcomes

The primary predictor used in this study was an adaptation of the CMD score that extended to incorporate additional factors known to be strongly associated with cardiac events. (Table 1) Prior research has demonstrated strong associations between CMR factors and increased risk of major adverse cardiac events (MACE). MACE includes cardiovascular death, nonfatal myocardial infarction, and nonfatal stroke.

Statistical Analysis

All baseline participant characteristics were compiled. Quantitative data is presented in means and standard deviations. All categorical data is presented as percentages. CMR scores were calculated using established cardiometabolic indicators: diagnosed hypertension, diagnosed diabetes, dyslipidemia, tobacco abuse, central adiposity, body fat percentage, and metabolic equivalence. Group comparisons were made between White non-Hispanic firefighters (n=150) and firefighters identified as racial/ethnic minorities (n=33). An independent samples t-test was conducted to evaluate group differences.

Chapter IV: Results

Baseline characteristics of the study participants (N = 183) are displayed in Table 3. The table lists the sample populations mean, standard deviations, percentage, and classification for variables such as age and cardiometabolic risk factors: android gynoid ratio (men and female), total body fat percentage (male and female), High Density Lipoproteins (male and female), Total Cholesterol, Triglycerides, Glucose, Low Density Lipoproteins, Metabolic equivalence, Systolic Blood Pressure, Diastolic Blood Pressure, diagnosed hypotension, undiagnosed hypertension, diagnosed dyslipidemia, and diagnosed diabetes. The present study tested the hypothesis that firefighters from racial and ethnic minority groups would demonstrate a higher relative risk for CVD, as measured by a composite CMR score, compared to their White, non-Hispanic counterparts.

An independent samples t-test was conducted to examine whether continuous metabolic risk scores differed between groups of White non-Hispanic and Minority firefighters. Levene's Test of Equality of Variances was assessed to determine the significance. Non-modifiable risk factors such as age and family history of CVD and/or diabetes were significant between groups of white non-Hispanics and minorities. Modifiable risk factors such as diagnosed diabetes, tobacco abuse, triglycerides, and HDL were significant between groups of white non-Hispanics and minorities. Levene's Test for Equality of Variances was assessed to determine the appropriate row to interpret for each comparison. Below are the key findings: Age: A statistically significant difference was observed between the groups, $t(179) = 2.675$, $p = .008$, with the comparison group being on average 5.07 years older (95% CI [1.33, 8.81]). **Family History (FamHx)**: Levene's test was significant ($F = 12.788$, $p < .001$), so unequal variances were assumed. The difference between groups was statistically significant ($t(91.78) = 2.365$, $p = .020$), indicating that individuals with a family history had significantly higher values (M = 0.096) than those without. **Diabetes Family History**: Levene's test was significant ($p = .002$), so unequal variances were assumed. The difference approached significance ($p = .105$), suggesting a trend toward higher values in individuals with a family history of diabetes, but this did not reach the conventional alpha level. **Diagnosis of Cardiovascular Disease (DxCVD)**: Levene's test was not significant ($p = .099$), and under the equal variances assumed row, the difference was not statistically significant ($p = .417$). However, under unequal variances assumed, the one-sided *p*-value was significant ($p = .042$), indicating a possible directional difference that should be interpreted with caution. **Hypertension Medication Use (Meds_HTN)**: No significant difference was found between groups ($p = .800$), and Levene's test indicated equal variances ($p = .617$). **Prehypertension**: No significant group differences were found ($p = .739$), and Levene's test indicated equal variances ($p = .477$). **Diabetes Diagnosis**: Levene's test was significant ($p < .001$), so unequal variances were assumed. No statistically significant difference was found ($p = .228$), although the equal variances row showed marginal significance for the one-tailed test ($p = .040$), suggesting potential group differences. **Hyperlipidemia Medication Use (Meds_HLD)**: No significant group differences were observed ($p = .930$), and Levene's test was not significant ($p = .860$). **Tobacco Abuse**: Levene's test was significant ($p < .001$), so unequal variances were assumed. A statistically significant difference was found $t\,(62.11) = 2.573$, $p = .013$), with those reporting tobacco abuse having higher values (Mean Diff = 0.177, 95% CI [0.039, 0.314]). **Total Risk Score**: Levene's test was not significant ($p = .138$). No statistically significant group difference was found under either assumption ($p > .05$), though the unequal variances row showed a near-significant one-tailed test (*p* = .081). **Composite Risk Category (Low, Normal, Elevated, High, Very High)**: No significant differences were found (*p* = .329), and Levene's test was not significant (*p* = .162). Resting Systolic Blood Pressure (SBP): No significant difference was found between groups, t(179) = 0.998, p = .320. Resting Diastolic Blood Pressure (DBP): There was no statistically significant difference between groups, t(179) = 1.533, p = .127. Glucose: No significant difference was found between groups, t(179) = 0.828, p = .409. Total Cholesterol (TC): The difference in cholesterol levels between groups was not statistically significant, t(179) = 1.336, p= .183. Triglycerides (TG): A statistically significant difference was found between groups, t(179) = 2.094, p = .038, with the comparison group having higher triglyceride levels by 31.02 mg/dL (95% CI [1.78, 60.25]). High-Density Lipoprotein(HDL): A significant difference was observed, t(179) = -2.474, p = .014, indicating that the comparison group had significantly lower HDL levels by approximately 5.61 mg/dL (95% CI [-10.08, -1.13]). Low-Density Lipoprotein (LDL): The difference in LDL approached but did not reach significance at the .05 level, t(177) = 1.739, p = .084. Total Body Fat Percentage (FMI): No significant group differences were observed, t(178) = 0.221, p = .825. Android/Gynoid Fat Ratio (A/G): No significant difference was found, t(178) = 0.850, p = .396. Exercise Capacity (METs): There was no statistically significant difference between the groups, t(178) = -0.335, p = .738.

