MUSCLE DAMAGE, INFLAMMATION, AND MUSCULAR PERFORMANCE FOLLOWING THE PHYSICAL ABILITIES TEST IN PROFESSIONAL FIREFIGHTERS

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MATTHEW L. SOKOLOSKI, M.S.

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ABSTRACT

MATTHEW SOKOLOSKI

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Proper monitoring of fatigue, cardiovascular disease, and muscular damage may be used to decrease the high levels of cardiovascular disease, overuse musculoskeletal injuries, and workers compensation claims within the profession of firefighting. The purpose of this study was to examine muscle damage, muscular fatigue, and inflammation responses following a typical firefighting shift. Twenty-four professional firefighters completed two physical abilities tests (PATs) to standardize the tasks typically performed in a day of work and elicit similar physiological responses. These individuals were then monitored for 48 hrs. Prior to and 48 hrs following the PAT these individuals were evaluated for changes in strength, power, range of motion, as well as blood markers including myoglobin, TNF-α, and C-Reactive Protein. Following the PAT significant differences in myoglobin ($p < 0.05$), grip strength ($p < 0.05$), vertical jump ($p < 0.05$), and sit-and-reach ($p < 0.05$) were observed. No differences in TNF-α or C-Reactive Protein were observed ($p > 0.05$). Twenty-four hours following a shift firefighter still shows decreased levels of strength, power, and range of motion. This may lead to decreases in performance and an increased risk of injury.

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CHAPTER I

INTRODUCTION

Over 1 million people in the United States are professional or volunteer firefighters (National Fire Protection Association [NFPA], 2019). Whether done professionally or on a volunteer basis, this is commonly classified as one of the most unpredictable, stressful, and dangerous occupations. Every year, an average of 100 firefighters die while on duty (Kunadharaju et al., 2011). Many of these deaths that occur while on duty are attributed to complications from cardiovascular disease (CVD), with an increase in the incidence of these deaths within the last several decades (Kahn et al., 2015; Kales et al., 2007). Despite this, the overall risk of death attributed to CVD is similar to other occupations and the general population (Crawford & Graveling, 2012). Strong associations between CVD and associated risk factors, including elevated blood pressure, high levels of triglycerides, low levels of high-density lipoproteins, glucose intolerance, and a sedentary lifestyle, have been shown in firefighters (Durand et al., 2011). Other risk factors for CVD, such as poor dietary habits, chronically high levels of sympathetic stimulation, strenuous workloads, exposure to high temperatures, and poor sleep habits, are specific to the profession of firefighting (Farioli et al., 2014). The typically sedentary lives led by first responders only increase these risks.

The occupation of firefighting is extremely unpredictable, which may further contribute to the risks of CVD. First responders may have one shift with a low call volume and experience high call volume on the next shift (Paley & Tepas 1994). The highly varying nature of this profession makes adhering to healthy eating habits more difficult than a typical, 8-hour shift. Firefighters may complete an exhausting shift, that included a large volume of calls, and feel no desire to cook at the station or when they get home. This makes the convenience of fast food and

premade meals, which have higher concentrations of trans-fats, appealing (Yang et al., 2015). Professional firefighters are typically scheduled to work 24 consecutive hours, with the next 48 hours off (i.e., shift work). Shift workers have higher levels of low-density lipoproteins (LDLs), triglycerides, free-fatty acids, and glucose levels in the blood compared to individuals working a more typical daily shift (Puttonen et al., 2010). "Firehouse culture" has also been cited as a dietary factor increasing the risk of CVD. Firefighters consuming diets high in fat and refined carbohydrates are typically unwilling to change regardless of increased risk (Deutsch, 2005).

In addition to dietary habits, the inherent stressful nature of the occupation can add to the risk of developing CVD in this population. Sympathetic stimulation is elevated in any individual during times of high stress, in chaotic environments, loud environments, and at times when eyesight is impaired. These environmental factors are all commonplace for professional firefighters (Farioli et al., 2014). When analyzing heart rate responses in firefighters, it is not uncommon for these individuals to reach their age-predicted maximal heart rate while on duty, and to maintain very high heart rate values that approach this maximal value for long durations of time (Sothmann et al., 1992). These large fluctuations in heart rate and sympathetic stimulation greatly increase the risk for a myocardial infarction or cardiovascular accident (CVA), specifically sudden cardiac arrest or death while on duty (Sothmann et al., 1992). Moreover, structural fire suppression is the primary responsibility of firefighters. Structure fires typically burn at temperatures over 1,000 °F and take over 38 minutes to suppress (Cheung et al., 2010). These calls expose firefighters to a large amount of cardiovascular-related stress. This stress to the individual's cardiovascular system may be related to the increased efforts to regulate body temperature and overcome dehydration (Smith et al., 2016).

The health and fitness levels of firefighters can be overlooked, particularly because many of these individuals are only subjected to fitness screenings once per year (Storer et al., 2014). Furthermore, most departments throughout the United States do not mandate their first responders to exercise during their careers. Professional firefighters that possess high levels of aerobic fitness, anaerobic capacity, and muscular strength and endurance have increased mobility, energy, and endurance (Smith, 2011). This may allow these first responders to perform their occupational responsibilities in a safer and more efficient manner. Those with higher fitness levels may also be less likely to jeopardize the safety of their fellow firefighters and the public they serve while performing these duties. Despite this, mandating participation in a training program, and the tracking of health-related measures of physical fitness, is not mandatory for employment. However, guidelines for some measures have been outlined by the NFPA. Specifically, the NFPA advises firefighters to possess a maximal oxygen consumption (VO_{2max}) of at least 42 ml/kg/min. This is critical, as more than 70% of firefighters in the United States have a body mass index (BMI) categorized as overweight or obese (Wilkinson et al., 2014).

Fire departments typically conduct an annual assessment to test the physical fitness of their city's firefighters. Typically known as the physical abilities test (PAT), firefighters are required to perform tasks commonly performed while extinguishing a fire, or during a search and rescue. Due to the PAT's specificity to firefighting, this assessment is considered a reliable predictor of firefighting performance (Michaelides et al., 2011). Some of these tasks, depending on department preferences, may include a dummy drag, repeated sledgehammer strikes, and ladder climb. Firefighters are instructed to complete these tasks as fast as possible and are given a score to determine their fitness level following the assessment.

While a well-rounded exercise training program recommended by the American College of Sports Medicine (ACSM) may improve physical fitness measures such as VO_{2max} and body composition (Riebe et al., 2018), sustained periods of strenuous activity may have negative consequences related to health and fitness. Indeed, immediately following strenuous physical activity, there is a significant drop in performance that lasts several days depending on the intensity, duration, and type of exercise (Armstrong et al., 1991). The factors affecting this decrease in performance include myofibrillar disruption, swelling in the damaged area caused by an efflux of enzymatic activity, and the inflammatory process. While the exact time to fully regain performance capabilities varies between individuals, muscle damage, resulting from a single bout of exercise, may elicit negative changes in range-of-motion (Reinold et al., 2008), cognition (Moore et al., 2012), speed of muscular contraction (Bergström et al., 1991), muscular strength, and VO_{2max} up to 96 hours post-exercise (Eston et al., 2003). An inability to fully recover from strenuous bouts of exercise can increase the risk of injury and further decrease optimal performance (Soligard et al., 2016). In addition to increased risk of injury, markers of muscle damage and inflammation are also elevated for 72 hours post-exercise. Some of these markers have also been associated with an increased risk of myocardial infarction (Ridker et al., 2003), metabolic syndrome, arthritis (Raychaudhuri et al., 2010), and pulmonary disease (Nocker et al., 1996). These chronic diseases are among the most common causes of death and injury among firefighters.

Due to the high variability in call volume, firefighters may be asked to repeat maximal-effort activities, regardless if performance is hindered by activities completed in a previous call, or if the first responder is optimally recovered. These factors may allow for a higher risk of injury. The relationship between muscle damage, inflammation, and recovery among firefighters

is not well characterized. The combination of risk factors, lifestyle choices, and high physical workloads expected of professional firefighters greatly increases their risk of developing CVD or cardiovascular-related incidents (Soteriades et al., 2005). To understand the duration of time necessary for firefighters to optimally recover from a bout of physical activity, research that includes muscle-damaging protocols among firefighters must be completed. The effects of job-related tasks on markers of muscle damage, inflammation, and their relationship to physical fitness among firefighters will be analyzed in this study.

Problem Statement

CVD is the leading cause of on-duty deaths among firefighters. Due to the high incidence of CVD, cities typically allocate millions of dollars yearly to workers compensation and overtime costs for firefighters who are affected by this disease. Indeed, the combination of poor fitness levels, with inadequate recovery from work-related tasks may increase the risk of a cardiac related incident. However, there is currently no known research monitoring adequate recovery durations with this population following work-related tasks. In an effort to advocate for this underserved population, it is imperative that research is performed. This research study will serve as an initial investigation into firefighter-specific tasks, and how these tasks may affect physical fitness and consequently elicit muscle damage. Therefore, the purpose of this study is to characterize markers of muscle damage, physical fitness, and CVD risk following a physical abilities test in firefighters.

Aims of the Study

Aim 1) To characterize the duration of time for markers of muscle damage to return to baseline in professional firefighters following a PAT.

Aim 2) To characterize the duration of time for vertical jump, flexibility, and strength to return to baseline in professional firefighters following a PAT.

Hypotheses

The hypotheses tested in this study are as follows:

1. Markers of muscle damage (i.e., Myoglobin [Mb]) are significantly elevated 48 hrs following PAT.

2. Markers of cardiovascular disease (i.e., C-reactive protein [CRP] and tumor necrosis factor alpha [TNF-α]) are significantly elevated 48 hrs following PAT.
3. Measures of physical fitness (i.e., grip strength, vertical jump and flexibility) are significantly decreased 48 hrs following the PAT.
4. Measures of physical fitness (i.e., grip strength, vertical jump and flexibility) are strongly correlated with markers of muscle damage (i.e., Mb) and cardiovascular disease (i.e., CRP and TNF-α).

Definitions

Physical Abilities Test (PAT)- A physical assessment used by fire departments across North America to determine if firefighters possess the minimal physical capabilities to complete common firefighting tasks.

C-reactive protein (CRP)- An inflammatory protein produced in the liver. High CRP levels can also indicate inflammation in the arteries of the heart, which can mean a higher risk of heart attack.

Myoglobin (Mb)- A protein found in cardiac and skeletal muscle. This protein serves primarily reverse the binding of oxygen. Mb can receive oxygen from hemoglobin and store or deliver it to the working muscle during exercise. This protein is released from muscle tissue as a result of

skeletal muscle damage.

Tumor Necrosis Factor Alpha (TNF-α)- An inflammatory cytokine produced by macrophages during inflammation. Chronically elevated levels are associated with increased risk of arthritis diabetes, and cardiovascular disease related events.

Assumptions

Assumptions for this study include the following:

1. Participants were in a fasted state for at least 8 hrs prior to each blood draw.
2. Participants abstained from physical activity between each blood draw.
3. Participants abstained from alcohol or tobacco use 48 hrs prior to the PAT, and until all blood samples were obtained.
4. Participants abstained from any caffeine intake prior to all blood draws.
5. Participants completed PAT to the best of their ability.

Limitations

1. The job of firefighting is unpredictable. In order to encompass external validity for this population a PAT was chosen as the exhaustive exercise for this population. It is possible that this protocol did not create enough muscle damage for reliable findings.

Delimitations

1. Participants for this study were limited to only male professional firefighters.
2. Participants for this study were limited to those considered non recreationally trained.
3. Participants for this study were recruited in the Dallas-Fort Worth area.

Significance of the Study

Complications from CVD are the leading cause of on-duty firefighter deaths (45% of on-duty fatalities) and a leading cause of morbidity in this population (Soteriades et al., 2005).

Through the implementation of proper physical fitness requirements, in addition to monitoring recovery, the onset of a CVD may be delayed or prevented. Markers of muscle damage (Mb), inflammation (TNF-α), and physical performance (hand grip, vertical jump, and sit-and-reach) following a PAT have not yet been characterized with professional firefighters. Due to the high incidents of CVD and musculoskeletal injury along with the high costs of workers compensation, a better understanding of the physiological responses experienced during the subsequent days post shift is necessary. This may help fire stations advocate for changes to shift rotations (i.e., 24 hours on 48 hours off, 48 hours on 96 hours off), implement methods to monitor fatigue, and create wellness initiatives in their departments. These findings would expand the research behind the physiological stress that professional firefighters undergo to enhance the efficacy of fire station teams and prevent debilitating injuries. Through this research, a gap will be narrowed in the tactical performance literature.

CHAPTER II

REVIEW OF LITERATURE

The purpose of this study is to determine how physical tasks specific to firefighting affect markers of muscle damage, CVD, and physical fitness in firefighters. Throughout this literature review, the characteristics of the profession of firefighting will be explained, including dangers unique to the profession, diseases associated with firefighting, and the typical lifestyle led by first responders. CVD, the leading cause of on-duty deaths, will also be discussed, including risk factors specific to firefighting. A link between inflammation and its direct relationship to CVD will also be given, including markers linking elevated levels to CVD and firefighters. Lastly, this review will summarize findings from previous research that utilized an exercise intervention with firefighters.

Firefighting

Firefighting can be defined as a constantly varying profession, with an increased amount of danger, when compared to other occupations (Gledhill & Jamnik, 1992). There are several factors that make firefighting a unique occupation. Cities and towns around the world employ firefighters both professionally and on a volunteer basis. The shift length is also unique. Professional firefighters typically perform shift work, meaning they work for 24 consecutive hours with the next 48 hours off. Some cities even have firefighters working 48 consecutive hours with the following 72 hours off. Unique hazards also play a role, including thermal, chemical, and psychological hazards, musculoskeletal injury, and the development of various chronic diseases in these individuals (Guidotti & Clough, 1992).

Guidotti and Clough (1992) cite the occupation of firefighting is made up of physical, thermal, chemical, and psychological hazards that are distinctive of profession. The amount of

risk associated with these hazards is dependent on the type of fire (structure, forest, vehicle, etc.), presence of chemicals, rescue required, and timeframe of the fire (Hill et al., 1972). With the improvements in self-contained breathing apparatuses and other protective gear, exposure to some of these hazards has been minimized, but even short duration exposures can be life threatening.

Exposure to extreme high temperatures is traditionally a common hazard the public associates with the profession of firefighting. This hazard can be increased with the combination of exertion from the individual and the insulating properties of the uniform. It is not uncommon for structure fires to burn at temperatures over 1,000 °F (Windisch et al., 2017), making the risk of burns to exposed skin and the airway upon inhalation common.

Carbon monoxide, hydrogen cyanide, nitrogen dioxide, sulfur dioxide, and hydrogen chloride are common chemical hazards that firefighters are exposed to during a structure fire, and make up the majority of the gases in smoke (Fabian et al., 2014). Firefighters are also exposed to a large amount of diesel fuel exhaust at their respective fire station. Chronic exposures to diesel fumes are associated with increased risk of asthma, lung disease, heart disease, and laryngeal cancer (Wheatley & Sadhra, 2004). More firefighters die every year from smoke and chemical exposure when compared to burns (Fabian et al., 2014). Hypoxic environments caused by smoke are the primary cause of these deaths (Fitzgerald & Flood, 2006). Firefighters working in these hypoxic environments experience decreases in physical and cognitive performance, thereby potentially making them unable to escape structure fires (Melnikov et al., 2017).

Firefighters can experience large amounts of psychological stress. This profession encourages running into life-threatening situations others are trying to escape. Guidotti and

Clough (1992) cite the loss of a victim, commonly a child, to be the most stressful experience for this population. Other than personal security, psychological damage can occur from witnessing pain, trauma, injury, or emotional loss of fellow coworkers and victims while on call (Guidotti & Clough, 1992).

Acute injuries that typically occur while on duty for firefighting are burns, falls, and injury from debris while fighting a structure fire (Karter & Molis, 2013). An increased risk of burns is based on the role played in fighting the fire and where the fire is located in the structure. Specifically, the highest rate of burns is in firefighting that involves an entry and exit, as well as fires in basements. Falls are strongly associated with firefighters due to wearing self-contained breathing apparatus (SCBA) gear and climbing ladders (Park et al., 2015). Despite being necessary to perform majority of tasks, SCBA gear decreases mobility and impairs normal gait patterns (Wang & Wang, 2022). Some firefighters are also known to take more chances when battling a fire, putting their lives in more danger.

Acute respiratory injuries often occur in this population due to smoke exposure. This danger is one of the most unique to this profession (Fabio et al., 2002). Banauch et al. (2013) found that 6 months following the collapse of the Twin Towers on September 11, 2001, many firefighters experienced episodes of bronchial hyperactivity. Smoke exposure is also often accompanied with burns and falls (Fitzgerald & Flood, 2006). The composition of particles and chemicals in smoke produced by a fire can affect the effects of smoke exposure, including irritation to the eye and lungs. The inhalation of smoke can increase bronchial hyperresponsiveness and bronchoconstriction, decreasing tidal volume and eliciting airway obstruction (Swiston et al., 2008). Minty et al. (1985) also found that smoke exposure increases

inflammation in the lungs and damages the integrity of the alveolar-capillary barrier (Minty et al., 1985).

Chronic diseases and conditions are prevalent among firefighters, due to inherent hazards of the occupation (e.g., smoke exposure) and lifestyle choices (e.g., diet). These include type 2 diabetes, obstructive pulmonary disease, and CVD (Nagaya et al., 2006). Nagaya et al. (2006) found that policemen and firefighters are at an increased risk to develop type 2 diabetes, as these individuals often have elevated values of BMI. Increasing physical activity and introducing nutritional interventions are more effective in improving insulin resistance, when compared to medication, among individuals diagnosed with type 2 diabetes (Carey et al., 2012). Unfortunately, adhering to an exercise program or dietary intervention is not mandated by a majority of fire departments throughout the United States (Yang et al., 2015). While on shift, firefighters are likely to choose unhealthy foods that are high in saturated fat to appeal to an entire crew. This only increases the likelihood of possessing higher fat mass, and a BMI classification of overweight or obese (Wooding et al., 2018).

Obstructive pulmonary disease is a group of lung diseases that block the amount of airflow reaching the lungs. The most common conditions classified in this group are emphysema and chronic bronchitis. Individuals suffering from these diseases typically experience shortness of breath, wheezing, and chronic coughing (Agusti et al., 2010). These diseases are commonly associated with breathing in smoke, radon, asbestos, and other particles. Firefighters are exposed to all of these chemicals and debris when performing occupational duties (Fabian et al., 2014). Fortunately, with the improvements in protective equipment and SCBA gear, exposure times have decreased. Rosenstock (1991) discovered firefighters have an increased risk for deaths from respiratory disease when compared to police officers, due to smoke exposure. The most common

chronic disease affecting firefighters, however, is CVD. This condition will be discussed further, as it is a focus of outcome measures in this study.

Cardiovascular Disease and Inflammation

CVD is the leading cause of death in the United States, killing one person every 36 seconds, and costs the United States over $200 billion dollars a year (Trogdon et al., 2007). The term "cardiovascular disease" encompasses coronary artery disease, heart failure, cardiomyopathy, aortic disease, peripheral vascular disease, and valvulitis (Anderson et al., 1991). A large amount of risk factors associated with developing CVD include age, sex, family history, smoking, dietary choices, hypertension, elevated cholesterol, diabetes, obesity, physical inactivity, and high amounts of stress (Anderson et al., 1991). Coronary artery disease is also referred to as ischemic heart disease. Coronary artery disease is known for having poor or no blood flow to the heart (Libby & Theroux, 2005). Over time, due to aging and poor dietary habits, plaque can accumulate in the arteries, reducing the diameter and compliance of the vessels (Libby & Theroux, 2005). When blood flow is decreased or stopped, acute myocardial infarctions can occur (Libby & Theroux, 2005). Angina is a common symptom that is associated with this type of CVD (Abrams, 2005). Heart failure occurs when the heart is unable to maintain a strong blood flow (Mosterd & Hoes, 2007). This results in chronic tiredness, reduced physical performance, and shortness of breath (Mosterd & Hoes, 2007). Heart failure can occur as a result of coronary heart disease, hypertension, cardiomyopathy, or vasculitis (Mosterd & Hoes, 2007). With heart failure, a decrease in cardiac output caused by a decrease in venous return is observed, resulting in a decrease in stroke volume (Braunwald, 2008). These physiological variables are critical to not only firefighting, but any physical fitness participation. Cardiomyopathy occurs when the muscles of the heart hypertrophy, thicken, and stiffen (Maron

et al., 1987). This ultimately reduces the effectiveness of the heart. Aortic disease is defined as an abnormal widening of the aorta, also known as an aortic aneurism (Milewicz et al., 2005). This widening of the aorta can cause weakening of the walls of the aorta and is accompanied by plaque formation along the wall (Milewicz et al., 2005). This plaque buildup can then detach from the wall, commonly referred to as an embolism, and lodge itself into other vessels blocking blood flow to the tissue being supplied (Milewicz et al., 2005). Aortic disease can also occur when blood fills the walls of the aortic vessels and accumulates in the walls of the aorta (Milewicz et al., 2005). This is referred to as aortic dissection. Peripheral vascular disease is a result of plaque formation in the peripheral blood supply (Palumbo & Melton, 1995). This disease is commonly known as atherosclerosis. If left untreated, peripheral vascular disease can stop blood supply to organs and muscles in the body, possibly causing organ failure (Palumbo & Melton, 1995). Valvulitis is another form of CVD that is diagnosed as chronic inflammation of the heart valves, commonly caused by rheumatic heart disease (Galvin et al., 2002).

Atherosclerosis is the leading cause of CVD. The pathogenesis of atherosclerosis is driven by oxidative stress and inflammation in the walls of the blood vessels, this develops slowly over many years (Ross & Glomset, 1976). This process starts with the oxidation of low-density lipoproteins (LDL; Ross & Glomset, 1976). These particles can get trapped in endothelium and can then be oxidized by reactive oxygen species (ROS; Ross & Glomset, 1976). ROS can be inactivated by eating diets high in antioxidants, such as glutathione peroxidase (Ross & Glomset, 1976). Conversely, high amounts of ROS are found in individuals with elevated blood pressure and among those who habitually smoke cigarettes (Falk, 2006). After being oxidized, LDLs can be engulfed by macrophages, causing them to develop a foamy exterior (Falk, 2006). This increases inflammation of the affected endothelium (Falk, 2006). As

inflammation increases, a cascade of cytokines and chemokines increase endothelial adhesion (Moore & Tabas, 2011). This dramatic increase in inflammation signals smooth muscle cells to proliferate and excrete collagen, leading to the development of fatty lesions commonly associated with atherosclerosis. CRP has been adopted as a marker of general inflammation and also has a direct correlation to atherosclerosis (Moore & Tabas, 2011). This protein is produced in the liver in response to interleukin-6 and helps oxidize LDL (Scott, 2004).

Inflammation is the body's response to protect against infection and injury. This process works to mobilize defensive cells to the site of injury or infection, decrease the spread of pathogens from the site of injury or infection to other parts of the body, kill those pathogens, and start the tissue repair process (Libby et al., 2002). Inflammation can occur anywhere in the body. Inflammation is a vital part of the repair process, but when the body is chronically inflamed, the response can damage healthy tissues (Libby et al., 2002). Acute inflammation is initiated when immune cells encounter an inflammatory stimulus, such as a pathogen, toxin, or an injured host cell (Ryan & Majno, 1977). When this stimulus binds to a receptor on an immune cell, a signaling cascade occurs that activates an increase in the production of cytokines and inflammatory mediators. These cytokines and mediators signal for the vasodilation and permeability of localized blood vessels, causing an increase in blood flow to the site of injury. This increase in vasodilation and permeability allows more fluid and immune cells to diffuse through the vessel and accumulate in the damaged tissues. Acute inflammation occurs in three distinct phases (Kushner, 1982). Phase 1 involves the influx of plasma containing lysosomes, antibodies, and platelets. The primary goal of this phase is to kill any pathogens located in the area, and stop any bleeding that may be occurring (Kushner, 1982). Phase 2 involves the influx of neutrophils. Neutrophils are white blood cells that undergo the majority of phagocytosis

(Kushner, 1982). Once in the muscle, neutrophils engulf bacteria and destroy them with enzymes and toxic peroxides. These white blood cells may also release reactive oxygen species which kill pathogens rapidly. Following the engulfment of bacteria, neutrophils die via apoptosis. Phase 3 involves the arrival of monocytes. Some monocytes, upon arrival, differentiate into macrophages, which remove pathogens, injured cells, and dying neutrophils via phagocytosis. Following this process, they are then removed from the muscle through the lymphatic system (Kushner, 1982). Once the site of injury is cleared of pro-inflammatory cytokines, anti-inflammatory mediators are then produced to finish the healing process. If the body is unable to switch from producing pro-inflammatory cytokines to anti-inflammatory cytokines, acute inflammation can turn chronic (Smith et al., 2008).