In summary, age, family history, diabetes diagnosis, tobacco abuse, and triglycerides and HDL from the lipid profile indicated significantly higher associated values, while the other variables showed no statistically significant group differences, although some exhibited trends toward significance, indicating marginal differences.

Chapter V: Discussion

Although CVD remains the leading cause of on-duty deaths among firefighters, with SCD accounting for a substantial portion of those fatalities, this study sought to evaluate racial and ethnic disparities in CMR among firefighters in Eastern North Carolina, a region that is underrepresented in firefighter health research and situated within the "Stroke Belt," an area with elevated morbidity and cardiovascular mortality rates. The primary objective of this study was to investigate whether minority firefighters exhibit elevated CMR scores when compared to their White non-Hispanic counterparts. Contrary to the initial hypothesis, the findings indicated no statistical difference in CMR scores between groups, both through independent samples t-tests. This suggests that within this sample, race alone does not account for significant variance in CMR score. Instead, CMR appears to be more strongly influenced by modifiable risk factors collectively, all of which were significant in the CMD score model. This is consistent with public health literature highlighting the need for personal awareness and motivation to pursue lifestyle changes that reduce risk. This unexpected outcome challenges the commonly held assumption that minority firefighters inherently possess greater CMR, which is often seen within the general population. The sample size for minority firefighters was notably small (n = 33) compared to their White non-Hispanic counterparts (n =150), which may have limited the power to detect small group differences. Additionally, the minority category was treated as a single, aggregated group, potentially obscuring differences among specific racial or ethnic subgroups. Future research would benefit from larger, more diverse samples that allow for more granular analyses across distinct minority populations. Moreover, while this study controlled for metabolic factors, psychosocial variables such as occupational hazards, stress, sleep patterns, rank, and fire station culture were not included. While the field is male-dominated, female firefighters have been increasing over the years and creating an inclusive data set that provides a representation for both males and females would also benefit this growing field. Incorporating such variables could offer a better understanding of the interplay between race, environment, and physiological health outcomes in firefighters.