Chronic inflammation is a known contributing factor to the pathogenesis of different types of cancers, diabetes, and cardiovascular disease, whereas acute inflammation is a healthy physiological response to healing (Feghali & Wright, 1997). Chronic inflammation can also occur from persistent infections, regular exposure to toxins in the environment, and recurrent attacks of acute inflammation (Feghali & Wright, 1997). This type of inflammation differs from acute in more ways than just duration. Chronic inflammation can take months or even years to develop, whereas acute inflammation can occur and resolve itself within hours. There is also a difference in the cells infiltrating the inflamed area (Feghali & Wright, 1997). Chronic inflammation involves monocytes, macrophages, and lymphocytes, whereas acute inflammation primarily involves neutrophils (Landskron et al., 2014). The amount of fibrosis and injury to the vascular and muscular tissue also differs between the types of inflammation. During chronic inflammation, a large amount of fibrous tissue is produced, which is commonly associated with atherosclerosis (Rupprecht et al., 2020). Chronic inflammation is harder to detect because these

signs are not found (Feghali & Wright, 1997). Those with acute inflammation will commonly have local signs of inflammation, such as redness and swelling (Gabay & Kushner, 1999). Lastly, the resultant effects of each differs. Chronic inflammation results in tissue destruction and fibrosis (Feghali & Wright, 1997). Acute inflammation results in healing, abscess formation, and/or eventual chronic inflammation (Ryan & Majno, 1977).

Insight into the role of inflammation in atherosclerosis and CVD has dramatically grown over the past 20 years. A link between inflammation and atherosclerosis, which can be used to predict and diagnose CVD, has recently been shown (Hansson et al., 2006). Associations between visceral fat and markers of inflammation, including IL-6, TNF-α, and CRP, have also been shown. As fat mass increases, the number of macrophages also increases. The increase in macrophages is associated with a reduction in the body's production of adipokines that have anti-inflammatory properties (Gustafson, 2010). These markers of inflammation are also associated with CVD (Gustafson, 2010).

Cytokines control a multitude of processes for skeletal muscle growth, including cell survival, death, and differentiation (Dinarello, 2000). One of the most well researched cytokines, TNF-α, is known for its ability to induce apoptotic cell death (Saghizadeh et al., 1996). This cytokine is a primary marker of systemic inflammation and is secreted by macrophages as a result of injury or infection (Saghizadeh et al., 1996). This cytokine is referred to as the master regulator of inflammation (Saghizadeh et al., 1996). When levels of TNF-α increase, blood vessels vasodilate, causing an increase in blood to the injured area. Also, the permeability of the vessels increases, allowing more blood to leave the vessel and get into the injury site (Royall et al., 1989). Chronically elevated levels of TNF-α have been associated with Alzheimer's disease, cancer, depression, and type 2 diabetes (Royall et al., 1989). This cytokine also plays a major

role in bone remodeling by upregulating osteoclast activity (Steeve et al., 2004). In context of chronic inflammation, TNF-α is secreted and signals an increase in pro-inflammatory cytokines such as IL-1, IL-6, IL-1ra, and CRP, following the arrival of macrophages to the site of injury (Lee et al., 2003). As this cytokine is also associated with insulin resistance, levels are typically elevated in firefighters due to large amounts of stress regularly experienced (Wright-Beatty et al., 2014). A common recommendation for individuals with chronic inflammation caused by elevated TNF-α is to adhere to an exercise program, with the focus of decreasing TNF-α-producing body fat (Wright-Beatty et al., 2014).

Mb is a protein found in cardiac and skeletal muscle. This protein acts as an oxygen carrier that increases the rate of oxygen transportation within the muscle cell, and as a reservoir for oxygen. Mb is released from muscle tissues as a result of either muscle damage, possibly from exercise, and is an indicator of an increase in permeability of the muscle membrane and other pro-inflammatory processes. Mb levels also increase following a myocardial infarction (Montague & Kircher, 1995). This marker is a suitable indicator of muscle damage because it is released directly into the blood stream from the muscle (Sayers & Clarkson, 2003).

CRP is a protein made in the liver in response to increased inflammation. This protein is synthesized in response to elevated levels of IL-6 (Pepys & Hirschfield, 2003). When inflammation is high, white blood cells secrete IL-6, which is transported to the liver. This signals the liver to secrete CRP (Pepys & Hirschfield, 2003). During dramatic incidences of trauma, infections, and tissue necrosis, levels of CRP can increase 10,000-fold (Black et al., 2004). Once secreted by the liver, CRP binds to the phosphocholine receptors of bacteria. Following the binding of CRP to the bacteria, macrophages are stimulated to engulf the bacteria (Du Clos, 2000). Normative blood values for this metabolite are typically between 0.8 to

3.0mg/L (Pepys & Hirschfield, 2003). CRP is nonspecific, as inflammation, infection, trauma, and allergic reactions can all raise CRP levels in the blood. High plasma concentrations of CRP have been associated with CVD. It is important to note that elevated levels of CRP are not the cause of CVD, but represent elevated levels of inflammation, which are a known cause of CVD. Atherosclerosis leads to elevated levels of macrophage and cytokine production, including IL-6, causing the liver to produce CRP. CRP may be a useful marker that quantifies the significance or extent of atherosclerosis that someone is unknowingly undergoing. Low risk should be considered with a value of < 1 mg/L, intermediate risk of 1 to 3 mg/L, and high risk > 3 mg/L (Danesh et al., 2004). These levels should be combined with family history and health habits, including physical activity.

CVD is also the leading cause of mortality in professional firefighters (Melius, 2001). It has been shown that first responders, including firefighters, have some of the highest levels of CVD in the nation (Baird, 2022). Despite the vigorous physical activity required in this occupation, these bouts are typically interspersed with long durations of inactivity, increasing the likelihood of obesity. Obesity is a leading predictor of CVD. In one study by Smith et al. (2012), 51.7% of participating firefighters were obese. The inherent work of this occupation requires firefighters to be able to sustain high metabolic work outputs during bouts of fire suppression (Sempf & Thienes, 2022). The combination of vigorous activity and thermal strain from the environment and the added 60-80 lbs of gear significantly increases cardiovascular strain. Firefighters possessing increased physical fitness perform tasks safer and faster (Rhea et al., 2004). There are many in this population who are undertrained and possess an unhealthy body composition and associated concentration of blood markers indicative of metabolic health. The occupation also shows increase likelihood of increasing these risk factors. Also, as firefighters' careers lengthen, risk factors of CVD may increase. Indeed, Soteriades et al. (2011) reported an

increase in obesity, as measured by BMI, by 5% over 5 years.

A majority of risk factors associated with CVD are modifiable. Yusuf et al. (2020) found tobacco use, low amounts of physical activity, and a diet comprised of low-nutrient dense foods as behavioral risk factors strongly associated with CVD (Yusuf et al., 2020). Metabolic risk factors, including hypertension, elevated cholesterol, and an increased waist-to-hip ratio, are other risk factors strongly associated with CVD (Yusuf et al., 2020). Lastly, low levels of education, depression, lack of grip strength, and chronic exposures to air pollution also elicited a significant positive relationship with CVD (Yusuf et al., 2020). As previously mentioned, firefighters commonly exhibit sedentariness (Elliot et al., 2004), rely heavily on smokeless tobacco to stay alert (Haddock et al., 2011), and make poor food choices (Farioli, et al., 2014).

Despite popular belief, only 1 to 5% of a firefighter's career is suppressing fires, and 65% of their time is spent performing station and nonemergency duties (Guidotti & Clough, 1992). The combination of shiftwork and the variable nature of the profession can make adhering to a proper diet difficult, making fast food a viable option (Banes, 2014). Fire stations across the United States are not uniform. Some facilities budget funds for fitness equipment, while others do not (Sokoloski et al., 2020). Departments also typically do not strictly mandate adherence to an exercise training program, and even fewer departments budget for advice or programming from a strength training professional. In summary, obesity, poor dietary habits, and long bouts of inactivity can increase the risk of CVD in this population (Soteriades et al., 2005).

Cardiovascular Disease and Firefighters

Firefighters are commonly overweight and possess low levels of physical fitness. However, exercise interventions can elicit improvements in fitness levels, risk factors of CVD, and injury rates in this population (Ras et al., 2022). In my pilot work, improvements in measures of physical fitness, including mean power, VO_{2max}, muscular endurance, and time to exhaustion during a VO_{2max} test, were recorded in professional firefighters following 6 months of group exercise (Sokoloski et al., 2020). We also found improvements in flexibility in the low back and hamstrings (Sokoloski et al., 2020). Firefighter performance has also been studied following exercise interventions. Pawlak et al. (2015) developed a unique exercise protocol that utilized equipment found in a fire station (e.g., hoses, ladders, sledgehammers). Following 12 weeks of a circuit style training intervention, improvements in time to complete a simulated fire ground test, body mass, fat mass, and BMI were improved (Pawlak, 2015).

Due to the large prevalence of CVD attributed to arteriosclerosis in firefighters, a method to measure vascular health, flow mediated dilation (FMD), has been proposed as a viable method to determine the risk of CVD in this population. Getty et al. (2018) measured changes in FMD, systolic blood pressure (SBP), diastolic blood pressure (DBP), carotid artery intima media thickness (IMT), BMI, fat mass (FM), high density lipoproteins (HDL), triglycerides (TRG), and fitness variables including VO_{2peak}, 2-minute stair climb, max effort plank, and max effort wall sit following a 4-week fitness intervention with volunteer firefighters. Following the exercise intervention, improvements were observed with SBP, DBP, BMI, FM, HDL, TRG, and wall sit time (Getty et al., 2018). While adherence to traditional exercise programs for 4 weeks may not be of sufficient duration to observe improvements in these variables (Getty et al., 2018), functional fitness interventions have not been regularly employed.

Low levels of cardiopulmonary fitness are a major concern in this tactical population. Abd El-Kader (2010) compared aerobic versus anaerobic exercises in an effort to determine the optimal modality of exercise to improve cardiopulmonary fitness in firefighters. Forty firefighters were randomly selected complete aerobic training or anaerobic training. Firefighters exercised four times per week for 3 months. Outcome measures included resting SBP, DBP, heart rate, and minute ventilation, and VO_{2max}. Following the intervention, those who completed the aerobic training intervention had decreased resting SBP, DBP, and heart rate. Those in this group also experienced improvements in resting ventilation and VO_{2max}. No statistically significant decreases in resting SBP, DBP, or heart rate were found among those who completed the anaerobic training. This group, similar to those in the aerobic group, improved in resting ventilation and VO_{2max}. Aerobic exercise may therefore be the more appropriate modality of exercise to improve levels of cardiopulmonary fitness in firefighters (Abd El-Kader, 2010).

High-intensity exercise training has increased in popularity among firefighters. This may be due to its direct similarities to the firefighting, with anaerobic bouts separated by short bouts of rest. Jahnke et al. (2015) surveyed 625 male firefighters and obtained their demographics and exercise habits. Approximately 33% responded that they engage in high-intensity training. Firefighters engaging in this type of exercise were approximately half as likely to have a BMI classification of obese, and were more than twice as likely to meet fitness requirements of firefighters (Jahnke et al., 2015).

The effects of acute bouts of exercise among firefighters have also been characterized in the literature. Fitness norms have been established (Storer et al., 2014), fitness has been correlated to job performance (Rhea et al., 2004), and cardiovascular strain has been quantified among firefighters (Smith et al., 2016).

Rhea et al. (2004) determined which measures of physical fitness best correlate to firefighting performance. Firefighters were recruited and performed multiple tests, while different measures of physical fitness were analyzed. Job-related tasks, such as a hose pull, dummy drag, stair climb, and an equipment hoist, were also performed. Significant correlations between overall job performance and VO_{2max}, upper body strength, grip strength, upper and lower body endurance, and 400-meter sprint time were found (Rhea et al., 2004). The authors concluded that firefighters should not limit their training to one aspect of physical fitness.

When any individual is exposed to excessive temperatures, the risk of experiencing a cardiac event is increased (Kang et al., 2016). This is a risk that firefighters are commonly subjected to. Angerer et al. (2008) studied heart rate and associated electrocardiogram, core temperature, fluid loss, and blood pressure responses to firefighting simulated tasks. During the fire simulation trial, body temperature significantly increased 0.9 °C, average heart rate rose to 177 bpm, and body weight decreased due to a loss of fluid by 0.6 kg. This research team concluded that fitness levels of firefighters should be elevated to handle the excess amount of cardiovascular strain when exposed to heat (Angerer et al., 2008).

Firefighters are exposed to large quantities of sympathetic stimulation, stress, and anxiety while on shift. During moments of stress and anxiety, salivary alpha-amylase (sA-A) and cortisol (sC) are produced by the body. Perroni et al. (2009) studied the salivary concentrations of each of these hormones, along with mood states and levels of anxiety in firefighters following a simulated firefighting intervention (i.e., a three-story ladder ascent and descent, 250 m run, and completing a maze in a dark chamber). During the intervention, firefighters spent 63% of the time working above 85% of their respective age-predicted heart rate. Following the 12-minute intervention, peak lactate reached 9.2 mM and rating of perceived exertion reached a 16 out of

20. Thirty minutes following the completion of the task, sA-A increased 174% and sC increased 109%. This increase was attributed to the intense physical stress experienced by these firefighters (Perroni et al., 2009).

Exercise and Its Effectiveness With Decreasing Injury Risk in Firefighters

Functional Movement Screening (FMS) has recently increased in popularity as a method to identify areas of musculoskeletal weakness. In this assessment, seven exercises are judged by a certified coach on a 1 to 3 scale (Teyhen et al., 2012). Receiving a score below 14 has been identified as being associated with an increased risk of musculoskeletal injury. Stanek et al. prescribed corrective exercises to firefighters who scored below a 14 on the FMS assessment. Following the 8-week exercise prescription, an improvement of 69% from pretest to posttest was found, thus decreasing the risk of musculoskeletal injury (Stanek et al., 2017).

The profession of firefighting carries an elevated risk of musculoskeletal injury when compared to most other occupations (Butler et al., 2013). Chronic low back pain is a leading cause of lost work time among those in this profession. Mayer et al. (2015) designed an exercise intervention focusing on improving back and core muscular endurance with firefighters. Following 24 weeks of exercise, firefighters had 12% greater endurance in the musculature of the lower back and 21% greater endurance in the musculature of the core, possibly decreasing the likelihood of injury to this susceptible area (Mayer et al., 2015).

Search and rescue tasks are commonplace for firefighters. During a fire, first responders are required to crawl on the ground to put their bodies as far as possible from burning ceilings. Davis and Gallagher (2014) investigated the physiologic demands placed upon firefighters when performing this form of locomotion. Twenty-five male firefighters participated in this study that required them to crawl, wearing full gear, while simultaneously performing a simulated search

and rescue. The duration of the exercise lasted 14.4 to 21.0 minutes. Researchers found a dramatic increase in heart rate of 165% compared to rest. Based on the findings, search and rescue tasks increase cardiovascular strain and consequently the risk of injury in firefighters (Davis & Gallagher, 2014).

Correlations between a large variety of physical fitness measures and the physical demands of firefighting are critical to identify specific fitness tests, along with designing and implementing a fitness program to improve work performance in first responders. The vigorous demands of firefighting commonly include pulling fire hoses, carrying heavy loads up and down ladders and stairs, breaking down doors and walls, as well as dragging victims to safety. Sheaff (2009) found that VO_{2max} and anaerobic fatigue resistance during the Wingate Anaerobic Cycling Test were the best predictor of firefighter performance on the PAT. Choosing assessments that strongly correlate to these tasks, as well as designing exercises to improve these abilities, are necessary.

Vertical Jump

The body's ability to produce power is imperative to performance in sport and physical activity (Harman et al., 1991). A commonly used tool to assess lower-body power is vertical jump. Vertical jump tests have been used to assess performance in weightlifters, power lifters (Garhammer & Gregor, 1992; Garhammer, 1993), swimmers (Ballow, 1979), and volleyball (Ziv & Lidor 2010), football (Sawyer et al., 2002), and basketball players (Ziv & Lidor, 2010). This assessment has also been used to assess changes across different periodization models of training (Hedrick & Anderson, 1996). Anaerobic power production is a predictive measure of firefighting performance, including tasks that incorporate charged hose advances and rescue mannequins (Michaelides et al., 2011).

Grip Strength

Muscular strength can be assessed by measuring the maximal amount of force the body can produce at one time. Decreased amounts of muscular strength are associated with a decreased ability to perform activities of daily living, decreased independence, and an increased risk of falls (Hasegawa et al., 2008; Landi et al., 2012). Muscular strength has been assessed in many populations, including tactical populations (Stone et al., 2020).

Measuring muscular strength via a hand grip dynamometer has also been well documented as a reliable and valid assessment of total body strength (DeBeliso, 2015). An added benefit to this test is that it is considered "non-fatiguing." This method is typically performed by squeezing a hand grip dynamometer, as hard as possible for 1 to 2 seconds, while keeping the elbow at 90 degrees. Participants are typically given two to three trials per hand, and the best repetition with each hand is combined to get their final score (Riebe et al., 2018).

Handgrip strength has been correlated to firefighting performance. A positive relationship between hand grip strength and firefighter performance, specifically performing during the hose drag exercise, has been documented (Rhea et al., 2004).

Flexibility

Flexibility is the body's ability to move a joint through a full range-of-motion (Riebe et al., 2018). Common modalities of improving flexibility include both active and passive stretching, dynamic stretching, and proprioceptive neuromuscular facilitation (Riebe et al., 2018). Range-of-motion can be affected by the swelling of a joint, warmup, muscle viscosity, and tightness of surrounding ligaments and tendons (Bushman, 2016). Low amounts of flexibility are associated with an increased risk of musculoskeletal injury (Hrysomallis, 2009).

The sit-and-reach assessment quantifies flexibility of the musculature in the lower back and hamstring. This assessment has been used to measure changes in flexibility among athletic populations (Rodríguez-García et al., 2008), tennis players (Chandler et al., 1990), and firefighters (Butler et al., 2013). Low back pain can be caused by poor flexibility in the erector spinae and hamstrings (Stutchfield & Coleman, 2006). The prevalence of low back pain is common in the profession of firefighting (Damrongsak et al., 2018). The effects of exercise on preventing low back pain, and thus decreasing work-related injuries in professional firefighting, has been studied (Butler, 2013; Noh et al., 2018). Adherence to an exercise intervention was found as an effective intervention for reducing perceived levels of low back pain and decreasing risk of injury to this musculature.

Summary

Following strenuous exercise, performance in athletic populations decreases for up to 72 hrs post-exercise (Eston, 2003). Regardless of readiness or soreness, firefighters are expected to perform their required duties, leaving them more susceptible to injury. The occupation of firefighting is unique. This is due to the unpredictability of the job, exposure to hazardous chemicals, and the physical workload. Firefighters are also prone to CVD, which may be caused by elevated levels of inflammation, poor recovery, inadequate nutrition, or a sedentary lifestyle. The benefits of exercise interventions on these first responders has been studied. However, to date, performance, muscle damage, or markers of CVD in firefighters following work-related tasks has not been characterized.

CHAPTER III

METHODS

Experimental Approach to the Problem

In this study, markers of muscle damage, inflammation, and muscular performance in professional firefighters following a PAT were measured. All participants were required to perform baseline measures to assess markers of muscle damage, including CRP, TNF-α, and Mb. Firefighters were also required to perform non-fatiguing measures of physical fitness, including handgrip strength, vertical jump, and a sit-and-reach test. Participants were tested 1 hour prior to the PAT, and 3 hours, 24 hours, and 48 hours post-PAT.

Participants

Twenty-four male professional firefighters, from the Dallas-Fort Worth area, were recruited using convenience sampling. Firefighters were recruited primarily from the fire stations of Addison and Carrollton via word of mouth. The following inclusion criteria were met: a) must be employed as a full-time firefighter, b) have no limiting musculoskeletal injury that would preclude them from exercise, c) identify as male, d) not adhering to any specialized diet (i.e., vegetarian). Firefighters were excluded from participation if they: a) were unable to perform any task within the PAT, b) were unable to attend or perform any task in the testing visits, c) report the regular consumption of any medication that may influence inflammatory or CVD markers, d) perform any further exercise over the following 48 hours, as this may affect results, e) consume any performance enhancing drugs (e.g., testosterone replacement therapy), and f) are diagnosed with CVD, pulmonary disease, or metabolic disease. Firefighters were excluded from participation in the study if they reported undergoing a stressful work shift or an atypical night of sleep that they felt would negatively impact their ability to participate. Females were eliminated

from this study due to an inability to control for menstrual cycles in the scheduling of PAT facilities.

Preliminary Testing

All baseline testing occurred at the location of the PAT, 4798 Airport Parkway, Addison, TX, starting between 0700 and 0900 hours. Firefighters arrived in a fasted state (i.e., 10-12 hour fast). During the preliminary visit, each subject provided written consent approved by the Institutional Review Board at Texas Woman's University and completed a medical history questionnaire and the Physical Activity Readiness Questionnaire Plus (PAR-Q+). Preliminary testing was required due to the nature of scheduling at this fire department (24 hours on and 48 hours off). A double baseline approach ensured the participants in this study did not have elevated blood markers or decreased physical performance measures prior to participation.

Baseline Blood Draw

Following the completion of the necessary paperwork, participants sat upright for 5 minutes. A 10 mL blood sample was taken from the antecubital vein of the right arm. Blood samples were collected into BD Vacutainer K2 EDTA 10 ml tubes and immediately put on ice and transported to Texas Woman's University (Denton, TX) to be centrifuged at 3000 RPM for 10 min at 4 °C. Plasma samples were then aliquoted into cryotubes to be frozen at -80 °C for further analysis.

Anthropometrics

Basic anthropometric data was also measured. Height (cm) was measured using a stadiometer (Perspective Enterprises, Kalamazoo, MI) and weight (kg) was measured on a digital scale (Tanita, Arlington Heights, IL). Body mass index was calculated from these measures using the following equation:

$$\text{BMI} = \frac{\text{mass (kg)}}{height^2(m^2)}.$$

Following the anthropometrics, participants were given a standardized snack of 4 kcal/kg of body weight (Clif Bar & Company, Emeryville, CA; 250 kcal per 68 g serving; 18% fat, 68% carbohydrate, 14% protein) 15 minutes prior to beginning a dynamic warm-up.

Vertical Jump

Following the consumption of the snack and a 15 minute rest period, participants underwent a standardized warmup found in Table 3.1. Following the dynamic warmup, participants were instructed on how to perform a counter movement vertical jump. This test was performed using a Just Jump Mat (Perform Better, Fredonia, NY). Participants performed three vertical jumps, and the highest trial was used for data analysis.

Table 3.1

Dynamic Warm-Up

Exercise	Reps
Jumping Jacks	20
Knee Pull to Chest	5
Reverse Lunge and Reach	5
Walking Toe Touch	5
Quad Pull and Reach	5
Shin Pull	5
Arm Circles	10
Trunk Rotations	5

Hand Grip

Administration of hand grip dynamometer was in accordance with the recommendations of the American Society of Hand Therapists. Firefighters sat with their shoulders adducted, elbows flexed 90°, and their forearms in neutral rotation. Firefighters were then asked to "squeeze as hard as possible" and given consistent verbal encouragement to squeeze "harder, harder, harder" during a 4.0 to 5.0-second effort. Two trials were allowed with each hand, with a 30-second rest between trials. The best scores of each hand was added together and averaged before being used for data analysis.

Flexibility

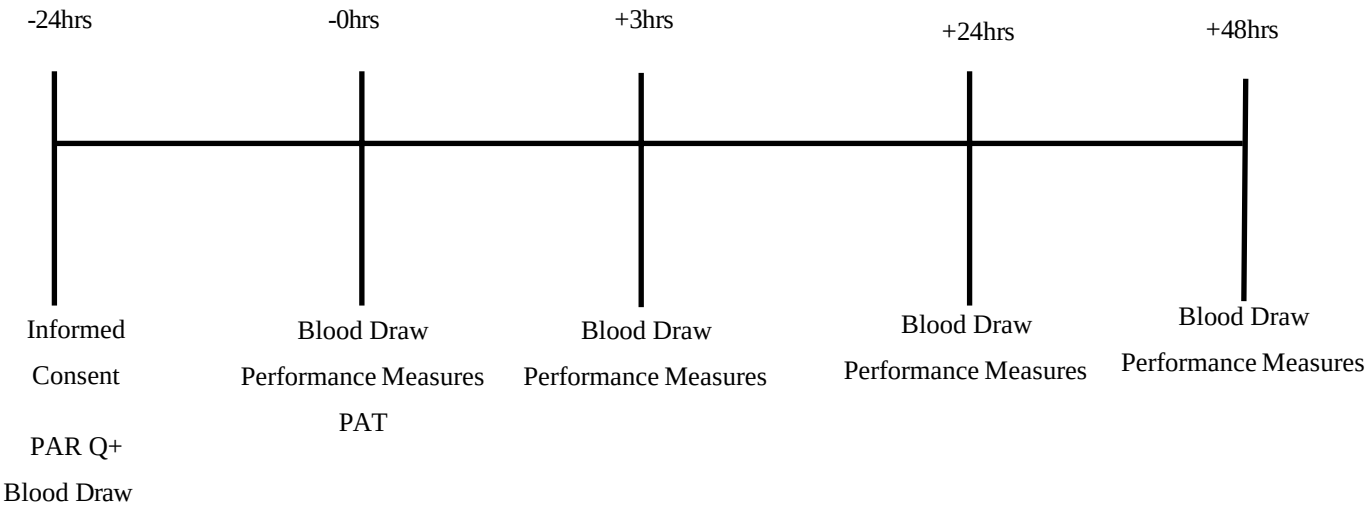
Trunk and hamstring flexibility was measured next using a sit-and-reach test (Novel Products, Inc., Rockton, IL). For this test, firefighters removed their shoes and sat with their feet flat against the box. Keeping their legs extended and their hands overlapped, the participants reached forward slowly and pushed the pin on the box as far forward as possible. Participants were asked to hold the terminal position for 2 seconds and keep their knees extended throughout the test.

Post-Testing Procedures

Following the PAT, firefighters immediately took off all firefighter equipment and rested. Baseline measures, including a blood draw, vertical jump, hand grip, and a sit-and-reach test, were administered 3 hrs after completion of the PAT. Firefighters were then sent home and returned to complete the same procedures 24 hrs and 48 hrs post-PAT at their respective fire station. A timeline of events can be seen in Figure 3.1.

Figure 3.1

Study Timeline for a Given Treatment



Physical Abilities Test

Firefighters performed two rounds of identical PATs. The PAT consisted of 10 events: a) 500-meter row, b) ladder climb, c) hose drag, d) stair climb with hose pack, e) hose pull, f) crawl, g) stair decent, h) Kaiser machine sledgehammer strikes, i) hose couple, and j) dummy drag. Following the first PAT, firefighters immediately performed the identical PAT again with no rest period separating the tests. A detailed description of each test can be found in Table 3.2.

Table 3.2

Physical Abilities Test

Event	Description
500-meter row	Row 500 meters on a Concept 2 rower on resistance setting 5 out of 10. A maximum of four minutes will be permitted.
Ladder Climb	The firefighter, wearing the proper PPE, shall climb a 75' aerial ladder, fully extended, at a 72- degree angle and return to the starting position on the pedestal. There is a five- minute time maximum. Each rung must be touched in the assent and decent.
Hose Drag	The firefighter will drag a 150 ft of charged hose 100 ft. The firefighter will then pull 25 ft of the charged hose around a 90°. If the firefighter fails to properly complete the task, he / she must be told to complete the task before moving on.
Stair Climb with Hose Pack	The firefighter climbs the stairs while carrying the hose pack. If the firefighter fails to properly complete the task, he must be told to complete the task before moving on. The hose must be carried, not dragged or tossed. If it is, the firefighter must return to the point the improper action took place and continue. After reaching the 3 floor, the firefighter must place the hose pack in the red square before moving on to the next step. Skipping steps are not allowed while climbing the stairs.
Hose Pull	The firefighter must pull two sections of a hose up via the provided rope one at a time. The hand over hand method is to be used. The firefighter is not allowed to pull the rope over the railing to utilize the railing like a pulley. The firefighter may rest the rope on the railing if needed. If the firefighter utilized the railing as a pulley, the advantage gained will be eliminated by stopping the firefighter and requiring him/her to lower the hose to the position where the advantage began. The firefighter will then begin to raise the hose again.
Crawl	Starting at the designated cone, the firefighter shall crawl on their hands and knees 64 ft.
Stair Decent	Carry the hose pack downstairs. The hose must be carried, not dragged or tossed. If it is, the firefighter must return to the point the improper action took place and continue. After reaching the first floor, the firefighter must place the hose pack in the red square, before moving on to the next step. Skipping steps are not allowed on decent of the stairs.
Kaiser Machine	Utilizing the provided sledge, strike the weight with the sledge to move the weight the prescribed distance. The firefighter's hands must rise to their head-level on the up stroke.

Hose Couple	The task must be completed properly before the firefighter moves to the next step. If the firefighter fails to properly complete the task, he must be told to complete the task before moving on. Two sections of 3 in hose will be stretched out 3 ft apart with a nozzle at the end of the hose 3 ft away. The firefighter will pull the first section of hose to the second section of hose and couple them to gather. The firefighter will then pull both sections to the nozzle and couple the nozzle to the hose.
Dummy Drag	The firefighter shall move the dummy the prescribed distance (40 ft), utilizing any carry they desire.

Blood Collection Analyses

All blood samples were obtained in the morning (starting between 0700 and 0900 hours), with the exception of the first blood draw post-PAT, in a fasted state (i.e., 10-12 hours) at the Addison Fire station. Concentrations of CRP, Mb, and TNF-α were analyzed with the Luminex MagPix® using a custom bead panel kit (EMD Millipore Corporation, Bellerica, MA, USA). Researchers followed the manufacturer's instructions for all procedures, and all measures were performed in duplicate. Measured serum values found within expected normal physiological reference interval were recorded as the average of the duplicate results. Values that fell outside of expected physiological reference interval were removed as outliers and the single measure within range was recorded.

Statistical Analysis

An *a prior* power analysis (G*power 3.1.9.2, Dusseldorf, Germany) was conducted to determine the minimum sample size required to find statistical significance. With a desired power level of .80, an alpha (α) level set at .05, and a moderate effect size of .25 (*f*), it was determined that 24 participants would be required for this study. Repeated measures analysis of variance (RM ANOVA) was performed to determine differences for all variables between pre-

and post-PAT time points. Tukey post-hoc testing was used to determine differences between time points when a main effect was observed. Pearson's *r* product moment correlation coefficient was used to explore the relationship between BMI, markers of muscle damage and inflammation, muscular performance, and performance on the PAT. Significance in this study was set at $p < 0.05$. All statistical analyses were performed using SPSS statistical software (IBM SPSS Statistics v.28, Armonk, NY, USA).

CHAPTER IV

RESULTS

Participant Characteristics

Twenty-six professional male firefighters were initially recruited. Two participants were dropped from data collection due to scheduling conflicts. Twenty-four firefighters completed all procedures. Inflammatory and muscle damage measures were not obtained on some participants due to error during blood marker analysis in the pre- and post-PAT periods. Descriptive characteristics of the participants in this study (n = 24), as well as performance on the PAT (min), are outlined in Table 4.1.

Table 4.1

Descriptive Characteristics of Participants

Variable	Mean ± SD
Age (yrs)	31.2 ± 4.3
Height (cm)	178.9 ± 5.7
Weight (kg)	94.2 ± 8.9
BMI (kg/m^2)	29.5 ± 2.9
PAT Performance (min)	31.2 ± 6.1

Note. Values are presented as mean ± SD. BMI = Body Mass Index, calculated as body mass (kg) / height (m^2), PAT = Physical Abilities Test.

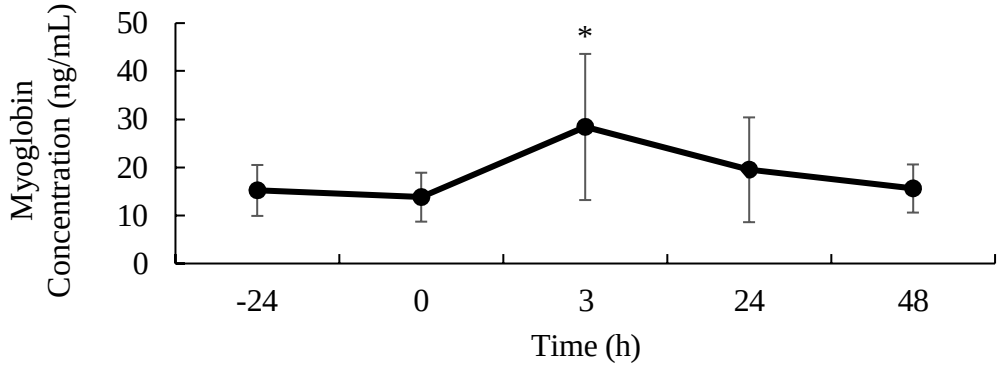
Muscle Damage and Inflammatory Response

Myoglobin Concentrations

There was a main effect for Mb concentrations (ng/mL) across time (-24, 0, 3, 24, 48 hours; $p < 0.001$). In addition, Mb at 3 hours post-PAT was increased compared to -24 ($p > 0.05$), 0 ($p < 0.001$), and 48 hours ($p = 0.003$). No other differences in Mb were observed ($p > 0.05$; see Figure 4.1).

Figure 4.1

Myoglobin Concentrations



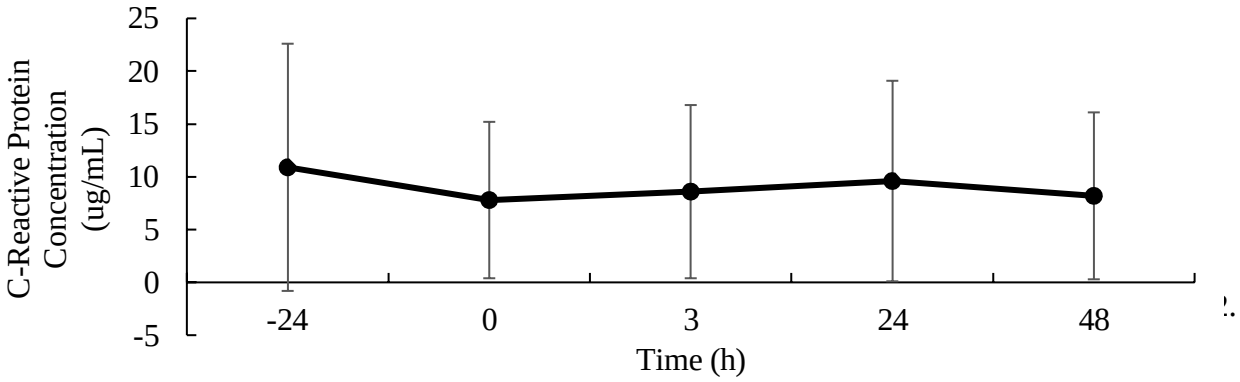
Note. Values are presented as mean ± SD; -24 = 24 hours prior to PAT, 0 = Immediately following PAT, 3 = 3 hours post-PAT, 24 = 24 hours post-PAT, 48 = 48 hours post-PAT, * = significant difference compared to -24 h, 0 h, and 48 h. n = 21.

C-Reactive Protein Concentrations

There was no main effect for CRP concentrations (ug/mL) across the time (p > 0.05; see Figure 4.2).

Figure 4.2

C-Reactive Protein Concentrations



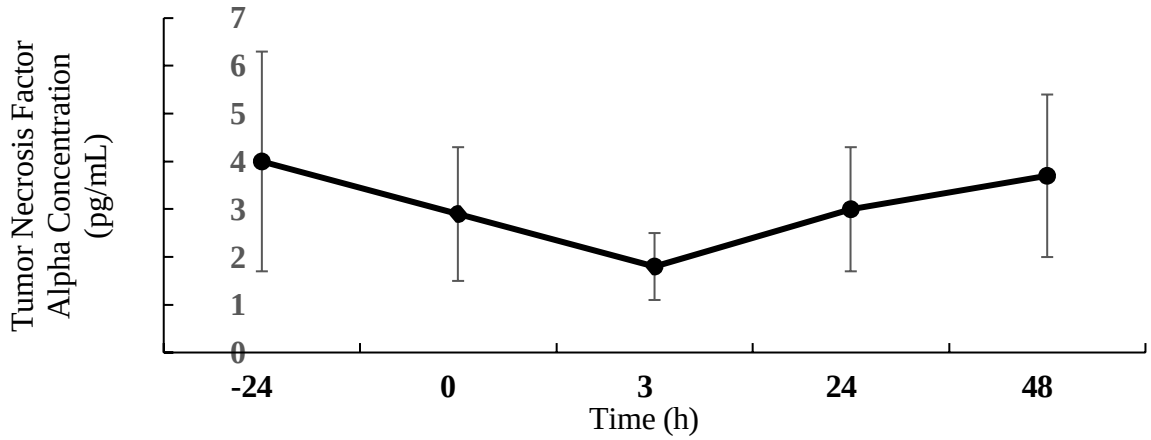
Note. Values are presented as mean ± SD; -24 = 24 hours prior to PAT, 0 = Immediately following PAT, 3 = 3 hours post-PAT, 24 = 24 hours post-PAT, 48 = 48 hours post-PAT, * = significant difference compared to -24 h, 0 h, and 48 h. n = 24.

Tumor Necrosis Factor Alpha Concentrations

There was no main effect for TNF-α concentrations (pg/mL) across time ($p > 0.05$; see Figure 4.3). A summary of all values can be found in Table 4.2.

Figure 4.3

Tumor Necrosis Factor Alpha Concentrations



Note. Values are presented as mean ± SD; -24 = 24 hours prior to PAT, 0 = Immediately following PAT, 3 = 3 hours post-PAT, 24 = 24 hours post-PAT, 48 = 48 hours post-PAT, *n* = 8.

Table 4.2

Blood Markers

Time	Mb (ng/mL)	TNF-α (pg/mL)	CRP (ug/mL)
-24 hr	15.2 ± 5.3	4 ± 2.3	10.9 ± 11.7
-0 hr	13.8 ± 5.1	2.9 ± 1.4	7.8 ± 7.4
+3 hr	38.4 ± 15.2	1.8 ± 0.7	8.6 ± 8.2
+24 hr	19.5 ± 10.9	3 ± 1.3	9.6 ± 9.5
+48hr	15.6 ± 5	3.7 ± 1.7	8.2 ± 7.9

Note. Results are documented as mean ± SD. Mb = Myoglobin; TNF-α = Tumor Necrosis Factor Alpha; CRP = C-Reactive Protein.

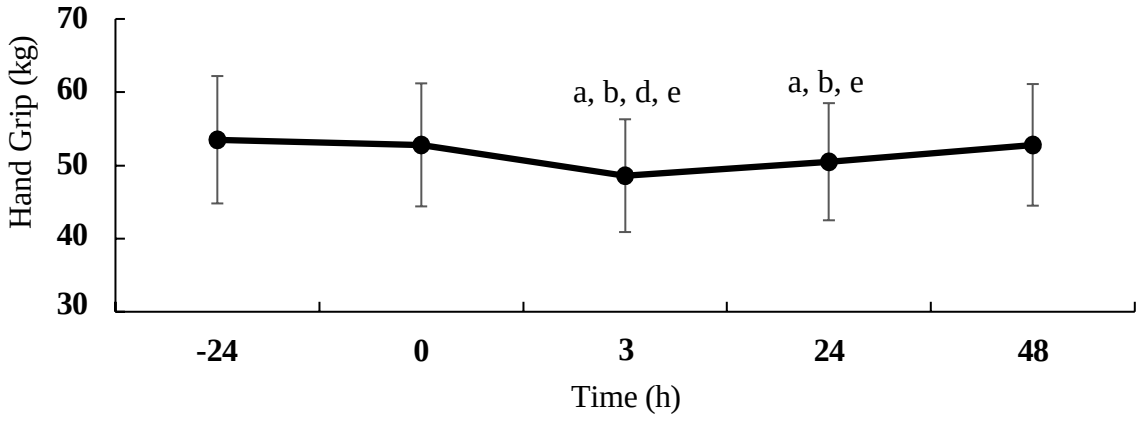
Performance Measures

Hand Grip Performance

There was a main effect for hand grip strength (kg) across time (-24, 0, 3, 24, 48 hours; $p = 0.007$). Hand grip performance at 3 hours post-PAT was decreased compared to -24 (p 0.001), 0 ($p < 0.001$), 24 ($p = 0.001$), and 48 hours ($p < 0.001$). In addition, hand grip performance at 24 hours post-PAT was decreased compared to -24 hours ($p < 0.001$), 0 ($p = 0.004$), and 48 hours ($p < 0.001$). No other differences in hand grip were observed ($p > 0.05$; see Figure 4.4).

Figure 4.4

Hand Grip Performance



Note. Values are presented as mean ± SD; -24 = 24 hours prior to PAT, 0 = Immediately f following PAT, 3 = 3 hours post-PAT, 24 = 24 hours post-PAT, 48 = 48 hours post-PAT, a = significant difference compared to -24 h, b = significant difference compared to 0 h, d = significant difference compared to 24 h, e = significant difference compared to 48 h. $n = 24$.

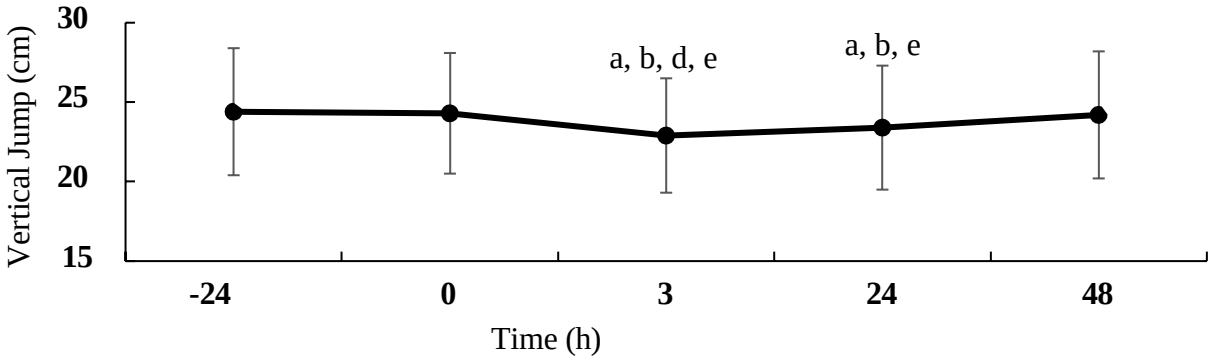
Vertical Jump Performance

There was a main effect for vertical jump (cm) across time (-24, 0, 3, 24, 48 hours; $p < 0.001$). Vertical jump performance at 3 hours post-PAT was decreased compared to -24 ($p < 0.001$), 0 ($p < 0.001$), 24 ($p = 0.020$), and 48 hours ($p < 0.001$). In addition, vertical jump

performance at 24 hours post-PAT was decreased compared to -24 ($p = 0.002$), 0 ($p = 0.005$), and 48 hours ($p < 0.001$). No other differences in vertical jump scores were observed ($p > 0.05$; see Figure 4.5).

Figure 4.5

Vertical Jump Performance



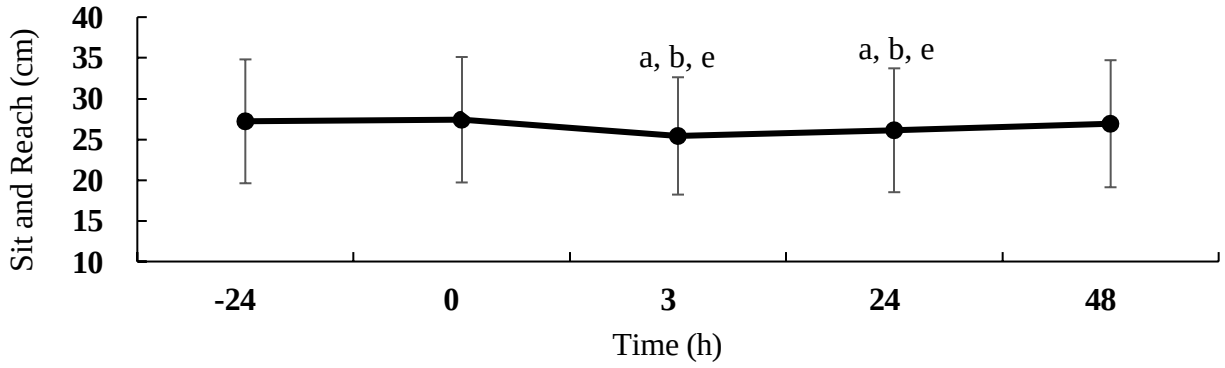
Note. Values are presented as mean ± SD; -24 = 24 hours prior to PAT, 0 = Immediately following PAT, 3 = 3 hours post-PAT, 24 = 24 hours post-PAT, 48 = 48 hours post-PAT, a = significant difference compared to -24 h, b = significant difference compared to 0 h, d = significant difference compared to 24 h, e = significant difference compared to 48 h. n = 24.

Sit-and-Reach Performance

There was a main effect for the sit-and-reach (cm) across time (-24, 0, 3, 24, 48 hours; $p < 0.001$). Sit-and-reach performance at 3 hours post-PAT was decreased compared to -24 ($p < 0.001$), 0 ($p < 0.001$), and 48 hours ($p < 0.001$). In addition, sit-and-reach performance at 24 hours post-PAT was decreased compared to -24 ($p < 0.001$), 0 ($p < 0.001$), and 48 hours ($p = 0.013$). No other differences in sit-and-reach were observed ($p > 0.05$; see Figure 4.6). A summary of all performance measures can be found in Table 4.3.

Figure 4.6

Sit-and-Reach Performance



Note. Values are presented as mean ± SD; -24 = 24 hours prior to PAT, 0 = Immediately following PAT, 3 = 3 hours post-PAT, 24 = 24 hours post-PAT, 48 = 48 hours post-PAT, a = significant difference compared to -24 h, b = significant difference compared to 0 h, e = significant difference compared to 48 h. *n* = 24.

Table 4.3

Performance Measures

Time	VJ (in)	HG (kg)	S&R (cm)
-24 hr	24.4 ± 4.0	53.5 ± 8.7	27.2 ± 7.6
-0 hr	24.3 ± 3.8	52.8 ± 8.4	27.4 ± 7.7
+3 hr	22.9 ± 3.6	48.6 ± 7.7	25.4 ± 7.2
+24 hr	23.4 ± 3.9	50.5 ± 8.0	26.1 ± 7.6
+48 hr	24.2 ± 4.0	52.8 ± 8.3	26.9 ± 7.8

Note. Values are presented as mean ± SD. VJ = Vertical Jump; HG = Hand Grip; S&R = Sit-and- Reach. Handgrip values are (right hand score + left hand score) / 2.

PAT Performance, BMI, Performance Measures, and Blood Markers

Using Pearson's *r* product moment correlation coefficient, associations between PAT performance (min) and BMI, as well as PAT performance and blood markers of muscle damage and inflammation (Mb, CRP, and TNF-α) were assessed to determine if PAT performance was related to these factors. In this study, PAT performance was not associated with participant BMI or concentrations of Mb, CRP, or TNF-α at the 48-hour mark ($p > 0.05$; see Table 4.4) Markers of muscle damage (Mb, CRP, and TNF-α) were also compared to performance measures 48-hours post PAT. TNF-α 48 hours post PAT was found to be significant ($p = .009$), and possess a large negative association ($r = -.672$; Table 4.5)

Table 4.4

Correlation PAT Time and Blood Markers

	BMI	Mb + 48 hr	CRP + 48 hr	TNF-α +48 hr
PAT Time	$r = -.007$; $p = .973$	$r = -.300$; $p = .174$	$r = .257$; $p = .248$	$r = .228$; $p = .556$

Note. PAT Time = Time to completion for the Physical Abilities Test; BMI = Body Mass Index; Mb = myoglobin; CRP = C-Reactive Protein TNF-α = Tumor Necrosis Factor Alpha.