In conclusion, the present findings suggest the need for equitable evidence-based approaches to occupational health screenings and interventions, with a focus on clinical indicators that truly impact cardiometabolic outcomes. This study highlighted the value of annual health assessment and the need for ongoing, regionally focused risk assessments. Implementing programs like East Carolina University's Cardiovascular Health Assessment Program represents a pivotal step towards closing gaps in preventive care and data collection in the firefighter population. The findings of this study underscore the significance of modifiable risk factors such as obesity, smoking, and metabolic syndrome in contributing to health disparities among minority populations. These findings highlight the need for further research to explore how cultural health patterns, particularly in rural southeastern communities, influence these modifiable risk factors. Further research is warranted to explore longitudinal outcomes, including larger and more demographically diverse samples, while also examining the impact of environmental factors, regulations, standards, and behavioral factors in modulating CMR. Such research can inform more culturally and geographically responsive public health interventions. Ultimately, adopting a comprehensive and inclusive approach for firefighter health holds the potential to drive more equitable care, improve long term health outcomes, and enable early detection of cardiovascular disease risk, saving lives and strengthening workforce readiness.

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Tables & Figures

Table 1 Risk Factors and Covariates Used in Predication Model	
Model	Variables in Model
(CMDS) ***LDL-c instead of non-HDL-C** ***A/G instead of WC or BFP**	A/G + SBP + DBP + glucose + HDL + LDL + triglycerides + MET + tobacco abuse + diabetes status + Cholesterol medication use + hypertension medication use + DxCVD
Smoking coded as current smoker vs non-smoker. Tobacco Use coded as current or prior user **A/G = android gynoid distribution; CMDS = Cardiometabolic Disease Score; DBP = diastolic blood pressure; HDL = high density lipoproteins; LDL= low density lipoproteins; SBP = systolic blood pressure; MET = metabolic equivalence; FamHx = cardiac family history; DxCVD = diagnosed cardiovascular disease**	

Table 2 The Cardiometabolic Disease Staging System (CMDS)		
Stage	**Descriptor**	**Criteria**
Stage 0	Metabolically Healthy	No risk factors
Stage 1	One or Two Risk Factors	Have one or two of the following risk factors: a. high waist circumference (≥112 cm in men,≥88 cm in women) b. elevated blood pressure (systolic≥130 mmHg and/or diastolic =85 mmHg) or on anti-hypertensive medication c. reduced serum HDL cholesterol (<1.0 mmol/L or 40 mg/dL in men; <1.3 mmol/L or 50 mg/dL in women) or on medication d. elevated fasting serum triglycerides (≥1.7 mmol/L or 150 mg/dL) or on medication
Stage 2	Metabolic Syndrome or Prediabetes	Have only one of the following three conditions in isolation a. Metabolic Syndrome based on three or more of four risk factors: high waist circumference, elevated blood pressure, reduced HDL-c, and elevated triglycerides b. Impaired Fasting Glucose (IFG; fasting glucose ≥5.6 mmol/L or100 mg/dL) c. Impaired Glucose Tolerance (IGT; 2-hour glucose ≥7.8 mmol/L or140 mg/dL)
Stage 3	Metabolic Syndrome + Prediabetes	Have any two of the following three conditions: a. Metabolic Syndrome b. IFG c. IGT

Stage 4	T2DM and/or CVD	Have Type 2 Diabetes Mellitus (T2DM) and/or Cardiovascular Disease (CVD): a. T2DM (fasting glucose ≥126 mg/dL or 2-hour glucose ≥200 mg/dL or on anti-diabetic therapy) b. active CVD (angina pectoris, or status post a CVD event such as acute coronary artery syndrome, stent placement, coronary artery bypass, thrombotic stroke, non-traumatic amputation due to peripheral vascular disease)

Table 3 Baseline Characteristics of Firefighter Participants			
Race	White non-Hispanic (n = 150)	Minority (n = 33)	Categorization
Age	38.88 ± 9.45	33.81 ± 10.95	General Population
Modified CMDS Factors			
Android Gynoid Ratio[a]	1.12 ± 0.15	1.10 ± 0.15	Above Desirable
Android Gynoid Ratio[b]	0.98 ± 0.15	0.88 ± 0.17	Above Desirable
Total Body Fat Percentage[a]	29.85 ± 6	29.58 ± 7.37	Obese
Total Body Fat Percentage[b]	41.47 ± 6.91	37.30 ±7.74	Obese
Total Cholesterol	190.05 ± 36.88	180.34 ± 39.24	Normal
Glucose	92.75 ± 13.65	90.34 ± 19.94	Normal