Table 4.5

Correlation Performance Measures and Blood Markers

Time	VJ + 48hr	HG + 48hr	S&R + 48hr
Mb + 48 hr	$r = -.154$; $p = .495$	$r = .168$; $p = .456$	r = .093; $p = .679$
CRP + 48 hr	$r = -.068$; $p = .764$	$r = -.264$; $p = .236$	$r = -.223$; $p = -.223$
TNF-α +48 hr	$r = -.672$; $p = .009$	$r = -0.074$; $p = .800$	$r = .330$; $p = .249$

Note. VJ = Vertical Jump; HG = Hand Grip; S&R = Sit-and-Reach; Mb = Myoglobin; TNF-α = Tumor Necrosis Factor Alpha; CRP = C-Reactive Protein

Summary of Results

To summarize, Mb concentrations were elevated 3 hours post-PAT and concentrations returned to baseline by 48 hours post-PAT. Other blood markers reflecting muscle damage were not significantly altered in response to the PAT, though TNF-α concentrations were reduced in the post-PAT period. Hand grip strength, vertical jump, and sit-and-reach performance were impaired for up to 24 hours following the PAT. Performance on the PAT was not associated with participant BMI, or Mb and CRP concentrations at any time point. Handgrip, sit-and-reach, or vertical jump at the 48-hour mark was not associated with myoglobin or TNF-α at the 48-hour mark.

CHAPTER V

DISCUSSION AND CONCLUSIONS

Firefighters routinely perform one of the most stressful, unpredictable, and dangerous jobs. In response to a reported emergency or fire, firefighters are subjected to significant cardiovascular, respiratory, muscular, and psychological strain (Cheung et al., 2010; Smith et al., 2016, Sothmann et al., 1992). A firefighter's job-related requirements, in addition to a variety of occupational and lifestyle factors, put these individuals at an increased risk for cardiovascular disease and cardiovascular-related events such as a myocardial infarction (Farioli et al., 2014). Moreover, firefighters are required to perform strenuous job-related tasks for unpredictably lengthy periods, with the additional possibility that they may have to perform similar tasks within the same or subsequent work shifts. This type of activity, along with occupational factors and hazards of being a firefighter, contribute to the increased incidence of CVD in this profession, while also impairing task performance and ability, particularly when individuals are required to repeatedly perform similar tasks within a short timeframe (i.e., within 24-48 hours; Kales et al., 2007).

Within this occupational population, it is necessary to explore physiological responses to performing firefighter duties, while also trying to gain a greater understanding of how long it takes firefighters to fully recover from their occupational tasks. This may identify time periods, as well as performance variables that are negatively affected by task performance, that may result in firefighters performing their job at a sub-optimal level. This information may then be translated to determining a firefighter's level of fitness that prevents the onset of occupation-related CVD while also allowing them to perform their job at a high level. Identifying this need in firefighter-related research, this study aimed to characterize how systemic markers of muscle

damage and inflammation, as well as markers associated with muscular performance, are affected following the PAT in professional firefighters.

Muscle Damage and Inflammation

Muscle damage is a relatively common phenomenon that occurs in response to intense mechanical load and force requirements, with eccentric muscle contractions contributing to muscle damage to a much greater degree than concentric muscle contractions (Chen et al., 2019; Peake et al., 2005). Muscle damage following a single bout of exercise may reduce range-of-motion (Reinold et al., 2008), negatively affecting the speed and strength of muscle contraction (Bergstrōm & Hultman, 1991; Eston et al., 2005). Muscle damage is characterized by morphological changes within the muscle, resulting in the disruption of sarcomeres (Feasson et al., 2002; Peake et al., 2005). This disruption permits a multitude of localized proteins within muscle to leak from the damaged muscle into the circulation (Peake et al., 2005), in addition to an accumulation of inflammatory markers near the injury site (Kushner, 1982; Moore & Tabas, 2011). These proteins are detectable within the circulation and can be used as markers reflecting muscle damage (Chen et al., 2019; Peake et al., 2005).

Mb, a commonly assessed marker of muscle damage (Sayers & Clarkson, 2003), was significantly increased 3 hours following the PAT in this study. Concentrations gradually returned to basal levels 48 hours post-PAT. In addition, CRP and TNF-α, both markers representative of localized and systemic inflammation, were assessed. There were no differences in CRP or TNF-α prior to, or following, the PAT. Collectively, it appears the PAT was strenuous enough to promote damage of muscle tissue in the early periods following the PAT, as evidenced by an increase in Mb within the circulation, though this was accompanied by no significant changes in CRP and TNF-α. The observed increase in Mb following strenuous exercise has been

documented in previous studies. Nybo et al. (2013) investigated markers of muscle damage and performance, including Mb, in semiprofessional soccer players in response to matches performed in both neutral and hot environments. The authors reported elevations in Mb immediately following both matches, with environmental temperature having no effect on Mb. Also, Mb returned to basal levels at both 24 and 48 hours post-exercise (Nybo et al., 2013), similar to results reported in the current study. Ascensão et al. (2008) explored markers of oxidative stress and muscle damage in soccer players prior to, and during, a soccer match. The authors reported increases in Mb 30 minutes following the match, with Mb returning to pre-match levels 24 hours post-match, which follows the results reported in the current study. Neubauer et al. (2008) assessed markers of inflammation and muscular stress in triathlon athletes following an Ironman competition. Mb was significantly elevated immediately post-race compared to pre-race values, and Mb remained elevated up to 19 days post-exercise. Similar to results in the current study, Neubauer et al. reported Mb concentrations peaked immediately after the competition. However, in contrast to the results of the current study, elevations in Mb were observed over a longer period of time following exercise, which can be attributed to the significant muscular and metabolic requirements of the Ironman competition. Therefore, it appears Mb concentrations peak within a few hours following cessation of strenuous activity, and typically return to basal levels within 24 hours post-exercise (Gondal et al., 2021)

Despite changes in Mb within this study, no significant changes in CRP or TNF-α were observed in response to the PAT. As markers associated with localized and systemic inflammation, it was expected that changes would occur with both markers in response to the PAT. According to results in the current study, CRP concentrations remained relatively unchanged prior to, and following, the PAT, indicating little to no stimulatory effect on CRP in

response to the PAT. Although not statistically significant, TNF-α was reduced immediately post-PAT, and was decreased even further three hours following the PAT. This effect was observed up to 24 hours after the PAT.

Results for both CRP and TNF-α in the current study are similar to observations from previous investigations. Specifically, no changes in CRP in response to high-intensity endurance events (e.g., 10 km, marathon; de Gonzalo-Calvo et al., 2015) and high-intensity resistance training (Fatouros et al., 2006) have been reported. In addition, minimal to no changes in TNF-α have also been previously reported (Brenner et al. 1999; Marklund et al., 2013). Despite this, several studies have reported significant changes in both CRP and TNF-α in response to exercise. Specifically, increases in CRP concentrations in response to ultra-endurance exercise (Marklund et al., 2013; Spiropoulos et al., 2010) and high-intensity resistance training (Degerstrøm & Østerud, 2006; Draganidis et al., 2013) have been documented, with these increases in CRP lasting 24 or more hours. Also, short-term (i.e., 1 to 4 hours post-exercise) increases in TNF-α in response to moderate- and high-intensity exercise have been reported (Bernecker et al., 2013; Ostrowski et al., 1999). The uniqueness of the PAT, in addition to differences in the methodology employed in the current study in previous studies, creates challenges when generalizing our results. It is evident that exercise can promote increases in both CRP and TNF-α, though it appears these effects are observed to a greater degree when exercise is performed at higher intensities, over prolonged durations, or with exercise training. Thus, the intensity and duration of the PAT may not be significant enough to elicit these changes in CRP or TNF-α. As mentioned, TNF-α decreased in the post-PAT period, though it was not a significant decrease. Multiple errors made while performing biochemistry techniques to analyze TNF-α. Incorrect plates were purchased to analyze this blood marker. This error was thought to

be correct through dilution of the plates to the proper concentrations. While the plates with the samples were being stored, the fridge in the lab died and the samples were left to thaw for 72 hours rendering them unstable for reanalysis. Due to these errors, the total number of participant's samples analyzed for TNF-α was reduced from 24 to eight. It is possible that, with an appropriate sample size (i.e., 24), observations for TNF-α may have reached statistical significance following the PAT. Large standard deviations as well as large coefficient of variance were identified when performing statistical analysis of our chosen blood markers. These are findings are not atypical when performing research (Ter Horst et al., 2016) I believe this could have been due to the diversity of our participants that represent a firehouse (i.e., age, fitness level, stress level).

Muscular Performance

The time period immediately following intense, or long-duration exercise is typically characterized by significant reductions in exercise performance that can persist for several days (Armstrong et al., 1991). These effects on exercise performance are largely attributed to disruption of skeletal muscle at the myofibrillar level, localized swelling at the active tissue, dysregulation between the nervous system and skeletal muscle, and contributions from inflammatory cytokines (Armstrong et al., 1991). Importantly, this may negatively impact physical aspects of fitness, including range-of-motion (Reinold et al., 2008), the speed of muscle contraction (Bergstrōm & Hultman, 1991), muscle strength and VO_{2max} (Eston et al., 2003), and aspects of psychosocial health, including cognition (Moore et al., 2012). In this study, hand grip strength, vertical jump, and sit-and-reach performance was assessed before and after the PAT. Reductions in all three performance variables were documented at three and 24 hours following the PAT. In addition, hand grip strength and vertical jump performance was significantly

decreased at three hours post-PAT when compared to 24 hours post-PAT, which indicates participant performance was negatively impacted at a higher magnitude in the hours immediately following the PAT. The performance measures did not show a correlation to the markers of muscle damage or inflammation assessed in this study. It is possible that the PAT protocol used was not strenuous enough to elicit a cytokine response. This may be due to a lack of eccentric loading in our firefighter specific protocol.

It is well established that both endurance and resistance training can improve hand grip strength (Jordre & Schweinle, 2020), sit-and-reach (Barbosa et al., 2002), and vertical jump performance (Sharma & Geovinson, 2012). However, less is known regarding the effects of a single bout of exercise with these performance variables. García-Pinillos et al. (2015) explored the effects of acute interval training on countermovement jump performance and hand grip strength in endurance athletes. Participants performed 12 x 400 m runs, with countermovement jump performance and hand grip strength measured after every three runs. The authors reported consistent improvements in both variables throughout the testing duration in comparison to baseline scores. Importantly, similar improvements were observed at the conclusion of the last 400 m run; thus, it appears participants were able to minimize the accumulating fatiguing effects of these 400 m runs on both their countermovement jump and hand grip strength. The discrepancy between these results when compared to the results in the current study are likely due to differences in the type of tasks performed and participant exercise and training history.

In another study, the effects of repeated 20-minute work bouts were investigated on a variety of performance variables in Australian firefighters (Walker et al., 2015). Participants completed simulations consisting of two, 20-minute search and rescue tasks in an environmentally controlled heat chamber at approximately 105 °F. Performance variables were

measured at various points prior to, and following, each 20-minute simulation. Similar to results in the current study, the authors reported that hand grip strength was significantly decreased after the second 20-minute simulation in comparison to the first simulation (Walker et al., 2015). Muscular strength may therefore be reduced in firefighters following intensive occupational-related tasks. Alternatively, higher levels of hand grip strength are associated with improved time to completion for standardized tests for firefighters, including the hose drag and the stair climb with a high-rise pack (Nazari et al., 2018).

Michaelides et al. (2011) assessed the relationship between fitness measures and occupational task performance, including a stair climb, hose pull, and mannequin rescue drag in firefighters. The authors found several fitness variables predictive of performance with these tasks, including hand grip strength. However, vertical jump and sit-and-reach performance was not found to be predictive of ability test performance. A summary of the results obtained in the current study and those reported in previous investigations follows.

The results obtained for hand grip strength, vertical jump, and sit-and-reach performance in this study are similar to those reported in previous studies in which professional firefighters were participants. Several important concepts begin to emerge when considering our results, as well as those from previous studies exploring this topic. First, it is apparent that hand grip strength performance is sensitive to strenuous exercise, particularly during repetitive activities commonly performed by firefighters while on duty (García-Pinillos et al., 2015). Second, vertical jump performance, an assessment of anaerobic power production, appears to be negatively affected in response to similar activities; however, improvements were reported in previous studies (García-Pinillos et al., 2015). Third, the effects of acute exercise on sit-and-reach performance, particularly within the firefighter setting, are not well characterized in the

literature. Despite this, it is well established that range-of-motion is typically reduced following strenuous exercise or physical activity (Reinold et al., 2008), which is similar to the current observations in this study. Finally, hand grip strength predicts occupational task performance in firefighters, while vertical jump and sit-and-reach performance do not (Michaelides et al., 2011). Thus, it appears the measurement of hand grip strength may be of great significance within the firefighter population with regard to the prediction of task-specific performance.

Limitations

A central limitation to this study is the use of the PAT as a reflection of occupational tasks that a firefighter may experience. Though the PAT may be a reliable determinant of firefighting performance and task requirements (Michaelides et al., 2011), firefighters are frequently subjected to unpredictable and prolonged occupation-specific responsibilities and hazards, making it difficult to fully replicate the tasks these individuals may face during a shift. Additionally, the PAT was chosen as the form of exhaustive exercise in this study and does not follow traditional aerobic or resistance exercise protocols. Taking into consideration the structure and predictability of the PAT in comparison to more variable firefighter tasks (e.g., responding to a fire or emergency, multiple tasks in a shift, not aware of the task ahead of time), it is possible that the magnitude of muscle damage and inflammation may be greater during real-time firefighter tasks. Though challenging from a feasibility perspective, it would be beneficial to observe these markers of muscle damage and inflammation in response to real-time firefighter tasks. Muscle damage was not directly assessed in this study, though the markers used in this study (i.e., Mb, CRP, TNF-α) reflect muscle damage. Errors were made during the analysis of TNF-α, which may render this variable useless for comparison and interpretation in this study. Another limitation is that maximum exercise effort and maximal oxygen consumption (VO_{2max})

were not directly measured. As such, exercise intensities, such as those experienced during the PAT, in terms of a percentage of HR_{max} or VO_{2max} or expressed as a percentage of HR or VO2 reserve are not reported. Additionally, in this study, I did not collect information on participants' exercise history or years working as a firefighter. As both factors can influence performance on tasks such as the PAT, it is possible these factors could have influenced outcomes in this study. This should be taken into consideration when examining the results of this study. Limitations arose when performing correlations according to the fourth hypothesis due to our under powered sample size. For proper power, the study would have required 85 participants.

Conclusions and Future Directions

In this study, an increase in Mb concentrations were observed 3 hours following the PAT in firefighters. In addition, hand grip strength, vertical jump, and sit-and-reach performance was impaired for up to 24 hours following the PAT. These results indicate muscle damage, as well as reductions in muscular performance, occur following strenuous activity specific to the occupation of firefighting. This information is particularly relevant, as it implies a firefighter's capability to perform routine tasks may be impaired during shifts in which prolonged, or repetitively strenuous tasks, must be performed. The results of this study also suggest that if our intervention did replicate the workload of a typical shift, the model of a 24-hour shift followed by 48 hours of rest is appropriate for recovery. This is one of the first studies that included an investigation of markers related to inflammation and muscle damage in firefighters. Future studies may expand upon this topic by exploring this relationship, while also assessing muscular performance, in response to multiple bouts of activity (e.g., repetitive PAT attempts). Moreover, it would seem prudent to further determine if there are any associations between markers of inflammation and muscle damage, as well as muscular performance, on PAT performance (i.e.,

time trial or outcomes specific to the PAT), while also assessing any potential effects of age, experience in the profession, obesity, and training status. A possible explanation for the decrease in physical performance without an elevation in markers of muscle damage and inflammation may be related to neuromuscular fatigue. Future studies utilizing a similar protocol, may additionally use electromyography to assess maximal voluntary neural activation. Lastly, it is possible that the study participants did not complete the PAT as fast as possible despite being highly encouraged to do so. This may be due to experience in completion of these tasks in a paced fashion. Although, this study did not measure heart due to a lack of necessary equipment and time constraints future studies could measure heart rate and rate of perceive exertion as a measure of intensity for the intervention.

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APPENDIX A

INFORMED CONSENT, SCREENING FORMS, RECRUITMENT FLYER

PI: Matthew Sokoloski
Cell: 570-594-0050
Msokoloski@twu.edu

Advisor: Rhett Rigby, Ph.D.
Office: 940-898-2473
Fax: 940-898-2581
brigby@twu.edu

TEXAS WOMAN'S UNIVERSITY

TEXAS WOMAN'S UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH
for a Research Study entitled

"MUSCLE DAMAGE, INFLAMMATION, AND MUSCULAR PERFORMANCE FOLLOWING THE PHYSICAL ABILITES TEST IN PROFESSIONAL FIREFIGHTERS"

SUMMARY AND KEY INFORMATION ABOUT THE STUDY

You are being asked to participate in a research study at Texas Woman's University. The purpose of this research is to determine the duration of time necessary for firefighters to optimally recover from a bout of physical activity. You have been invited to participate in this study because you are a healthy male who is a fulltime firefighter. You will be asked to perform two consecutive rounds of the Physical Abilities Test. Following the Physical Abilities Test, you may experience some muscle soreness and minor swelling of the damaged muscles. Blood will be collected, and performance measures (vertical jump, handgrip strength, flexibility) will be assessed, at strategic times before and after the Physical Abilities Test over a period of 72 hours. There will be 4 total visits and the approximate time commitment is 7.25 hours. The greatest risks of this study include injury, soreness from performing strenuous exercise, and bruising or infection from blood collection. We will discuss these risks and the rest of the study procedures in greater detail below.

Your participation in this study is completely voluntary. If you are interested in learning more about this study, please review this consent form carefully and take your time deciding whether or not you want to participate. Please feel free to ask the researchers any questions you have about the study at any time.

INVITATION and PURPOSE

You are being asked to participate in a study that examines the duration of time necessary for firefighters to optimally recover from a bout of physical activity, and if this limits performance. **The purpose of this study is to determine if firefighters are given enough time to recover from strenuous activity following a shift.**

PARTICIPANT REQUIREMENTS and PRELIMINARY SCREENING

Participant Criteria

There will be 24 males recruited for this study. Enrollment is open to men of all ethnicities. In order to be eligible to participate, you must have the following characteristics:

1. Must be employed as a fulltime firefighter
2. Have no limiting musculoskeletal injuries that would preclude you from exercise
3. Identify as male
4. Not adhering to any specialized diet (e.g., vegetarian)

Initials_____

You will be excluded from participation if you meet any of the following characteristics:

1. Unable to perform any task within the PAT
2. Unable to attend or perform any task in the testing visits
3. Report the regular consumption of any medication that may influence inflammatory or CVD markers
4. Perform any structured exercise while on shift as well as 48 hours following the PAT
5. Consume any performance enhancing drugs (e.g., testosterone replacement therapy)
6. Diagnosed with CVD, pulmonary disease, or metabolic disease

EXPERIMENTAL METHODS and APPROACH

A within subjects, repeated-measures design will be used to determine if differences exist with regards to markers of muscle damage, inflammation, and performance. You will be asked to complete 4 visits in total. With regard to timeline, all visits will occur over a period of 72 hours. This does not mean the visits together total 72 hours, just that they will take place within a 72-hour time period.

Visit 1 will occur within 1 hour prior to a work shift. Visit 2 will occur immediately following the same work shift. Visit 3 will occur 24 hours following the same work shift. Visit 4 will occur 48 hours following the shift, or immediately before the next scheduled work shift.

Visit 1: Screening and Baseline

Location: Addison Fire Department

Following recruitment, Visit 1 will be scheduled. In this visit, you will arrive fasted (8-hour fast; water only, no caffeine). First, you will be asked to complete a PAR-Q+ form and an additional inclusion/exclusion criteria form, and be presented with this informed consent document. You will be shown all of the equipment used in the study, and the PI will demonstrate all performance measures (including the vertical jump, handgrip test, flexibility test). Following the completion of the necessary paperwork, you will be instructed to sit upright for 5 minutes. A 10 mL blood sample will then be taken from the antecubital vein of the right arm. Blood samples will be collected into BD Vacutainer K2 EDTA 10 mL tubes and immediately put on ice to be transported to Texas Woman's University (Denton, TX). Following the blood sample, your basic anthropometric data will be collected. Height (cm) will be measured using stadiometer (Perspective Enterprises, Kalamazoo, MI) and weight (kg) will be measured using a digital scale (Tanita, Arlington Heights, IL). Then, your body mass index will be calculated from these measures. Following the anthropometrics, you will be given a standardized snack of 4 kcal/kg of body weight (Clif Bar & Company, Emeryville, CA; 250 kcal per 68 g serving; 18% fat, 68% carbohydrate, 14% protein) prior to starting any further testing.

Following the consumption of the snack, you will be instructed to sit quietly for 15 minutes, then undergo a standardized dynamic warm-up including jumping jacks, knee pulls to chest, reverse lunges, toe touches, quad pulls, shin pulls, arm circles, and trunk rotations. You will then be instructed to perform three counter movement vertical jump using the Just Jump Mat (Perform Better, Fredonia, NY). You will be allowed 5 sub-maximal warm-up jumps with 30 seconds of rest between jumps prior to beginning the test. You will then be asked to step on the mat and place your hands on your hips. You will be instructed to bend until the knees are at 45° of flexion (halfway down) before performing a maximum effort vertical jump. You will be asked to perform 3 maximum effort jumps with 1 minute of rest between each repetition. Next, your handgrip strength will be assessed using a hand grip dynamometer, which is in accordance with the recommendations of the American Society of Hand Therapists. You will sit with shoulders adducted, elbows flexed 90°, and forearms in neutral rotation. You will be asked to squeeze the dynamometer as hard as possible and will be given consistent verbal encouragement to squeeze

"harder, harder, harder" during a 4.0 to 5.0-second effort. You will be allowed two trials with each hand, with a 30-second rest between trials. The best scores of each hand will be added together per ACSM guidelines. Your trunk and hamstring flexibility will then be measured next using a Sit-and-Reach Test (Novel Products, Inc, Rockton, IL). For this test, you will remove your shoes and sit with your feet flat against the box. Keeping your legs extended and hands overlapped, you will reach forward slowly and push the pin on the box as far forward as possible. You will be asked to hold the terminal position for two seconds and to keep your knees extended throughout the test.

Visit 2: Physical Abilities Test and Testing

Location: Addison Fire Department Training Center

Approximately 24-hrs following visit 1, you will be asked to report to the Addison Fire Department Training Center, following a work shift and a concurrent 8-hr fast (water only, no caffeine) and having performed no strenuous, structured physical activity for 72 hrs prior. A blood sample will be collected first, and then a snack will be given. You will then complete a 10-minute dynamic warm-up followed by a vertical jump test, handgrip test, and flexibility test. All of these procedures, beginning with the blood sample, will be identical to Visit 1. You will then be instructed to rest in a sitting position for 2.5 hours, in which you may watch television, work on your computer, or other activity in this position. Then, you will perform the Physical Abilities Test (PAT). The PAT consists of 10 events: a) 500-meter row, b) ladder climb, c) hose drag, d) stair climb with hose pack, e) hose pull, f) crawl, g) stair decent, h) sledgehammer strikes, i) hose couple, and j) dummy drag. Following the PAT, you will immediately perform the PAT again with no rest period separating the tests. The order of tasks within the PAT will remain the same between the 2 rounds. You will be instructed to complete the PATs as quickly as possible**.** Immediately following the PATs, a blood sample will be collected, a snack will be given and the 3 performance measures (vertical jump, handgrip, flexibility) will be assessed again, in the exact same manner as in Visit 1 and earlier in Visit 2.

Visit 3: Testing

Location: Addison Fire Department

You will be asked to return to the Addison Fire Department 24 hours following the start of Visit 2 and will be in a fasted state (8 hours; water only, no caffeine). Blood will be collected upon arrival. A snack will then be given. Next, you will complete a dynamic warm-up and the 3 performance measures (vertical jump, handgrip, and flexibility). All of these procedures, beginning with the blood sample, will be identical to those procedures in Visits 1 and 2.

Visit 4: Testing

Location: Addison Fire Department

You will return to the Addison Fire Department approximately 48 hours following the start of Visit 2 and will be in a fasted state (8 hours; water only, no caffeine). Procedures for this visit will be exactly the same as those in Visit 3.

Blood Collection and Biochemical Analysis

Researchers will alternate arms for each successive blood draw. Concentrations of C-reactive protein (CRP), myoglobin (Mb), and tumor necrosis factor-alpha (TNF-a) will be analyzed with the Luminex MagPix® using a custom bead panel kit (EMD Millipore Corporation, Bellerica, MA, USA). The analysis will follow the manufacturer's instructions for preparation. This procedure will require 25 ml of each sample in duplicate for each well. Researchers will follow the manufacturer's instructions for all procedures, and all measures will be performed in duplicate. Inter-assay and intra-assay coefficients of

variation (standard deviation / mean) will be reported. CRP, Mb, and TNF-a are blood biomarkers that indicate levels of muscle damage and inflammation.

To complete all requirements of this study, the total time commitment is:

Visit 1:	**45 minutes**
Visit 2:	**5 hours**
Visit 3:	**45 minutes**
Visit 4:	**45 minutes**
TOTAL TIME COMMITMENT:	**7.25 hours**

Participant Benefits

For your participation, you will receive:
1. Your individual results from all performance testing and blood measures.
2. A written summary of the findings upon completion of the study.

Potential Risks and Protection of Participants

RISK	STEPS TO MINIMIZE RISK
Loss of confidentiality	It is possible that there might be a loss of participant confidentiality with data stored offline. To minimize this risk, all data forms collected will be coded using alphanumeric IDs. A single identification form linking names with their respective IDs will be kept in a separate folder form from the other data. Persons not associated with the study will have no access to the folders. Data collection sheets will be locked in a file cabinet in Pioneer Hall 123B. There is also a potential risk of loss of confidentiality in all email, downloading, and internet transactions.
Coercion	Participation in this research is entirely voluntary. The decision whether or not to participate will not jeopardize future relations with Texas Woman's University and the School of Health Promotion and Kinesiology. The participant may withdraw their consent and discontinue participation at any time and for any reason without prejudice. Discontinuing participation will involve no penalty.
Risks associated with submaximal exercise	According to the American College of Sports Medicine, there is little to no risk of an adverse event during submaximal exercise. However, risks include injury to muscles, joints, or organs, a sudden cardiac event or even death. The participant may rest as needed, are encouraged to be properly hydrated, and will undergo proper warm-up and cool-down sessions each testing and training day to minimize the risk of injury. All of the physiologic risks inherent with exercise testing and training will be minimized through preliminary screening, adherence to standards of practice for exercise testing published by the American College of

	Sports Medicine, and personal monitoring of each test by trained personnel.
Cardiac or cerebrovascular event during high-intensity exercise	The overall risk of a cardiac or cerebrovascular event has been estimated at 6 in 10,000 during high-intensity exercise among healthy individuals and individuals with a known cardiovascular disease (Gibbons et al., 1980). All technicians present during testing and training are certified in CPR and AED techniques.
Injury during the performance and/or muscle damaging sessions	Injuries can occur during the visits, which can include (but are not limited to) falling, collisions with equipment, and injury to soft tissues (muscle, ligaments, tendon, cartilage). To minimize this risk, the protocols will be reviewed with the participant each day, and the participant will be familiarized with the proper form of the exercises during the initial familiarization session. If needed, first aid and CPR will be administered immediately.
Shortness of breath, lightheadedness, nausea	High-intensity exercise training has been associated with shortness of breath, light-headedness, and in some cases, nausea. To minimize these effects, proper warm-up, cool-down, and rest periods will be integrated into the visits. Participants will have close access to water and restrooms if needed. Exercise will immediately cease and the participant will be placed in a resting (sitting) position in the event of lightheadedness. An active recovery, which is associated with a reduction in these risks, will be implemented. Proper supervision by trained personnel will take place. Participants will be reminded that they can withdraw from the study at any time
Muscle soreness and fatigue	The participant may feel periods of soreness and/or fatigue during and after the physical abilities test. The participant may take breaks as needed and proper hydration will be encouraged. Proper warm-up and cool-down sessions will also be integrated into all visits.
Embarrassment	There is a possibility that participants may be embarrassed by their performance on the testing. Words of encouragement and motivational language will be spoken by the investigators in the event participants are embarrassed due to their performance during visits. The investigators will remind the participants that participation is voluntary and that the participant may withdraw at any time without penalty.
Peripheral venous blood draw infection, bleeding, and/or bruising	There is a small risk of the needle going through the vein or not going into a blood vessel. Also, the participant may experience discomfort, bleeding, and/or bruising. On a rare occasion, one may feel dizzy or faint. The likelihood of these complications is very remote (about 1

	in 10,000), when the procedure is carried out by trained personnel and proper equipment is used. Precautions will be used during all blood draw procedures. Sites for blood draws will be cleaned with alcohol immediately before each blood draw. Each new needle that is opened will be disposed of in proper containers after use. A trained individual (the PI) will obtain these blood samples to minimize these risks. The amount of blood taken over the course of the study is about 80 mL and will not affect normal daily activities. A typical donation of blood is about one pint (1 pint = 450mL, American Red Cross).
Emotional discomfort	Participation in this study is voluntary, and participants are free to withdraw at any time. Participants may experience some emotional discomfort based on their physical performance on the testing sessions. Researchers will use positive feedback during each training and testing session to reinforce a positive atmosphere.
Food allergies	Snacks will be provided to participants so there is a risk of a potential food allergy. Researchers will ask participants if they are allergic to any foods prior to giving the participant the snack. Researchers will also read through the list of ingredients on the snack to ensure that each participant is aware of the contents of the snack.

The researchers will try to prevent any problem that could happen because of this research. You should let the researchers know at once if there is a problem and they will help you. However, TWU does not provide medical services or financial assistance for injuries that might happen because you are taking part in this research.

The researchers will remove all of your personal or identifiable private information from your data and biospecimens. After such removal, the data and biospecimens could be used for future research studies or distributed to another investigator for future research studies without additional informed consent.

If you would like to participate in the current study, but not allow your de-identified data to be used for future research, please initial here _____.

YOUR RIGHTS TO PRIVACY

Confidentiality will be protected to the extent that is allowed by law. All individual information obtained in this study will remain confidential and your right to privacy will be maintained. Data collected will be used for research purposes only and will be limited to access by the investigators of this study. Only data reported as group means or responses will be presented in scientific meetings and published in scientific journals. Data will be destroyed within 5 years of study completion.

QUESTIONS ABOUT THIS RESEARCH

As investigators, it is our obligation to explain all of the procedures to you. We want to make sure that you understand what is required of you and what you can expect from us in order to complete this study.

Please do not hesitate to inquire about the research, your rights and responsibilities as the participant, or our roles as the investigators now or at any time throughout the study.

YOUR CONSENT TO PARTICIPATE

Failure to comply with all of the procedures and to follow the instructions necessary for reliable and valid scientific measurements may result in termination of your participation in this study without your consent. You may be asked to withdraw if you fail to comply with all of the requirements for participation listed above. If you are withdrawn from participation by one of the investigators, our decision will not jeopardize your future relations with Texas Woman's University and the School of Health Promotion and Kinesiology.

CONTACT INFORMATION

Matthew Sokoloski
Doctoral Candidate
Cell: 570-5940-0050
Msokoloski@twu.edu

Rhett Rigby, Ph.D.
Associate Professor
Office: 940-898-2473
brigby@twu.edu

YOU WILL BE GIVEN A COPY OF THIS SIGNED AND DATED CONSENT FORM TO KEEP. IF YOU HAVE ANY QUESTIONS ABOUT THE RESEARCH STUDY YOU SHOULD ASK THE RESEARCHERS. IF YOU HAVE ANY QUESTIONS ABOUT YOUR RIGHTS AS A PARTICIPANT IN THIS RESEARCH OR THE WAY THIS STUDY HAS BEEN CONDUCTED, YOU MAY CONTACT THE TEXAS WOMAN'S UNIVERSITY OFFICE OF RESEARCH AND SPONSORED PROGRAMS AT 940-898-3378 OR VIA EMAIL AT IRB@twu.edu

Participant's Signature	Date	Investigator Obtaining Consent	Date
Printed Name		Printed Name	

2021 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition ☐ **OR** high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** _____	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** _____	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:** _____	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age (https://www.who.int/publications/i/item/9789240015128).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION

If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

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2021 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?

If the above condition(s) is/are present, answer questions 1a-1c If **NO** ☐ go to question 2

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you currently have Cancer of any kind?

If the above condition(s) is/are present, answer questions 2a-2b If **NO** ☐ go to question 3

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm

If the above condition(s) is/are present, answer questions 3a-3d If **NO** ☐ go to question 4

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you currently have High Blood Pressure?

If the above condition(s) is/are present, answer questions 4a-4b If **NO** ☐ go to question 5

4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5. Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes

If the above condition(s) is/are present, answer questions 5a-5e If **NO** ☐ go to question 6

5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

2021 PAR-Q+

6. Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome

If the above condition(s) is/are present, answer questions 6a-6b — If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐

7. Do you have a Respiratory Disease? *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*

If the above condition(s) is/are present, answer questions 7a-7d — If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. Do you have a Spinal Cord Injury? *This includes Tetraplegia and Paraplegia*

If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. Have you had a Stroke? *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*

If the above condition(s) is/are present, answer questions 9a-9c — If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. Do you have any other medical condition not listed above or do you have two or more medical conditions?

If you have other medical conditions, answer questions 10a-10c — If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: _____

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

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2021 PAR-Q+

If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

For more information, please contact

www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Key References

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2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.
3. Chisholm DM, Collis ML, Kulak LL, Davenport W, and Gruber N. Physical activity readiness. British Columbia Medical Journal. 1975;17:375-378.
4. Thomas S, Reading J, and Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). Canadian Journal of Sport Science 1992;17:4 338-345.

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01-11-2020

RESEARCH STUDY

MUSCLE DAMAGE, INFLAMMATION, AND MUSCULAR PERFORMANCE FOLLOWING THE PHYSICAL ABILITES TEST IN PROFESSIONAL FIREFIGHTERS

Be part of an important study that will help us measure the physiological changes that occur following a typical firefighting shift.

If you are selected to participate you will be required to:

1. Complete 4 visits at the Addison Fire Department over a 72-hour period.
2. Perform 2 physical abilities test in one visit.
3. Undergo a total of 5 blood draws over a 72-hour period.

Participation is voluntary. All volunteers will receive:

1. A report of their individual blood test results and a final report of our study results.

You may be eligible to participate if you:

1. Are employed as a fulltime firefighter
2. Have no limiting musculoskeletal injuries that would preclude you from exercise
3. Are deemed healthy as determined by a PAR-Q+ questionnaire
4. Have the ability to follow verbal directions
5. Identify as male
6. Not adhering to any specialized diet

For more information please contact:

Matthew Sokoloski
570-594-0050
Msokoloski@twu.edu

Rhett Rigby, PhD
940-898-2473
brigby@twu.edu

Note: There is a potential risk of loss of confidentiality with any email, downloading, and internet transactions

The study is being conducted by the
Exercise Physiology Laboratory
Pioneer Hall room 116
School of Health Promotion and Kinesiology
Texas Woman's University

APPENDIX B

DATA COLLECTION FORM

DATA COLLECTION SHEET

Participant ID

Height (cm) **Weight (kg)**

Physical Fitness Measures (1)

Trial 1 Trial 2 Trial 3

Vertical Jump Grip Strength Sit-and-Reach

Physical Fitness Measures (2)

Trial 1 Trial 2 Trial 3

Vertical Jump Grip Strength Sit-and-Reach

Blood Collection

Mb TNF-a CRP

Sample 1

Sample 2

Sample 3

Sample 4

Sample 5

APPENDIX C RAW DATA

ID	CRP (ng/mL)					MB (ng/mL)					TNFα (ng/mL)				
	P- 24	P-0	P+3	P+2 4	P+4 8	P- 24	P-0	P+3	P+2 4	P+4 8	P- 24	P-0	P+ 3	P+2 4	P+4 8
1	3.26	3.45	3.23	5.84	8.76	16.05	9.53	20.89	14.76	17.52	n/a	n/a	n/a	n/a	n/a
2	15.67	17.21	15.58	20.37	16.37	8.09	6.25	20.19	11.65	4.50	n/a	n/a	n/a	n/a	n/a
3	6.73	3.74	3.70	4.20	5.75	18.18	14.06	17.16	10.67	12.19	n/a	n/a	n/a	n/a	n/a
4	18.96	13.19	15.18	23.11	18.51	8.17	6.81	13.49	7.68	10.37	n/a	n/a	n/a	n/a	n/a
5	51.16	27.46	34.74	24.50	32.59	11.18	15.73	57.40	24.60	19.10	n/a	n/a	n/a	n/a	n/a
6	13.27	15.18	13.89	37.24	21.93	16.24	26.83	60.29	10.18	14.66	n/a	n/a	n/a	n/a	n/a
7	23.56	2.77	2.75	4.57	3.35	16.28	11.22	11.91	15.53	15.75	n/a	n/a	n/a	n/a	n/a
8	5.85	3.45	3.69	4.57	4.34	26.84	69.66	127.64	21.59	28.23	n/a	n/a	n/a	n/a	n/a
9	4.34	3.78	2.90	4.12	4.39	8.53	11.24	15.07	17.07	15.48	n/a	1.11	2.20	1.93	1.10
10	n/a	n/a	n/a	n/a	n/a	13.18	11.60	20.20	19.33	9.23	8.22	5.32	2.77	4.53	2.35
11	2.33	2.94	3.56	3.61	3.25	28.57	18.93	27.37	24.16	11.88	4.41	1.68	0.46	0.91	1.89
12	2.63	3.16	5.99	2.60	2.30	26.39	24.38	38.76	41.03	41.98	2.24	3.04	1.23	0.24	n/a
13	3.21	3.16	2.92	2.27	2.66	19.03	16.57	36.97	20.19	18.86	3.95	0.61	n/a	n/a	0.76
14	2.34	3.91	2.41	2.35	2.28	20.54	18.31	43.48	28.51	15.71	0.36	1.26	1.25	2.31	6.77
15	1.51	1.81	2.63	1.92	1.69	16.24	13.27	31.93	26.45	49.40	2.14	2.09	2.66	1.81	n/a
16	10.09	11.37	11.86	10.15	5.06	13.96	15.33	45.64	52.70	23.86	1.47	0.84	5.15	n/a	0.46
17	2.16	2.20	4.25	2.90	3.34	12.08	9.24	19.70	18.54	16.96	n/a	2.25	2.50	3.90	8.04
18	15.70	7.62	10.10	13.13	9.57	11.34	11.85	23.43	17.08	11.87	2.40	3.45	2.05	2.63	3.21
19	24.35	25.17	24.08	41.61	n/a	20.25	20.95	55.77	41.32	25.13	2.45	2.30	2.34	3.06	3.04
20	7.96	24.81	24.18	19.20	9.38	15.57	10.93	24.75	10.39	11.38	4.42	1.73	1.59	2.29	2.62

2	17.	3.4	4.0	3.4	3.6	18.	15.	27.0	20.	22.	4.2	3.8	2.1	4.8	4.9
1	69	6	2	0	0	88	28	6	73	76	5	2	5	7	5
2	3.3	4.2	4.6	5.0	5.1	22.	19.	22.9	20.	18.	5.0	3.9	1.9	3.6	4.8
2	4	6	2	1	6	10	50	8	82	82	9	1	4	7	0
2	25.	8.6	12.	10.	13.	9.6	10.	16.4	7.6	14.	7.21	1.	1.9	9.2	6.7
3	43	1	68	50	51	2	13	6	9	80	1	16	4	7	1
2	2.3	3.9	4.7	5.1	3.1	11.	9.0	16.7	15.	16.	n/		3.8	5.7	4.2
4	8	3	8	0	5	10	5	6	04	02	a	n/a	6	6	9

ID	Vertical Jump (in)					Sit and Reach (cm)					Hand Grip (kg)				
	P- 24	P-0	P+3	P+2 4	P+4 8	P- 24	P-0	P+3	P+2 4	P+4 8	P- 24	P-0	P+3	P+2 4	P+4 8
1	23.40	23.00	19.50	19.60	22.20	34.50	33.00	31.25	34.00	33.50	51.82	50.00	45.91	50.00	52.27
2	24.50	23.90	22.10	22.80	23.50	28.00	27.50	25.50	26.25	28.25	65.91	61.82	59.09	61.36	64.09
3	19.30	19.90	18.10	19.00	19.30	23.50	24.00	23.00	22.50	23.00	46.82	46.36	41.82	44.55	47.73
4	25.10	24.50	22.80	22.70	24.90	19.50	18.25	16.50	17.25	18.50	40.45	41.82	37.73	38.18	40.91
5	18.80	19.00	18.30	19.20	19.40	19.25	21.00	20.00	19.25	20.00	35.45	36.36	32.27	37.27	37.27
6	28.40	27.80	26.40	25.30	27.90	18.75	19.00	17.75	17.75	19.00	60.91	61.36	58.18	60.00	62.73
7	24.60	24.60	23.10	22.70	24.00	36.50	35.50	32.75	35.75	37.50	49.09	49.09	45.45	45.91	46.82
8	23.60	23.00	21.50	22.20	23.00	25.50	24.50	23.75	23.25	24.50	70.45	72.27	64.09	64.09	65.91
9	29.10	29.30	27.90	28.40	29.20	17.75	18.00	18.00	18.00	17.00	56.36	54.55	50.91	54.09	55.91
10	29.60	29.20	27.90	29.50	29.90	29.50	29.75	26.25	26.75	28.00	44.09	41.82	40.91	43.64	45.91
11	20.60	20.20	21.90	21.50	20.90	42.50	43.75	41.25	42.75	43.25	54.55	54.09	49.55	53.64	55.91
12	30.90	30.10	20.90	20.50	30.90	25.75	25.00	25.00	25.00	25.00	55.09	55.09	45.91	45.91	45.91
13	23.60	23.20	21.90	20.50	23.00	27.50	28.00	26.25	27.75	28.00	59.55	59.09	54.55	58.64	59.09
14	20.50	20.00	20.90	20.00	20.00	25.00	25.00	25.00	25.00	25.00	55.45	55.09	50.91	50.91	50.91
15	30.60	29.80	28.40	29.50	30.30	18.50	18.25	17.75	18.00	19.00	50.91	50.45	46.82	46.82	47.73
16	20.80	20.90	20.00	20.70	20.40	75.00	75.00	75.00	75.00	75.00	90.00	90.45	82.73	82.73	82.73
17	18.60	18.40	17.90	17.60	18.20	37.50	36.75	34.75	34.75	35.00	42.73	41.82	39.55	40.00	40.91
18	40.20	40.60	40.90	40.50	40.50	50.00	50.00	50.00	50.00	50.00	27.73	27.82	27.55	27.45	27.91
19	21.60	21.20	20.90	20.50	21.00	33.50	35.00	31.25	32.75	36.75	52.73	50.91	49.55	50.91	51.82
20	80.50	50.80	80.90	90.00	00.00	00.00	00.00	00.00	00.00	5.00	73.45	45.55	55.91	91.82	82.73
21	25.60	25.20	24.90	25.50	25.00	24.50	24.00	21.25	22.75	23.50	57.73	54.55	52.73	53.64	58.18
22	60.10	70.40	70.00	75.00	25.00	25.00	00.00	27.73	55.27	64.18					
23	22.60	22.20	22.90	22.50	22.00	28.00	27.50	25.25	24.75	25.00	61.36	60.00	55.45	57.27	61.36
24	40.10	00.30	50.00	25.75	75.00	25.00	36.00	45.27	55.09	36.00					
25	26.60	27.20	25.90	26.50	27.00	32.50	33.00	30.25	30.75	31.00	54.09	53.64	46.82	48.64	50.91
26	80.20	30.70	75.00	75.00	00.50	09.64	36.00	18.00							
27	31.60	30.20	28.90	30.50	31.00	28.50	28.00	26.25	27.75	28.00	62.36	60.00	55.45	55.91	58.64
28	40.00	40.10	00.00	25.50	25.00	25.25	25.00	73.00	00.00	45.64					
29	28.60	27.20	25.90	26.50	27.00	26.50	27.00	25.25	25.75	26.75	43.64	43.64	40.91	40.91	40.91
30	80.10	40.90	90.50	50.00	25.00	25.50	25.00	18.64	00.45	91.00					
31	19.60	20.20	19.90	19.50	20.00	20.50	21.00	19.25	20.00	21.00	55.36	56.36	50.91	54.55	58.18
32	90.10	00.30	00.00	50.50	00.75	00.00	36.91	09.64							
33	28.60	28.20	27.90	27.50	28.00	19.50	18.00	16.25	16.75	17.00	48.64	49.09	44.55	43.64	47.73
34	10.80	40.20	80.00	60.75	00.00	25.00	75.00	00.75	00.00	18.09	55.64	27.00			

2	18.	18.	17.	17.	18.	42.	43.	40.	42.	42.0	56.	54.	49.	46.	54.
3	90	10	70	90	00	50	75	50	50	0	82	55	55	82	55
2	25.	25.	23.	23.	24.	19.	21.	19.	20.	19.7	64.	62.	58.	64.	64.
4	10	50	50	90	80	75	00	75	00	5	09	73	64	09	09

APPENDIX D

SPSS OUTPUT

General Linear Model

Notes

Output Created		15-JUN-2022 12:50:16
Comments		
Input	Data	C:\Users\tdejong\Dropbox\Active Student\Sokolski, M - Ex Phys - Rigby\Sokoloski_Dissertation_Stats.sav
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	Weight	<none>
	Split File	<none>
N of Rows in Working Data File		24

Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM MB1 MB2_OR MB3_OR MB4 MB5_OR /WSFACTOR=Time 5 Polynomial /MEASURE=Myoglobin /METHOD=SSTYPE(3) /PLOT=PROFILE(Time) TYPE=LINE ERRORBAR=NO MEANREFERENCE=N O YAXIS=AUTO /EMMEANS=TABLES(Time) COMPARE ADJ(SIDAK) /PRINT=DESCRIPTIVE

		ETASQ OPOWER /CRITERIA=ALPHA(.05) /WSDESIGN=Time.
Resources	Processor Time	00:00:00.19
	Elapsed Time	00:00:00.16

Within- Subjects Factors

Measure: Myoglobin

Time	Dependent Variable
	MB1
	MB2_OR
	MB3_OR
	MB4
	MB5_OR

Descriptive Statistics

	Mean	Std. Deviation	N
MB1	15.18692857142854	5.288434655950	21
MB2_OR	13.77769047619045	5.134085345697398	21
MB3_OR	28.42745238095238	15.19598286382355	21
MB4	19.45902380952380	10.88671166431373	21
MB5_OR	15.55785714285714	4.991005422614909	21

Multivariate Tests[a]

Effect	Value	F	Hypothesis df	Error df	Sig.
Time	Pillai's Trace	.800	16.987[b]	4.000	17.000	<.001
	Wilks' Lambda	.200	16.987[b]	4.000	17.000	<.001
	Hotelling's Trace	3.997	16.987[b]	4.000	17.000	<.001
	Roy's Largest Root	3.997	16.987[b]	4.000	17.000	<.001

Multivariate Tests[a]

Effect		Eta Squared	Partial Noncent. Parameter	Observed Power[c]
Time	Pillai's Trace	.800	67.947	1.000
	Wilks' Lambda	.800	67.947	1.000
	Hotelling's Trace	.800	67.947	1.000
	Roy's Largest Root	.800	67.947	1.000

a. Design: Intercept Within Subjects

Design: Time

b. Exact statistic

c. Computed using alpha = .05

Mauchly's Test of Sphericity[a]

Measure: Myoglobin

					Epsilon[b]
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser
Time	.052	54.280	9	<.001	.528

Mauchly's Test of Sphericity[a]

Measure: Myoglobin

		Epsilon	
Within Subjects Effect		Huy nh-Feldt	Lower -bound
Time		.592	.250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept Within Subjects Design: Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: Myoglobin