Triglycerides	129.7 ± 78.08	98.69 ± 65.42	Normal
HDL[a]	48.11± 11.76	53.72 ± 10.99	Low | Good
HDL[b]	57 ± 8.53	66.26 ±12.82	Good
LDL	118.39 ± 32.86	107.25 ± 32.85	Above Desirable
MET	11.46 ± 2.05	11.59 ± 1.77	Below Desirable
Systolic Blood Pressure	120 ± 13	117 ± 14	Normal
Diastolic blood pressure	74 ± 9	70 ± 11	Normal
Diagnosed Hypertension	16 (11%)	4 (12%)	
Undiagnosed Hypertension	54 (36%)	12 (36%)	

Diagnosed Dyslipidemia	13 (9%)	3 (9%)	
Diagnosed Diabetes	4 (3%)	3 (9%)	
Family History CVD	19 (13%)	1 (3%)	
Family History DM	35 (23%)	4 (12%)	
Tobacco Abuse	45 (30%)	4 (12%)	

HDL[b] = female (4)Minority (6)White Non-Hispanic

Total Body Fat Percentage[b] = female (4)Minority (6)White Non-Hispanic

Android Gynoid Ratio[b] = female (4)Minority (6)White Non-Hispanic

HDL[a] = male (29)Minority (144)White Non-Hispanic

Total Body Fat Percentage[a] = male (29)Minority (144)White Non-Hispanic

Android Gynoid Ratio[a] = male (29)Minority (144)White Non-Hispanic

Table 4 Independent Samples Test for Equality of Means

Statistic	White Non-Hispanic (n = 150)	Minority (n = 33)
F	2.225	
Sig. (p value)	0.162	
df	-0.868	
Two-sided p	0.161	
Mean	0.13	0.03
Mean Difference	0.576	
Std Error Mean	0.18	0.36
Std Error Difference	0.405	
STD Error	0.03	0.03
95% Confidence Interval for Mean Lower - Upper	-0.237 | 1.388	

Note. Minority group include all racial/ethnic identities other than White.

CI = Confidence Interval; SE = Standard Error

Appendix: IRB Approval Letter

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board
Willis Building · Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** ·
rede.ecu.edu/umcirb/

Notification of Initial Approval: Expedited

From:	Biomedical IRB
To:	Cathy Brown
CC:	Joseph Houmard
Date:	8/1/2025
Re:	UMCIRB 25-000887 Health Disparities Amongst Eastern North Carolina Firefighters Using Cardiometabolic Risk Scores

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) occurred on 8/1/2025. The research study is eligible for review under expedited category # 5. The Chairperson (or designee) deemed this study no more than minimal risk.

As the Principal Investigator you are explicitly responsible for the conduct of all aspects of this study and must adhere to all reporting requirements for the study. Your responsibilities include but are not limited to:

1. Ensuring changes to the approved research (including the UMCIRB approved consent document) are initiated only after UMCIRB review and approval except when necessary to eliminate an apparent immediate hazard to the participant. All changes (e.g. a change in procedure, number of participants, personnel, study locations, new recruitment materials, study instruments, etc.) must be prospectively reviewed and approved by the UMCIRB before they are implemented;

2. Where informed consent has not been waived by the UMCIRB, ensuring that only valid versions of the UMCIRB approved, date-stamped informed consent document(s) are used for obtaining informed consent (consent documents with the IRB approval date stamp are found under the Documents tab in the ePIRATE study workspace);

3. Promptly reporting to the UMCIRB all unanticipated problems involving risks to participants and others;

4. Submission of a final report application to the UMICRB prior to the expected end date provided in the IRB application in order to document human research activity has ended and to provide a timepoint in which to base document retention; and

5. Submission of an amendment to extend the expected end date if the study is not expected to be completed by