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Sphericity Assumed	2969.510	4	742.31477084		< 0
	Greenhouse-Geisser	2969.521012		1406.14202084		< 0
	Huynh-Feldt	2969.521067		1254.14408084		< 0
	Lower-bound	2969.511000		2969.14510084		.0
Error(Time)	Sphericity Assumed	4216.827	80	52.710		
	Greenhouse-Geisser	4216.842.27234		99.843		
	Huynh-Feldt	4216.847.27345		89.066		
	Lower-bound	4216.820.27000		210.841		

Tests of Within-Subjects Effects

Measure: Myoglobin

Source		Eta Squared	df	Partial Noncent. Parameter	Observed Power[a]
Time	Sphericity Assumed	.413		56.336	1.000
	Greenhouse-Geisser	.413		29.742	.998
	Huynh-Feldt	.413		33.341	.999
	Lower-bound	.413		14.084	.946
Error(Time)	Sphericity Assumed				
	Greenhouse-Geisser				
	Huynh-Feldt				
	Lower-bound				

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: Myoglobin

Source	Time	Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Linear	86.640	1	86.642.5031		.127
	Quadratic	1227.116	1	1227.14.116591		.001
	Cubic	253.718	1	253.77.41875		.013
	Order 4	1402.035	1	1402.23.035939		<.001
Error(Time)	Linear	684.568	20	34.228		
	Quadratic	1682.072	20	84.104		
	Cubic	678.864	20	33.943		
	Order 4	1171.322	20	58.566		

Tests of Within-Subjects Contrasts

Measure: Myoglobin

Source	Time	Eta Squared	Partial Noncent. Parameter	Observed Power[a]
Time	Linear	.112	2.531	.328
	Quadratic	.422	14.591	.953
	Cubic	.272	7.475	.739
	Order 4	.545	23.939	.996
Error(Time)	Linear			
	Quadratic			
	Cubic			
	Order 4			

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: Myoglobin

Transformed Variable: Average

Source	Type III Sum of SSquares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	35865.541	1	35865.541	164.647	<.001	.892
Error	4356.671	20	217.834			

Tests of Between-Subjects Effects

Measure: Myoglobin

Transformed Variable: Average

Source	SNoncent. Parameter	Observed Power[a]
Intercept	164.641.000	7
Error		

a. Computed using alpha = .05

Estimated Marginal Means

Time

Estimates

Measure: Myoglobin

Time	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
	115.187	1.154	12.780	17.594
	213.778	1.120	11.441	16.115
	328.427	3.316	21.510	35.345
	419.459	2.376	14.503	24.415
	515.558	1.089	13.286	17.830

Pairwise Comparisons

Measure: Myoglobin

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	1.409	.915	.777	-1.467	4.28
	3	-13.241*	3.183	.005	-23.247	-3.23
	4	-4.272	2.273	.541	-11.418	2.87
	5	-.371	1.313	1.000	-4.499	3.75
2	1	-1.409	.915	.777	-4.286	1.46
	3	-14.650*	2.560	<.001	-22.698	-6.60
	4	-5.681	2.183	.158	-12.545	1.18
	5	-1.780	1.153	.774	-5.404	1.84

3	1		13.243.183	.005	3.234	23.24
			1*			
	2		14.652.560	<.001	6.602	22.69
			0*			
		48.968	2.781	.042	.227	17.71
			*			
	5		12.872.934	.003	3.648	22.09
			0*			
4	1		4.2722.273	.541	-2.874	11.41
	2		5.6812.183	.158	-1.182	12.54
	3	-8.968*	2.781	.042	-17.710	-.22
	5		3.9011.829	.372	-1.847	9.64
5	1		.3711.313	1.000	-3.757	4.49
	2		1.7801.153	.774	-1.843	5.40
	3	-12.870*	2.934	.003	-22.091	-3.64
	4		-1.829	.372	-9.649	1.84
			3.901			

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Sidak.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.800	16.987[a]	4.000	17.000	<.001	.800
Wilks' lambda	.200	16.987[a]	4.000	17.000	<.001	.800
Hotelling's trace	3.997	16.987[a]	4.000	17.000	<.001	.800
Roy's largest root	3.997	16.987[a]	4.000	17.000	<.001	.800

Multivariate Tests

		NoncenObserved Power[b]
Pillai's trace	67.947	1.000
Wilks' lambda	67.947	1.000
Hotelling's trace	67.947	1.000
Roy's largest root	67.947	1.000

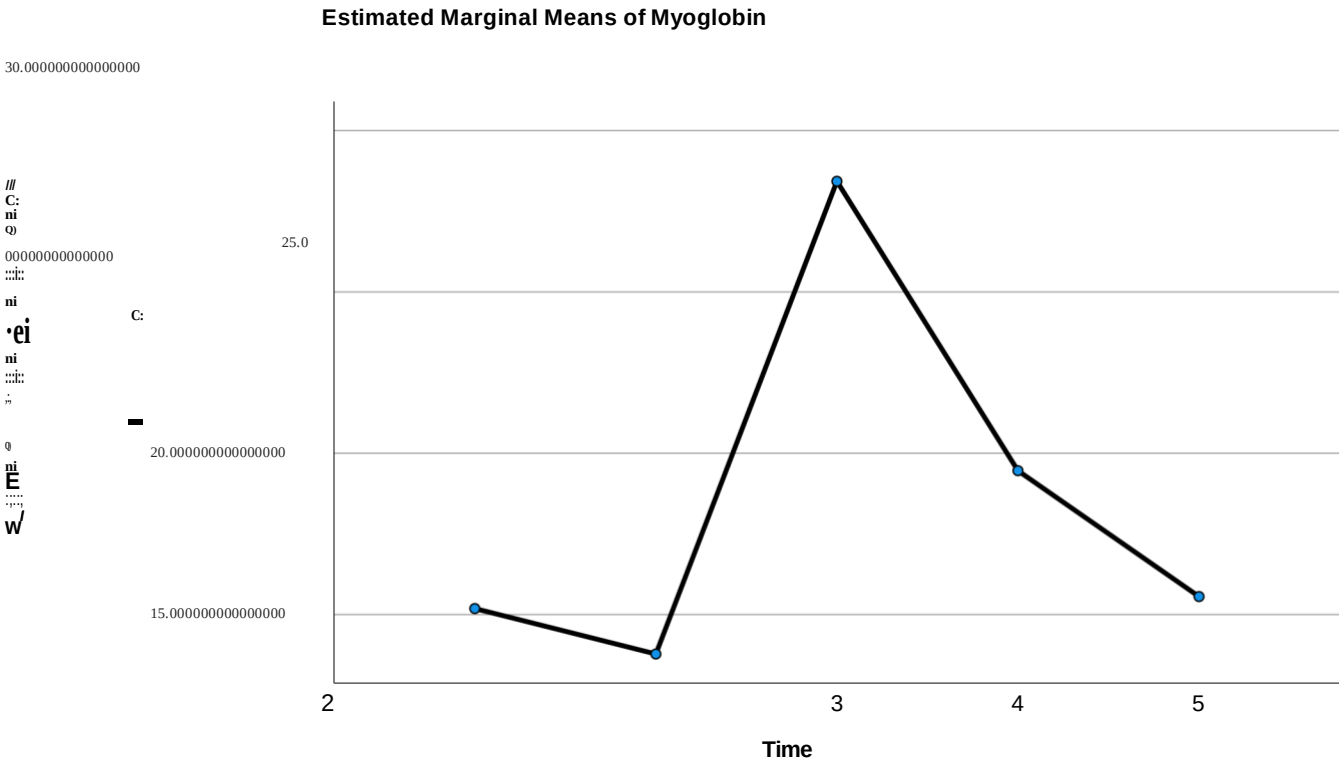
Each F tests the multivariate effect of Time.

These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

b. Computed using alpha = .05

Profile Plots



General Linear Model

Notes

Output Created		15-JUN-2022 12:50:21
Comments		
Input	Data	C:\Users\tdejong\Dropbox\Active Student\Sokolski, M - Ex Phys - Rigby\Sokoloski_Dissertation_Stats.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	24
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.

Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax	GLM CRP1 CRP2 CRP3 CRP4 CRP5 /WSFACTOR=Time 5 Polynomial /MEASURE=CRP /METHOD=SSTYPE(3) /PLOT=PROFILE(Time) TYPE=LINE ERRORBAR=NO MEANREFERENCE=N O YAXIS=AUTO /EMMEANS=TABLES(Ti me) COMPARE ADJ(SIDAK) /PRINT=DESCRIPTIVE ETASQ OPOWER /CRITERIA=ALPHA(.05) /WSDESIGN=Time.

Resources	Processor Time	00:00:00.16
	Elapsed Time	00:00:00.17

Within- Subjects Factors

Measure: CRP

Time	Dependent Variable
1	CRP1
2	CRP2
3	CRP3
4	CRP4
5	CRP5

Descriptive Statistics

	Mean	Std. Deviation	N
RP1	10.890 56818181818 2	11.703 27001138637 4	22
RP2	7.7934 99999999999	7.4086 06582887231	22
RP3	8.6214 77272727274	8.2462 43421036192	22
RP4	9.5758 40909090909	9.4835 80959675672	22
RP5	8.2233 63636363636	7.8802 64411477905	22

Multivariate Tests[a]

Effect	Value	F	Hypothesis df	Error df	Sig.
Time	Pillai's Trace	.392.9 879[b]	4.000	18. 000	.04 7
	Wilks' Lambda	.602.9 279[b]	4.000	18. 000	.04 7
	Hotelling's Trace	.662.9 279[b]	4.000	18. 000	.04 7
	Roy's Largest Root	.662.9 279[b]	4.000	18. 000	.04 7

Multivariate Tests[a]

Effect		Eta Squared	Partial Noncent. Parameter	Observed Power[c]
Time	Pillai's Trace	.398	11.914	.675
	Wilks' Lambda	.398	11.914	.675
	Hotelling's Trace	.398	11.914	.675
	Roy's Largest Root	.398	11.914	.675

a. Design: Intercept Within Subjects

Design: Time

b. Exact statistic

c. Computed using alpha = .05

Mauchly's Test of Sphericity[a]

Measure: CRP

				Epsilon[b]
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	Sig.	Greenhouse-Geisser
Time	.037	64.262	9<.001	.473

Mauchly's Test of Sphericity[a]

Measure: CRP

		Epsilon	
Within Subjects Effect	Huynh-Feldt	Lower-bound	
Time	.518	.250	

Tests the null hypothesis that the error covariance matrix of the orthonormalized

transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept Within Subjects Design: Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: CRP

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Sphericity Assumed	134.324	6	33.581.5247		.1
	Greenhouse-Geisser	134.321.8691		71.021.5647		.2
	Huynh-Feldt	134.322.0673		64.801.5747		.2

	Lower-bound	134.32	1.0	134.3	1.5	.2
		6	00	26	47	
Erro	Sphericity	1823.4	84	21.70		
r(Time)	Assumed	25		7		
	Greenhouse-	1823.4	39.	45.91		
	Geisser	25	716	2		
	Huynh-Feldt	1823.4	43.	41.89		
		25	527	2		
	Lower-bound	1823.4	21.	86.83		
		25	000	0		

Tests of Within-Subjects Effects

Measure: CRP

Source		Eta Squared	PartialNoncen t. Parameter	Observ ed Power[a]
Tim	Sphericity	.069	6.188	.459
e	Assumed			
	Greenhouse-	.069	2.926	.301
	Geisser			
	Huynh-Feldt	.069	3.207	.316
	Lower-bound	.069	1.547	.221

Erro r(Time)	Sphericity Assumed					
	Greenhouse-Geisser					
	Huynh-Feldt					
	Lower-bound					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: CRP

Source	Time	Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Linear	27.758	1	27.758	.945	.342
	Quadratic	20.542	1	20.542	.631	.436
	Cubic	85.440	1	85.447.1053		.014

		Order 4	.586	1	.586	.045	.834
Error(Time)	Linear		616.905	21	29.376		
	Quadratic		683.619	21	32.553		
	Cubic		250.852	21	11.945		
	Order 4		272.049	21	12.955		

Tests of Within-Subjects Contrasts

Measure: CRP

Source	Time		Eta Squared	Noncent. Parameter	Observed Power[a]
Time	Linear		.043	.945	.153
	Quadratic		.029	.631	.118
	Cubic		.254	7.153	.723

		Order 4	.002	.045	.055
Error(Time)		Linear			
		Quadratic			
		Cubic			
		Order 4			

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: CRP

Transformed Variable: Average

Source	Type III Sum of SSquares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	8951.5129	1	8951.529538	27.	<.001	.567

Error	6826.294	21	325.062

Tests of Between-Subjects Effects

Measure: CRP

Transformed Variable: Average

Source	SNoncent. Parameter	Observed Power[a]
Intercept	27.538	.999
Error		

a. Computed using alpha = .05

Estimated Marginal Means

Time

Estimates

Measure: CRP

Time	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
	10.891	2.495	5.702	16.080
	7.794	1.580	4.509	11.078
	8.621	1.758	4.965	12.278
	9.576	2.022	5.371	13.781
	8.223	1.647	4.729	11.717

Pairwise Comparisons

Measure: CRP

(I) Time	(J) Time	Mean (Difference (I-J))	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	2	3.097	1.907	.719	-2.862	9.056
	3	2.269	1.673	.877	-2.959	7.497
	4	1.315	2.200	1.000	-5.560	8.189
	5	2.667	1.555	.656	-2.194	7.528
2	1	-3.097	1.907	.719	-9.056	2.862
	3	-.828	.435	.520	-2.187	.531
	4	-1.782	1.156	.774	-5.397	1.832
	5	-.430	.979	1.000	-3.490	2.630
3	1	-2.269	1.673	.877	-7.497	2.959

			73	7		
	2	.828	.43	.52	-.531	2.187
			5	0		
	4	-.954	1.3	.99	-5.028	3.120
			04	8		
	5	.398	.93	1.0	-2.510	3.306
			0	00		
4	1	-1.315	2.2	1.0	-8.189	5.560
			00	00		
	2	1.782	1.1	.77	-1.832	5.397
			56	4		
	3	.954	1.3	.99	-3.120	5.028
			04	8		
	5	1.352	.99	.87	-1.760	4.465
			6	7		
5	1	-2.667	1.5	.65	-7.528	2.194
			55	6		
	2	.430	.97	1.0	-2.630	3.490
			9	00		
	3	-.398	.93	1.0	-3.306	2.510
			0	00		

4	-1.352	.996	.87	-4.465	1.760

Based on estimated marginal means

a. Adjustment for multiple comparisons: Sidak.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.398	2.979[a]	4.000	18.000	.047	.398
Wilks' lambda	.602	2.979[a]	4.000	18.000	.047	.398
Hotelling's trace	.662	2.979[a]	4.000	18.000	.047	.398
Roy's largest root	.662	2.979[a]	4.000	18.000	.047	.398

Multivariate Tests

	Noncent. Parameter	Observed Power[b]
Pillai's trace	11.914	.675

Wilks' lambda		11.914	.675
Hotelling's trace		11.914	.675
Roy's largest root		11.914	.675

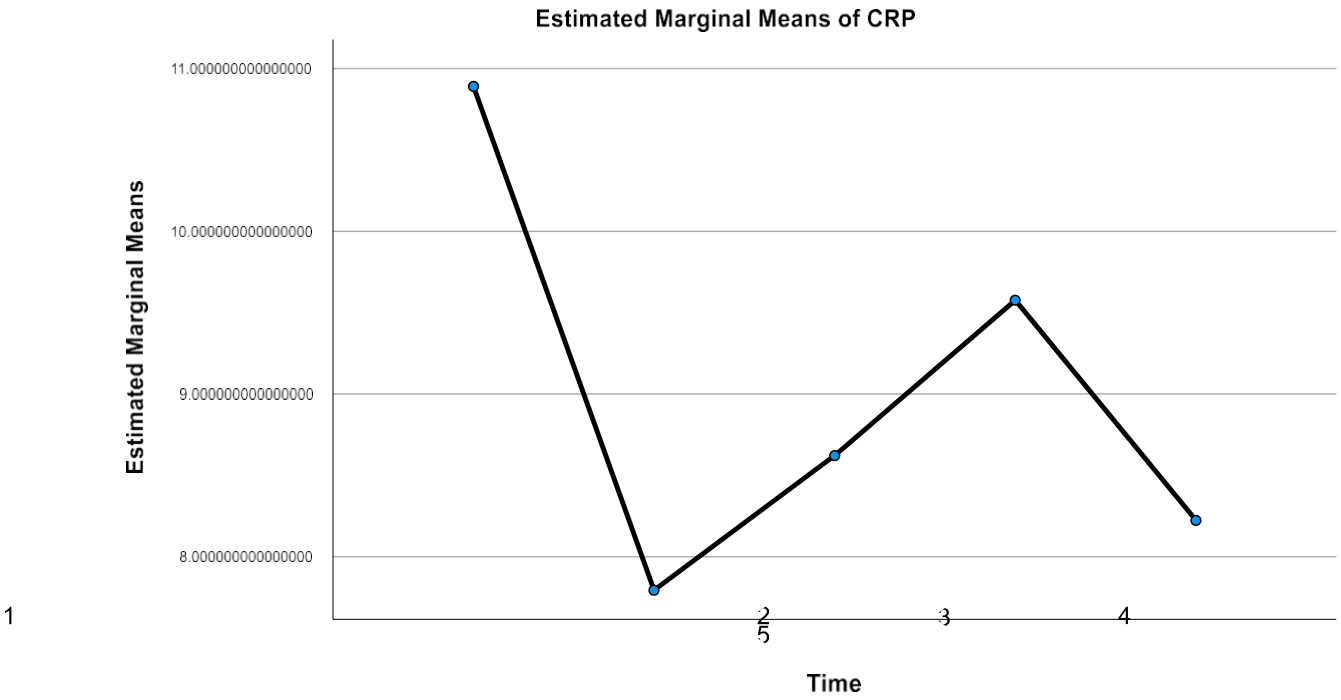
Each F tests the multivariate effect of Time.

These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

b. Computed using alpha = .05

Profile Plots



General Linear Model

Notes

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Within-

Subjects Factors

Measure:

HandGrip

Time	Dependent Variable
1	HG1

1	HG2
2	HG3
3	HG4
4	HG5
5	

Descriptive Statistics

	Mean	Std. Deviation	N
G1	11 7.71	19.14 6	24
G2	11 6.08	18.40 3	24
G3	10 7.04	16.99 5	24
G4	11 1.17	17.55 7	24
G5	11 6.13	18.32 9	24

Multivariate Tests[a]

Effect	Va lue	F	Hypot hesis df	Err or df	Si g.
T ime	Pillai's Trace	.923	60.341[b]	4.000	20.000	<.001
	Wilks' Lambda	.077	60.341[b]	4.000	20.000	<.001
	Hotelling's Trace	12.067	60.341[b]	4.000	20.000	<.001
	Roy's Largest Root	12.068	60.341[b]	4.000	20.000	<.001

Multivariate Tests[a]

Effect		Partial Eta Squared	Noncent. Parameter	Observed Power[c]
T ime	Pillai's Trace	.923	241.366	1.000
	Wilks' Lambda	.923	241.366	1.000
	Hotelling's Trace	.923	241.366	1.000
	Roy's Largest Root		241.366	1.000

	.923	241.36 6	1.000

a. Design: Intercept Within Subjects

Design: Time

b. Exact statistic

c. Computed using alpha = .05

Mauchly's Test of Sphericity[a]

Measure: HandGrip

					Epsilon[b]
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	Sig.	df	Greenhouse-Geisser
Time	.401	19.569	9	.021	.658

Mauchly's Test of Sphericity[a]

Measure: HandGrip

					Epsilon

Within Subjects Effect	Huy nh-Feldt	Lower -bound
Time	.751	.250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept Within Subjects Design: Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: HandGrip

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Sphericity Assumed	1880.417	4	470.14504700		< 0
	Greenhouse-Geisser	1880.421731		714.64525700		< 0
	Huynh-Feldt	1880.431702		626.34534700		< 0
	Lower-bound	1880.411700		1880.45417700		< 0
Error(Time)	Sphericity Assumed	946.383	92	10.287		
	Greenhouse-Geisser	946.3860.3521		15.637		
	Huynh-Feldt	946.3869.3052		13.705		
	Lower-bound	946.3823.3000		41.147		

Tests of Within-Subjects Effects

Measure: HandGrip

Source		Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Time	Sphericity Assumed	.665	182.799	1.000
	Greenhouse-Geisser	.665	120.252	1.000
	Huynh-Feldt	.665	137.203	1.000
	Lower-bound	.665	45.700	1.000
Error(Time)	Sphericity Assumed			
	Greenhouse-Geisser			
	Huynh-Feldt			
	Lower-bound			

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: HandGrip

Source	Time	Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Linear	156.817	1	156.88.71712		.007
	Quadratic	1188.762	1	1188.762	9.633	<.001
	Cubic	163.350	1	163.317.50819		<.001
	Order 4	371.488	1	371.467.88951		<.001
Error(Time)	Linear	413.983	23	17.999		
	Quadratic	195.810	23	8.513		
	Cubic	210.850	23	9.167		
	Order 4	125.740	23	5.467		

Tests of Within-Subjects Contrasts

Measure: HandGrip

Source		TiPartial Eta Squared	Noncent. Parameter	Observed Power[a]
Time	Linear	.275	8.712	.807
	Quadratic	.859	139.633	1.000
	Cubic	.437	17.819	.981
	Order 4	.747	67.951	1.000
Error(Time)	Linear			
	Quadratic			
	Cubic			
	Order 4			

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: HandGrip

Transformed Variable: Average

Source	Type III SSum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	154927 6.875	1	15492 76.875	97 0.056	<.001	.977
Error	36733. 325	23	1597. 101			

Tests of Between-Subjects Effects

Measure: HandGrip

Transformed Variable: Average

Source	SNoncent. Parameter	Observed Power[a]
Intercept	970.051	.000 6
Error		

a. Computed using alpha = .05

Estimated Marginal Means

Time

Estimates

Measure: HandGrip

95% Confidence Interval

Time	Mean	Std. Error	Lower Bound	Upper Bound
	113.924	7.70808	109.624	125.793
	113.712	6.08357	108.312	123.854
	10	3.4	99.86	114.2

3	7.042	69	5	18	
	11	3.5	103.7	118.5	
4	1.167	84	53	80	
	11	3.7	108.3	123.8	
5	6.125	41	85	65	

Pairwise Comparisons

Measure: HandGrip

					95% Confidence Interval for Difference[b]	
(I) Time	(J) Time	Mean (Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound
1	2	1.625	.707	.269	-.562	3.812
	3	10.667*	.736	<.001	8.388	12.945
	4	6.542*	1.155	<.001	2.969	10.115
	5	1.583	.915	.639	-1.247	4.414
2	1	-1.625	.707	.269	-3.812	.562

	3	9.042*	.748	<.001	6.727	11.357
	4	4.917*	1.195	.004	1.220	8.613
	5	-.042	1.086	1.000	-3.402	3.319
3	1	-10.667*	.736	<.001	-12.945	-8.388
	2	-9.042*	.748	<.001	-11.357	-6.727
	4	-4.125*	.895	.001	-6.896	-1.354
	5	-9.083*	.862	<.001	-11.750	-6.417
4	1	-6.542*	1.155	<.001	-10.115	-2.969
	2	-4.917*	1.195	.004	-8.613	-1.220
	3	4.125*	.895	.001	1.354	6.896
	5	-4.958*	.806	<.001	-7.454	-2.463

5	1	-1.583	.915	.639	-4.414	1.247
	2	.042	1.086	1.000	-3.319	3.402
	3	9.083*	.862	<.001	6.417	11.750
	4	4.958*	.806	<.001	2.463	7.454

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Sidak.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.923	60.341[a]	4.000	20.000	<.001	.923
Wilks' lambda	.077	60.341[a]	4.000	20.000	<.001	.923
Hotelling's trace	12.068	60.341[a]	4.000	20.000	<.001	.923

Roy's largest root	12.068	60.341[a]	4.000	20.000	<.001	.923

Multivariate Tests

t. Parameter		NoncenObserved Power[b]	
Pillai's trace	241.366		1.000
Wilks' lambda	241.366		1.000
Hotelling's trace	241.366		1.000
Roy's largest root	241.366		1.000

Each F tests the multivariate effect of Time. These tests are based on the linearly

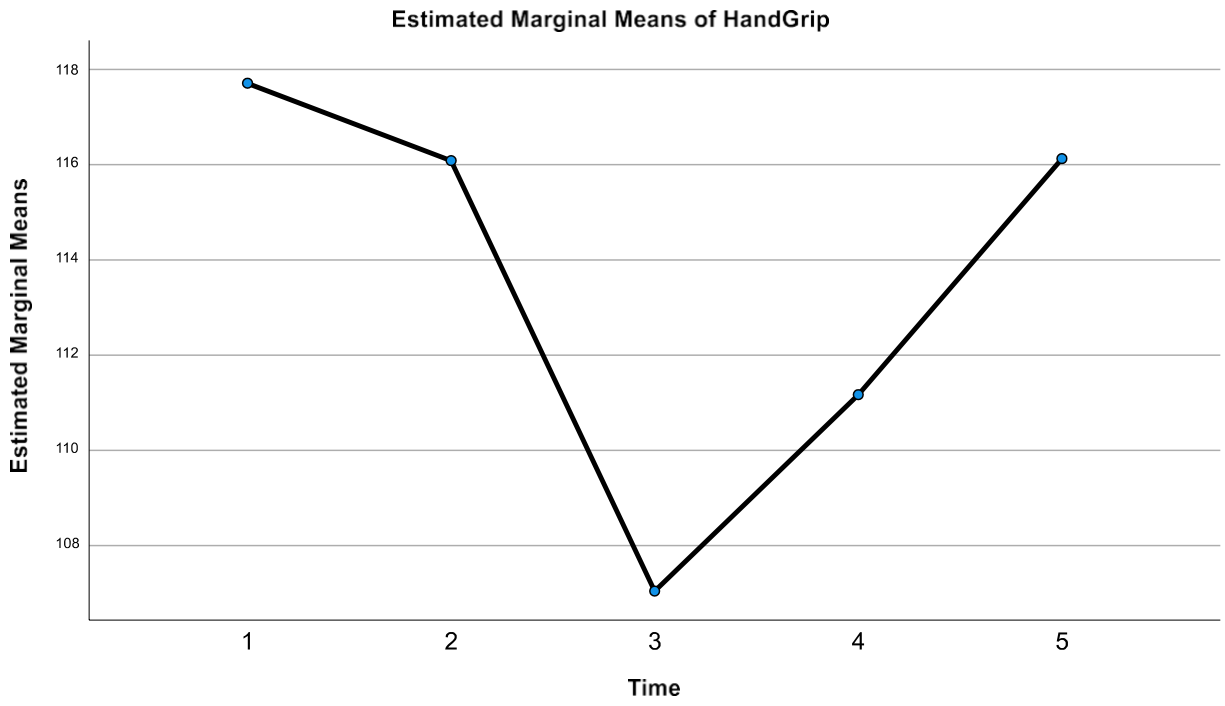
independent pairwise comparisons among the

estimated marginal means.

a. Exact statistic

b. Computed using alpha = .05

Profile Plots



General Linear Model

Notes

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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
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Within- Subjects Factors

Measure: VerticalJump

Time	Dependent Variable
1	VJ1
2	VJ2
3	VJ3
4	VJ4
5	VJ5

Descriptive Statistics

	Mean	Std. Deviation	N

	24.445	3.9827	24
J1	83333333333	86785620107	
	3		
	24.275	3.7997	24
J2	00000000000	99765891562	
	6		
	22.945	3.6413	24
J3	83333333333	06402768185	
	3		
	23.445	3.8950	24
J4	83333333332	33534115472	
	6		
	24.241	3.9534	24
J5	66666666666	15327741722	
	7		

Multivariate Tests[a]

Effect	Value	F	Hypothesis df	Error df	Sig.
Time	Pillai's Trace	.756	15.4.000	20.000	<.001

Wilks' Lambda		.244	15.522[b]	4.000	20.000	<.001
Hotelling's Trace	3.104		15.522[b]	4.000	20.000	<.001
Roy's Largest Root	3.104		15.522[b]	4.000	20.000	<.001

Multivariate Tests[a]

Effect		Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Time	Pillai's Trace	.756	62.086	1.000
	Wilks' Lambda	.756	62.086	1.000
	Hotelling's Trace	.756	62.086	1.000
	Roy's Largest Root	.756	62.086	1.000

a. Design: Intercept Within Subjects

Design: Time

b. Exact statistic

c. Computed using alpha = .05

Mauchly's Test of Sphericity[a]

Measure: VerticalJump

				Epsilon[b]
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	Sig.	Greenhouse-Geisser
Time	.156	39.838	9<.001	.519

Mauchly's Test of Sphericity[a]

Measure: VerticalJump

		Epsilon	
Within Subjects Effect	Huynh-Feldt	Lower-bound	
Time	.572	.250	

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept Within Subjects Design: Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: VerticalJump

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Sphericity Assumed	40.026	4	10.006051	30.	< 0

	Greenhouse-Geisser	40.026	2.077	19.273	30.051	<.001
	Huynh-Feldt	40.026	2.287	17.505	30.051	<.001
	Lower-bound	40.026	1.000	40.026	30.051	<.001
Error(Time)	Sphericity Assumed	30.634	92	.333		
	Greenhouse-Geisser	30.634	47.765	.641		
	Huynh-Feldt	30.634	52.591	.583		
	Lower-bound	30.634	23.000	1.332		

Tests of Within-Subjects Effects

Measure: VerticalJump

Source		Partial Eta Squared	Noncen. Parameter	Observed Power[a]
Time	Sphericity Assumed	.566	120.201	.000

	Greenhouse-Geisser	.566	62.409	1.000
	Huynh-Feldt	.566	68.714	1.000
	Lower-bound	.566	30.051	.999
Error(Time)	Sphericity Assumed			
	Greenhouse-Geisser			
	Huynh-Feldt			
	Lower-bound			

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: VerticalJump

Source	Time	Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Linear	3.675	1	3.675	11.467	.003

	Quadratic	24.268	1	24.268	47.545	<.001
	Cubic	5.075	1	5.075	15.322	<.001
	Order 4	7.007	1	7.007	41.274	<.001
Error(Time)	Linear	7.372	23	.321		
	Quadratic	11.740	23	.510		
	Cubic	7.618	23	.331		
	Order 4	3.905	23	.170		

Tests of Within-Subjects Contrasts

Measure: VerticalJump

Source	Time		Eta Squared	Partial	Noncent. Parameter	Observed Power[a]
Time	Linear	.333			11.467	.900

		Quadratic	.67447.545	1.000
		Cubic	.40015.322	.963
		Order 4	.64241.274	1.000
Error(Time)	Linear			
	Quadratic			
	Cubic			
	Order 4			

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: VerticalJump

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	68378.002	1	68378.002	936.311	<.001	.976
Error	1679.668	23	73.029			

Tests of Between-Subjects Effects

Measure: VerticalJump

Transformed Variable: Average

Source	Noncent. Parameter	Observed Power[a]
Intercept	936.311	.000
Error		

a. Computed using alpha = .05

Estimated Marginal Means

Time

Estimates

Measure: VerticalJump

Time	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1	24.446	.813	22.764	26.128
2	24.275	.776	22.670	25.880
3	22.946	.743	21.408	24.483
4	23.446	.795	21.801	25.091

4	24.242	.807	22.572	25.911
5				

Pairwise Comparisons

Measure: VerticalJump

(I) Time	(J) Time	Mean (Difference (I-J))	St d. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	.171	.116	.814	-.189	.530
	3	1.500*	.214	<.001	.837	2.163
	4	1.000*	.229	.002	.290	1.710
	5	.204	.109	.533	-.132	.541
2	1	-.171	.116	.814	-.530	.189
	3	1.329*	.172	<.001	.798	1.860
	4	.829*	.200	.002	.191	1.467

			6	5		
	5	.033	.09	1.0	-.266	.332
			7	00		
3	1	-1.500*	.21	<.0	-2.163	-.837
			4	01		
	2	-1.329*	.17	<.0	-1.860	-.798
			2	01		
	4	-.500*	.14	.02	-.945	-.055
			4	0		
	5	-1.296*	.15	<.0	-1.786	-.806
			8	01		
4	1	-1.000*	.22	.00	-1.710	-.290
			9	2		
	2	-.829*	.20	.00	-1.467	-.191
			6	5		
	3	.500*	.14	.02	.055	.945
			4	0		
	5	-.796*	.16	<.0	-1.301	-.291
			3	01		
5	1	-.204	.10	.53	-.541	.132
			9	3		

	2	-.033	.097	1.000	-.332	.266
	3	1.296*	.158	<.001	.806	1.786
	4	.796*	.163	<.001	.291	1.301

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Sidak.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.756	15.522[a]	4.000	20.000	<.001	.756
Wilks' lambda	.244	15.522[a]	4.000	20.000	<.001	.756
Hotelling's trace	3.104	15.522[a]	4.000	20.000	<.001	.756
Roy's largest root	3.104	15.522[a]	4.000	20.000	<.001	.756

Multivariate Tests

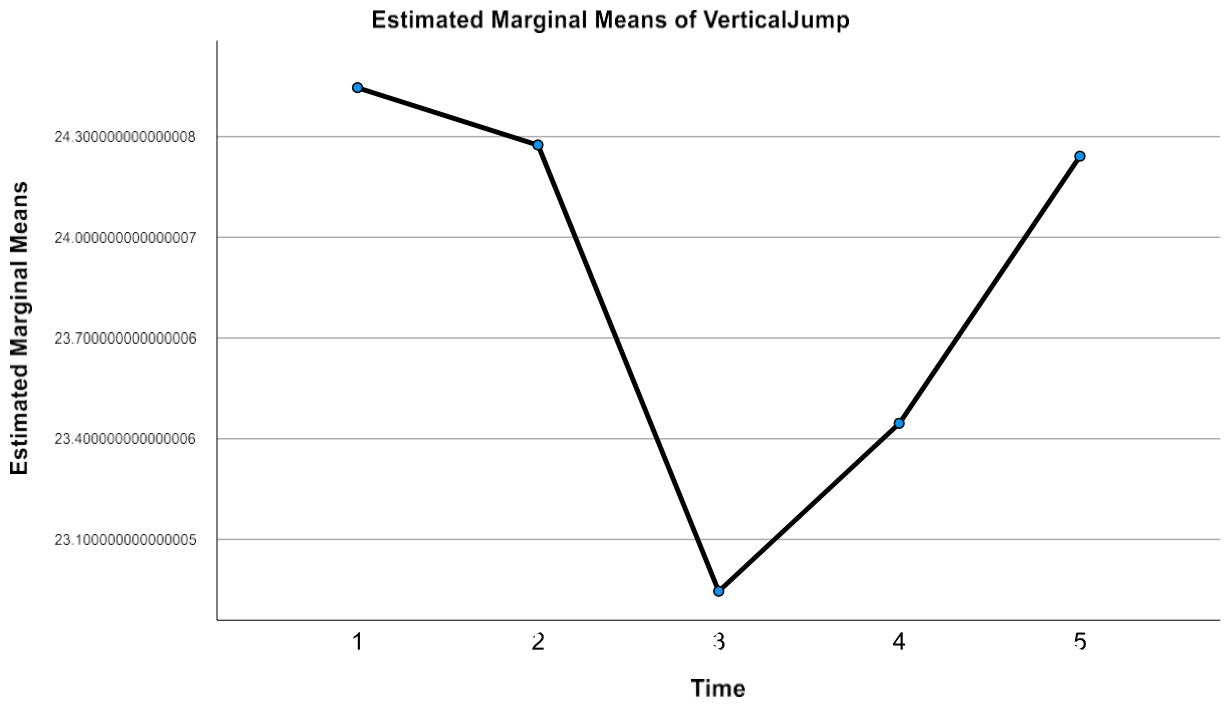
		NoncenObserved Power[b]	
t. Parameter			
Pillai's trace		62.086	1.000
Wilks' lambda		62.086	1.000
Hotelling's trace		62.086	1.000
Roy's largest root		62.086	1.000

Each F tests the multivariate effect of Time. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

b. Computed using alpha = .05

Profile Plots



General Linear Model

Notes

Output Created		15-JUN-2022 12:50:37
Comments		
Input	Data	C:\Users\tdejong\Dropbox\Active Student\Sokolski, M - Ex Phys - Rigby\Sokoloski_Dissertation_Stats.sav
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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with

		valid data for all variables in the model.
Syntax		GLM SR1 SR2 SR3 SR4 SR5 /WSFACTOR=Time 5 Polynomial /MEASURE=SitAndReach /METHOD=SSTYPE(3) /PLOT=PROFILE(Time) TYPE=LINE ERRORBAR=NO MEANREFERENCE=N O YAXIS=AUTO /EMMEANS=TABLES(Time) COMPARE ADJ(SIDAK) /PRINT=DESCRIPTIVE ETASQ OPOWER /CRITERIA=ALPHA(.05) /WSDESIGN=Time.
Resources	Processor Time	00:00:00.14

Elapsed Time	00:00:00.14

Within- Subjects Factors

Measure: SitAndReach

Time	Dependent Variable
1	SR1
2	SR2
3	SR3
4	SR4
5	SR5

Descriptive Statistics

	Mean	Std. Deviation	N
R1	27.2188	7.55426	24
R2	27.4375	7.66778	24
R3	25.3542	7.16191	24

	26.	7.595	24
R4	0521	76	
	26.	7.794	24
R5	8854	22	

Multivariate Tests[a]

Effect	Value	F	Hypothesis df	Error df	Sig.
Time	Pillai's Trace	.842	26.634[b]	4.000	20.000	<.001
	Wilks' Lambda	.158	26.634[b]	4.000	20.000	<.001
	Hotelling's Trace	5.327	26.634[b]	4.000	20.000	<.001
	Roy's Largest Root	5.327	26.634[b]	4.000	20.000	<.001

Multivariate Tests[a]

Effect	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Pillai's		.842	106.53	1.000

Time	Trace		6	
	Wilks' Lambda	.842	106.53	1.000
	Hotelling's Trace	.842	6 106.53	1.000
	Roy's Largest Root	.842	6 106.53	1.000
			6	

a. Design: Intercept Within Subjects

Design: Time

b. Exact statistic

c. Computed using alpha = .05

Mauchly's Test of Sphericity[a]

Measure: SitAndReach

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]

				Greenhouse-Geisser
Time	.549	12.838	9	.17.797 1

Mauchly's Test of Sphericity[a]

Measure: SitAndReach

		Epsilon	
Within Subjects Effect	Huy nh-Feldt	Lower -bound	
Time	.940	.250	

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept

Within Subjects Design: Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: SitAndReach

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Sphericity Assumed	72.420	4	18.1025.	5438	< 0
	Greenhouse-Geisser	72.4203.188		22.7125.	6438	< 0
	Huynh-Feldt	72.4203.761		19.2525.	5438	< 0
	Lower-bound	72.4201.000		72.4225.	0438	< 0
Error(Time)	Sphericity Assumed	65.480	92	.712		
	Greenhouse-Geisser	65.48073.325		.893		
	Huynh-Feldt	65.480	86.503			.75

	Lower-bound	65.480	23.000	2.84

Tests of Within-Subjects Effects

Measure: SitAndReach

Source		Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Time	Sphericity Assumed	.525	101.750	1.000
	Greenhouse-Geisser	.525	81.096	1.000
	Huynh-Feldt	.525	95.671	1.000
	Lower-bound	.525	25.438	.998
Error(Time)	Sphericity Assumed			
	Greenhouse-Geisser			
	Huynh-Feldt			
	Lower-bound			

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: SitAndReach

Source	Time	Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Linear	10.107	1	10.109.9776		.004
	Quadratic	27.572	1	27.5729.2392		<.001
	Cubic	14.259	1	14.2526.9522		<.001
	Order 4	20.482	1	20.4857.2177		<.001
Error(Time)	Linear	23.300	23	1.013		
	Quadratic	21.576	23	.938		
	Cubic	12.366	23	.538		

	Order 4	8.239		23	.358

Tests of Within-Subjects Contrasts

Measure: SitAndReach

Source	Time		Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Time	Linear		.303	9.976	.856
	Quadratic		.561	29.392	.999
	Cubic		.536	26.522	.998
	Order 4		.713	57.177	1.000
Error(Time)	Linear				
	Quadratic				
	Cubic				

Order 4	

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: SitAndReach

Transformed Variable: Average

Source	Type III Sum of SSquares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	84840.713	1	84840.713	30 0.052	<.001	.929
Error	6503.324	23	282.753			

Tests of Between-Subjects Effects

Measure: SitAndReach

Transformed Variable: Average

Source	Noncent. Parameter	Observed Power[a]
Intercept	300.05	1.000
Error		

a. Computed using alpha = .05

Estimated Marginal Means

Time

Estimates

Measure: SitAndReach

Time	Mean	95% Confidence Interval	
		Std. Error	Lower Bound	Upper Bound
	27.219	1.542	24.029	30.409
	27.438	1.565	24.200	30.675
	25.354	1.462	22.330	28.378
	26.052	1.550	22.845	29.259
	26.885	1.591	23.594	30.177

Pairwise Comparisons

Measure: SitAndReach

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
1	2	-.219	.215	.979	-.884	.447

	3	1.865*	.257	<.001	1.069	2.660
	4	1.167*	.248	<.001	.398	1.936
	5	.333	.288	.950	-.558	1.225
2	1	.219	.215	.979	-.447	.884
	3	2.083*	.196	<.001	1.477	2.690
	4	1.385*	.215	<.001	.720	2.050
	5	.552	.241	.275	-.194	1.299
3	1	-1.865*	.257	<.001	-2.660	-1.069
	2	-2.083*	.196	<.001	-2.690	-1.477
	4	-.698*	.210	.029	-1.346	-.049
	5	-1.531*	.312	<.001	-2.497	-.565

4	1	-1.167*	.248	<.001	-1.936	-.398
	2	-1.385*	.215	<.001	-2.050	-.720
	3	.698*	.210	.029	.049	1.346
	5	-.833*	.228	.013	-1.537	-.129
5	1	-.333	.288	.950	-1.225	.558
	2	-.552	.241	.275	-1.299	.194
	3	1.531*	.312	<.001	.565	2.497
	4	.833*	.228	.013	.129	1.537

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Sidak.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared

Pillai's trace	.842	26.634[a]	4.000	20.000	<.001	.842
Wilks' lambda	.158	26.634[a]	4.000	20.000	<.001	.842
Hotelling's trace	5.327	26.634[a]	4.000	20.000	<.001	.842
Roy's largest root	5.327	26.634[a]	4.000	20.000	<.001	.842

Multivariate Tests

t. Parameter	NoncenObserved Power[b]	
Pillai's trace	106.536	1.000
Wilks' lambda	106.536	1.000
Hotelling's trace	106.536	1.000
Roy's largest root	106.536	1.000

Each F tests the multivariate effect of Time.

These tests are based on the linearly

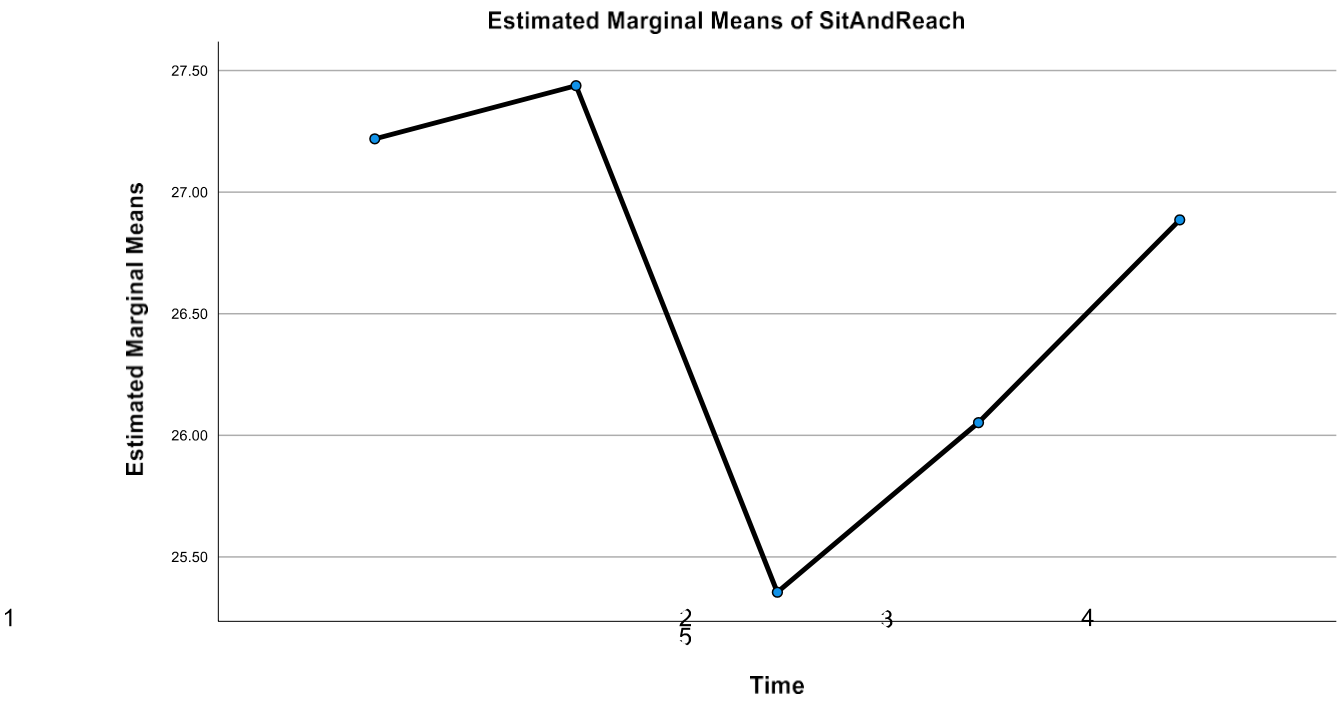
independent pairwise comparisons among the

estimated marginal means.

a. Exact statistic

b. Computed using alpha = .05

Profile Plots



General Linear Model

Notes

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Comments		
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	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	24
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		GLM TNF1 TNF2_OR TNF3 TNF4 TNF5 /WSFACTOR=Time 5 Polynomial /MEASURE=TNF

		/METHOD=SSTYPE(3) /PLOT=PROFILE(Time) TYPE=LINE ERRORBAR=NO MEANREFERENCE=N O YAXIS=AUTO /EMMEANS=TABLES(Ti me) COMPARE ADJ(SIDAK) /PRINT=DESCRIPTIVE ETASQ OPOWER /CRITERIA=ALPHA(.05) /WSDESIGN=Time.
Resources	Processor Time	00:00:00.14
	Elapsed Time	00:00:00.14

Within-

Subjects Factors

Measure: TNF

Time	Dependent Variable
1	TNF1

1	TNF2_	
2	OR	
		TNF3
3		TNF4
4		TNF5
5		

Descriptive Statistics

	Mean	Std. Deviation	N
TNF1	3.9500	2.31750	8
TNF2_OR	2.9338	1.41033	8
TNF3	1.8125	.71270	8
TNF4	3.0438	1.27796	8
TNF5	3.7038	1.65348	8

Multivariate Tests[a]

Effect	Va lue	F	Hypot hesis df	Err or df	Si g.
T ime	Pillai's Trace	.855.9 640[b]	4.000	4.0 00	.05 6
	Wilks' Lambda	.145.9 440[b]	4.000	4.0 00	.05 6
	Hotelling's Trace	5.95.9 4040[b]	4.000	4.0 00	.05 6
	Roy's Largest Root	5.95.9 4040[b]	4.000	4.0 00	.05 6

Multivariate Tests[a]

Effect	Eta Squared	Partial Noncent. Parameter	Observed Power[c]
T ime	Pillai's Trace	.85623.761	.602
	Wilks' Lambda	.85623.761	.602
	Hotelling's Trace	.85623.761	.602

Roy's Largest Root	.85623.761	.602

a. Design: Intercept Within Subjects

Design: Time

b. Exact statistic

c. Computed using alpha = .05

Mauchly's Test of Sphericity[a]

Measure: TNF

					Epsilon[b]
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	Sig.		Greenhouse-Geisser
Time	.023	20.368	9	.020	.352

Mauchly's Test of Sphericity[a]

Measure: TNF

					Epsilon

Within Subjects Effect	Huy nh-Feldt	Lower -bound
Time	.415	.250

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.[a]

a. Design: Intercept Within Subjects Design: Time

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: TNF

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Sphericity Assumed	22.199	4	5.5502.910		.0
	Greenhouse-Geisser	22.1991.409		15.752.910		.1
	Huynh-Feldt	22.1991.659		13.382.910		.1
	Lower-bound	22.1991.000		22.192.910		.1
Error(Time)	Sphericity Assumed	53.406	28	1.907		
	Greenhouse-Geisser	53.4069.864		5.414		
	Huynh-Feldt	53.40611.611		4.600		
	Lower-bound	53.4067.000		7.629		

Tests of Within-Subjects Effects

Measure: TNF

Source		Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Time	Sphericity Assumed	.294	11.638	.708
	Greenhouse-Geisser	.294	4.100	.385
	Huynh-Feldt	.294	4.826	.425
	Lower-bound	.294	2.910	.314
Error(Time)	Sphericity Assumed			
	Greenhouse-Geisser			
	Huynh-Feldt			
	Lower-bound			

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: TNF

Source	Time		Type III Sum of Squares	df	Mean Square	F	Sig.
Time	Linear		.117	1	.117	.020	.890
	Quadratic		18.598	1	18.5926.8434		.001
	Cubic		.174	1	.174	.226	.649
	Order 4		3.309	1	3.3097.848		.026
Error(Time)	Linear		40.136	7	5.734		
	Quadratic		4.925	7	.704		
	Cubic		5.393	7	.770		
	Order 4		2.952	7	.422		

Tests of Within-Subjects Contrasts

Measure: TNF

Source	TiPartial	Eta Squared	Noncent. Parameter	Observed Power[a]
Time	Linear	.003	.020	.052
	Quadratic	.791	26.434	.992
	Cubic	.031	.226	.070
	Order 4	.529	7.848	.673
Error(Time)	Linear			
	Quadratic			
	Cubic			
	Order 4			

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: TNF

Transformed Variable: Average

Source	Type III SSum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	381.615	1	381.615	82.861	<.001	.922
Error	32.239	7	4.606			

Tests of Between-Subjects Effects

Measure: TNF

Transformed Variable: Average

Source	SNoncent. Parameter	Observed Power[a]
Intercept	82.861	1.000
Error		

a. Computed using alpha = .05

Estimated Marginal Means

Time

Estimates

Measure: TNF

95% Confidence Interval

Time	Mean	Std. Error	Lower Bound	Upper Bound
	3.950	.819	2.013	5.887
	2.934	.499	1.755	4.113
		1.8	.25	1.217	2.408

3		13	2		
		3.0	.45	1.975	4.112
4		44	2		
		3.7	.58	2.321	5.086
5		04	5		

Pairwise Comparisons

Measure: TNF

					95% Confidence Interval for Difference[b]	
(I) Time	(J) Time	Mean (Difference (I-J)	St d. Error	Sig.[b]	Lower Bound	Upper Bound
1	2	1.016	.572	.719	-1.280	3.312
	3	2.137	.757	.228	-.898	5.173
	4	.906	.731	.947	-2.025	3.838
	5	.246	1.241	1.000	-4.731	5.224
2	1	-1.016	.572	.719	-3.312	1.280

	3	1.121	.347	.135	-.269	2.511
	4	-.110	.294	1.000	-1.288	1.068
	5	-.770	.823	.992	-4.072	2.532
3	1	-2.137	.757	.228	-5.173	.898
	2	-1.121	.347	.135	-2.511	.269
	4	-1.231*	.273	.027	-2.326	-.137
	5	-1.891	.642	.196	-4.468	.686
4	1	-.906	.731	.947	-3.838	2.025
	2	.110	.294	1.000	-1.068	1.288
	3	1.231*	.273	.027	.137	2.326
	5	-.660	.651	.985	-3.269	1.949

5	1	-.246	1.241	1.000	-5.224	4.731
	2	.770	.823	.992	-2.532	4.072
	3	1.891	.642	.196	-.686	4.468
	4	.660	.651	.985	-1.949	3.269

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Sidak.

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.856	5.940[a]	4.000	4.000	.056	.856
Wilks' lambda	.144	5.940[a]	4.000	4.000	.056	.856
Hotelling's trace	5.940	5.940[a]	4.000	4.000	.056	.856

Roy's largest root	5.940	5.940[a]	4.000	4.000	.056	.856

Multivariate Tests

t. Parameter		NoncenObserved Power[b]	
Pillai's trace	23.761		.602
Wilks' lambda	23.761		.602
Hotelling's trace	23.761		.602
Roy's largest root	23.761		.602

Each F tests the multivariate effect of Time. These tests are based on the linearly

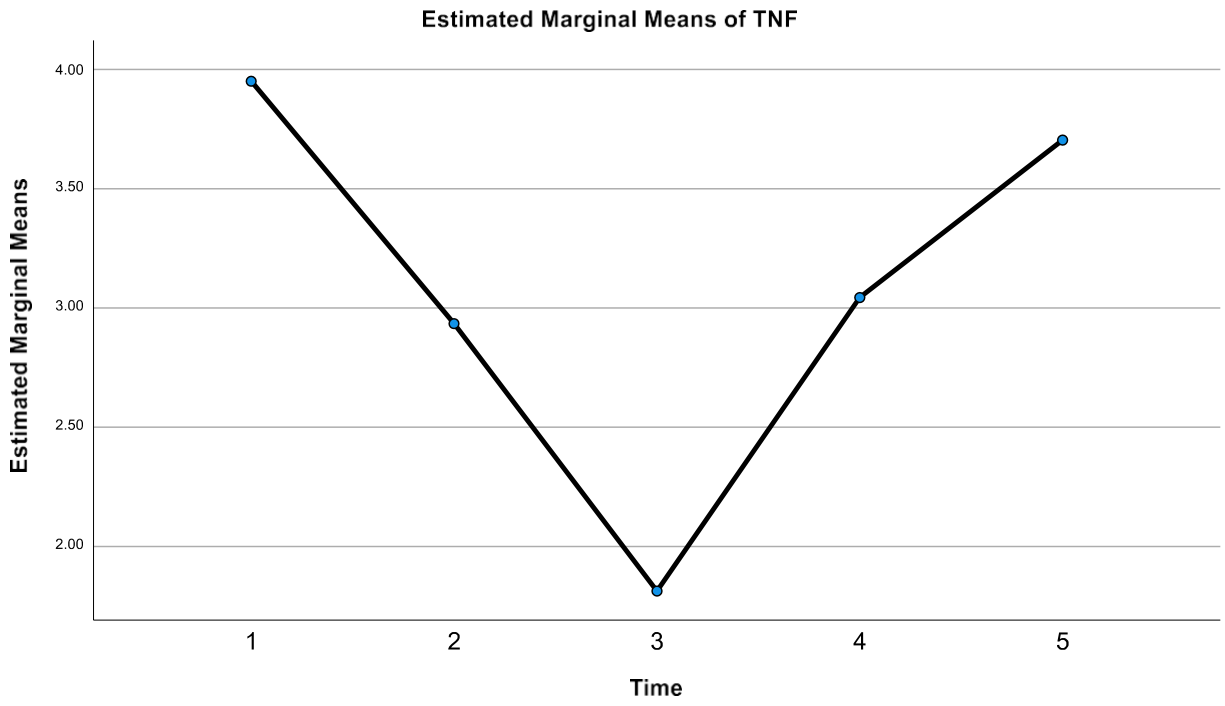
independent pairwise comparisons among the

estimated marginal means.

a. Exact statistic

b. Computed using alpha = .05

Profile Plots



Bootstrap

Notes

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Syntax		BOOTSTRAP /SAMPLING METHOD=SIMPLE /VARIABLES INPUT=BMI PAT /CRITERIA CILEVEL=95 CITYPE=PERCENTILE NSAMPLES=1000 /MISSING USERMISSING=EXCLUDE.
Resources	Processor Time	00:00:00.01
	Elapsed Time	00:00:00.00

Bootstrap Specifications

Sampling Method	Simple
Number of Samples	1000
Confidence Interval Level	95.0%
Confidence Interval Type	Percentile

Correlations

Notes

Output Created		22-MAR-2023 13:49:25
Comments		
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	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.
Syntax		CORRELATIONS /VARIABLES=BMI PAT /PRINT=TWOTAIL NOSIG FULL /STATISTICS DESCRIPTIVES /MISSING=PAIRWISE.
Resources	Processor Time	00:00:02.85
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Descriptive Statistics

			Bootstrap[a]			
					95% Confidence Interval	
		Statistic	Bias	Std. Error	Lower	Upper
BMI	Mean	29.4958	.0059	.6034	28.2667	30.6249
	Std. Deviation	2.96274	-.14267	.62983	1.59667	4.06303
	N	24	0	0	24	24
PAT	Mean	31.1992	.0241	1.2966	28.8531	33.9673
	Std. Deviation	6.12936	-.19720	.99048	4.07104	7.90769
	N	24	0	0	24	24

a. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Correlations

				BMI	PAT
BMI	Pearson Correlation			1	-.007
	Sig. (2-tailed)				.973
	N			24	24
	Bootstrap[c]	Bias		0	.005
		Std. Error		0	.172
		95% Confidence Interval	Lower	1	-.322
			Upper	1	.356
PAT	Pearson Correlation			-.007	1
	Sig. (2-tailed)			.973	
	N			24	24
	Bootstrap[c]	Bias		.005	0
		Std. Error		.172	0
		95% Confidence Interval	Lower	-.322	1
			Upper	.356	1

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Bootstrap

Notes

Output Created		22-MAR-2023 14:28:49
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Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.00

[DataSet1] /Users/chrisirvine/Downloads/Sokoloski_Dissertation_Stats (2).sav

Bootstrap Specifications

Sampling Method	Simple
Number of Samples	1000
Confidence Interval Level	95.0%
Confidence Interval Type	Percentile

Correlations

Notes

Output Created		22-MAR-2023 14:28:49
Comments		
Input	Data	/Users/chrisirvine/Downloads/Sokoloski_Dissertation_Stats (2).sav
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	Cases Used	Statistics for each pair of variables are based on all the cases with valid data for that pair.
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Resources	Processor Time	00:00:22.81
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Descriptive Statistics

			Bootstrap[a]		
		Statistic	Bias	Std. Error	95% … Lower
PAT	Mean	31.3091	-.0059	1.3457	28.6869
	Std. Deviation	6.31772	-.22917	1.01484	4.11566
	N	22	0	0	22
MB1	Mean	16.1350909	.008382636	1.22926639	13.7794277
	Std. Deviation	6.06467802	-.211591367	.798311599	4.12481195
	N	22	0	0	22
MB2	Mean	16.5496364	-.117380432	2.64980997	12.4504980
	Std. Deviation	12.9786696	-1.85796408	5.31234563	3.86401543
	N	22	0	0	22
MB3	Mean	32.6970682	-.224677636	5.19096618	23.9078181
	Std. Deviation	25.2264680	-2.65548851	8.38099262	9.98423661
	N	22	0	0	22
MB4	Mean	19.8663409	-.003648273	2.19989623	15.9205873
	Std. Deviation	10.7073324	-.592027233	2.40101633	5.55833128
	N	22	0	0	22
MB5	Mean	18.7254773	.004803682	2.10489860	15.2124970
	Std. Deviation	10.1172130	-.565761709	2.50848925	4.07185321
	N	22	0	0	22
CRP1	Mean	10.8905682	-.021121114	2.45769880	6.45668285
	Std. Deviation	11.7032700	-.633682581	3.16425334	5.92508555
	N	22	0	0	22
CRP2	Mean	7.79350000	.001995455	1.56987323	5.06763564
	Std. Deviation	7.40860658	-.288156220	1.48588078	4.01515019
	N	22	0	0	22
CRP3	Mean	8.62147727	.009126500	1.74890555	5.69153067
	Std. Deviation	8.24624342	-.384493211	1.98974501	4.16886157
	N	22	0	0	22
CRP4	Mean	9.57584091	.004590955	1.98959139	6.13174705
	Std. Deviation	9.48358096	-.361463598	1.91943159	5.25429217
	N	22	0	0	22
CRP5	Mean	8.22336364	.005345114	1.64956415	5.30120296
	Std. Deviation	7.88026441	-.340107398	1.81680722	4.03566784
	N	22	0	0	22

Descriptive Statistics

		Bootstrap[a] 95% Confidence . Upper
PAT	Mean	33.9933
	Std. Deviation	7.98590
	N	22
MB1	Mean	18.4738993
	Std. Deviation	7.32026405
	N	22
MB2	Mean	22.5445509
	Std. Deviation	20.4234205
	N	22
MB3	Mean	43.9251146
	Std. Deviation	38.0252176
	N	22
MB4	Mean	24.3473852
	Std. Deviation	14.3499752
	N	22
MB5	Mean	23.1057975
	Std. Deviation	14.0275563
	N	22
CRP1	Mean	16.4083154
	Std. Deviation	16.8616082
	N	22
CRP2	Mean	11.1845314
	Std. Deviation	9.77674873
	N	22
CRP3	Mean	12.4625210
	Std. Deviation	11.7722559
	N	22
CRP4	Mean	13.7379487
	Std. Deviation	12.6539691
	N	22
CRP5	Mean	11.8246518
	Std. Deviation	11.0070019
	N	22

a. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Correlations

				PAT	MB1	MB2	MB3
PAT	Pearson Correlation			1	.110	.153	.194
	Sig. (2-tailed)				.625	.498	.386
	N			22	22	22	22
	Bootstrap[c]	Bias		0	-.016	.066	.039
		Std. Error		0	.198	.215	.190
		95% Confidence Interval	Lower	1	-.269	-.128	-.087
			Upper	1	.488	.713	.634
MB1	Pearson Correlation			.110	1	.628**	.465*
	Sig. (2-tailed)			.625		.002	.029
	N			22	22	22	22
	Bootstrap[c]	Bias		-.016	0	.061	-.035
		Std. Error		.198	0	.096	.191
		95% Confidence Interval	Lower	-.269	1	.504	-.003
			Upper	.488	1	.893	.738
MB2	Pearson Correlation			.153	.628**	1	.927**
	Sig. (2-tailed)			.498	.002		<.001
	N			22	22	22	22
	Bootstrap[c]	Bias		.066	.061	0	-.076
		Std. Error		.215	.096	0	.133
		95% Confidence Interval	Lower	-.128	.504	1	.530
			Upper	.713	.893	1	.982
MB3	Pearson Correlation			.194	.465*	.927**	1
	Sig. (2-tailed)			.386	.029	<.001	
	N			22	22	22	22
	Bootstrap[c]	Bias		.039	-.035	-.076	0
		Std. Error		.190	.191	.133	0
		95% Confidence Interval	Lower	-.087	-.003	.530	1
			Upper	.634	.738	.982	1
MB4	Pearson Correlation			-.003	.392	.209	.298
	Sig. (2-tailed)			.991	.071	.350	.178
	N			22	22	22	22
	Bootstrap[c]	Bias		.001	.034	.108	.080
		Std. Error		.215	.198	.207	.184
		95% Confidence Interval	Lower	-.403	.054	.026	.097
			Upper	.451	.766	.820	.816
MB5	Pearson Correlation			-.300	.403	.337	.334
	Sig. (2-tailed)			.174	.063	.125	.129
	N			22	22	22	22
	Bootstrap[c]	Bias		.054	.017	.062	.041
		Std. Error		.276	.210	.187	.144

Correlations

				CRP3	CRP4	CRP5
PAT	Pearson Correlation			-.009	.264	.257
	Sig. (2-tailed)			.969	.235	.248
	N			22	22	22
	Bootstrap[c]	Bias		-.014	-.069	-.025
		Std. Error		.231	.330	.234
		95% Confidence Interval	Lower	-.529	-.483	-.312
			Upper	.362	.708	.617
MB1	Pearson Correlation			-.419	-.425*	-.469*
	Sig. (2-tailed)			.052	.049	.028
	N			22	22	22
	Bootstrap[c]	Bias		-.013	-.019	-.012
		Std. Error		.110	.143	.117
		95% Confidence Interval	Lower	-.651	-.718	-.710
			Upper	-.215	-.170	-.240
MB2	Pearson Correlation			-.154	-.077	-.112
	Sig. (2-tailed)			.493	.734	.620
	N			22	22	22
	Bootstrap[c]	Bias		.002	.000	-.001
		Std. Error		.140	.254	.198
		95% Confidence Interval	Lower	-.435	-.584	-.580
			Upper	.160	.501	.303
MB3	Pearson Correlation			.096	.119	.113
	Sig. (2-tailed)			.672	.599	.616
	N			22	22	22
	Bootstrap[c]	Bias		.049	.044	.033
		Std. Error		.256	.267	.275
		95% Confidence Interval	Lower	-.275	-.315	-.404
			Upper	.656	.693	.668
MB4	Pearson Correlation			-.113	-.335	-.319
	Sig. (2-tailed)			.617	.127	.147
	N			22	22	22
	Bootstrap[c]	Bias		-.044	-.024	-.046
		Std. Error		.222	.181	.205
		95% Confidence Interval	Lower	-.684	-.697	-.770
			Upper	.224	.025	.023
MB5	Pearson Correlation			-.259	-.387	-.347
	Sig. (2-tailed)			.244	.075	.114
	N			22	22	22
	Bootstrap[c]	Bias		-.015	-.011	-.022
		Std. Error		.140	.115	.145

Correlations

				PAT	MB1	MB2	MB3
		95% Confidence Interval	Lower	-.691	.001	.045	.133
			Upper	.443	.799	.788	.739
CRP1	Pearson Correlation			.121	-.420	-.139	.043
	Sig. (2-tailed)			.593	.051	.537	.848
	N			22	22	22	22
	Bootstrap[c]	Bias		-.014	-.015	-.021	.001
		Std. Error		.162	.119	.128	.263
		95% Confidence Interval	Lower	-.266	-.667	-.456	-.452
			Upper	.393	-.194	.098	.561
CRP2	Pearson Correlation			.007	-.415	-.152	.097
	Sig. (2-tailed)			.974	.055	.501	.669
	N			22	22	22	22
	Bootstrap[c]	Bias		.003	-.007	.009	.063
		Std. Error		.261	.116	.156	.246
		95% Confidence Interval	Lower	-.511	-.647	-.438	-.242
			Upper	.493	-.193	.239	.698
CRP3	Pearson Correlation			-.009	-.419	-.154	.096
	Sig. (2-tailed)			.969	.052	.493	.672
	N			22	22	22	22
	Bootstrap[c]	Bias		-.014	-.013	.002	.049
		Std. Error		.231	.110	.140	.256
		95% Confidence Interval	Lower	-.529	-.651	-.435	-.275
			Upper	.362	-.215	.160	.656
CRP4	Pearson Correlation			.264	-.425*	-.077	.119
	Sig. (2-tailed)			.235	.049	.734	.599
	N			22	22	22	22
	Bootstrap[c]	Bias		-.069	-.019	.000	.044
		Std. Error		.330	.143	.254	.267
		95% Confidence Interval	Lower	-.483	-.718	-.584	-.315
			Upper	.708	-.170	.501	.693
CRP5	Pearson Correlation			.257	-.469*	-.112	.113
	Sig. (2-tailed)			.248	.028	.620	.616
	N			22	22	22	22
	Bootstrap[c]	Bias		-.025	-.012	-.001	.033
		Std. Error		.234	.117	.198	.275
		95% Confidence Interval	Lower	-.312	-.710	-.580	-.404
			Upper	.617	-.240	.303	.668

Correlations

				MB4	MB5	CRP1	CRP2
		95% Confidence Interval	Lower	.375	1	-.525	-.588
			Upper	.879	1	.113	-.065
CRP1	Pearson Correlation			-.162	-.226	1	.645**
	Sig. (2-tailed)			.472	.313		.001
	N			22	22	22	22
	Bootstrap[c]	Bias		-.047	-.014	0	-.035
		Std. Error		.206	.153	0	.210
		95% Confidence Interval	Lower	-.664	-.525	1	.154
			Upper	.152	.113	1	.923
CRP2	Pearson Correlation			-.158	-.340	.645**	1
	Sig. (2-tailed)			.482	.121	.001	
	N			22	22	22	22
	Bootstrap[c]	Bias		-.036	-.006	-.035	0
		Std. Error		.223	.137	.210	0
		95% Confidence Interval	Lower	-.657	-.588	.154	1
			Upper	.214	-.065	.923	1
CRP3	Pearson Correlation			-.113	-.259	.743**	.972**
	Sig. (2-tailed)			.617	.244	<.001	<.001
	N			22	22	22	22
	Bootstrap[c]	Bias		-.044	-.015	-.057	.001
		Std. Error		.222	.140	.209	.013
		95% Confidence Interval	Lower	-.684	-.539	.205	.938
			Upper	.224	-.019	.964	.991
CRP4	Pearson Correlation			-.335	-.387	.543**	.821**
	Sig. (2-tailed)			.127	.075	.009	<.001
	N			22	22	22	22
	Bootstrap[c]	Bias		-.024	-.011	.025	.036
		Std. Error		.181	.115	.149	.065
		95% Confidence Interval	Lower	-.697	-.618	.279	.744
			Upper	.025	-.156	.863	.979
CRP5	Pearson Correlation			-.319	-.347	.791**	.821**
	Sig. (2-tailed)			.147	.114	<.001	<.001
	N			22	22	22	22
	Bootstrap[c]	Bias		-.046	-.022	-.046	-.003
		Std. Error		.205	.145	.168	.115
		95% Confidence Interval	Lower	-.770	-.643	.326	.576
			Upper	.023	-.068	.953	.980

Correlations

				CRP3	CRP4	CRP5
		95% Confidence Interval	Lower	-.539	-.618	-.643
			Upper	-.019	-.156	-.068
CRP1	Pearson Correlation			.743**	.543**	.791**
	Sig. (2-tailed)			<.001	.009	<.001
	N			22	22	22
	Bootstrap[c]	Bias		-.057	.025	-.046
		Std. Error		.209	.149	.168
		95% Confidence Interval	Lower	.205	.279	.326
			Upper	.964	.863	.953
CRP2	Pearson Correlation			.972**	.821**	.821**
	Sig. (2-tailed)			<.001	<.001	<.001
	N			22	22	22
	Bootstrap[c]	Bias		.001	.036	-.003
		Std. Error		.013	.065	.115
		95% Confidence Interval	Lower	.938	.744	.576
			Upper	.991	.979	.980
CRP3	Pearson Correlation			1	.771**	.854**
	Sig. (2-tailed)				<.001	<.001
	N			22	22	22
	Bootstrap[c]	Bias		0	.046	-.017
		Std. Error		0	.087	.103
		95% Confidence Interval	Lower	1	.673	.608
			Upper	1	.974	.972
CRP4	Pearson Correlation			.771**	1	.871**
	Sig. (2-tailed)			<.001		<.001
	N			22	22	22
	Bootstrap[c]	Bias		.046	0	.023
		Std. Error		.087	0	.043
		95% Confidence Interval	Lower	.673	1	.814
			Upper	.974	1	.973
CRP5	Pearson Correlation			.854**	.871**	1
	Sig. (2-tailed)			<.001	<.001	
	N			22	22	22
	Bootstrap[c]	Bias		-.017	.023	0
		Std. Error		.103	.043	0
		95% Confidence Interval	Lower	.608	.814	1
			Upper	.972	.973	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Bootstrap

Notes

Output Created		03-APR-2023 13:06:34
Comments		
Input	Data	/Users/chrisirvine/Downloads/Sokoloski_Dissertation_Stats (2).sav
	Active Dataset	DataSet5
	Filter	<none>
	Weight	<none>
	Split File	<none>
Syntax		BOOTSTRAP /SAMPLING METHOD=SIMPLE /VARIABLES INPUT=TNF1 TNF2 TNF3 TNF4 TNF5 PAT_Time /CRITERIA CILEVEL=95 CITYPE=PERCENTILE NSAMPLES=1000 /MISSING USERMISSING=EXCLUDE.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.00

Bootstrap Specifications

Sampling Method	Simple
Number of Samples	1000
Confidence Interval Level	95.0%
Confidence Interval Type	Percentile

Correlations

Correlations

				TNF4	TNF5	PAT_Time
TNF1	Pearson Correlation			.594	-.169	-.154
	Sig. (2-tailed)			.092	.664	.693
	N			9	9	9
	Bootstrap[c]	Bias		-.008	.043	.012
		Std. Error		.219	.449	.305
		95% Confidence Interval	Lower	-.033	-.820	-.739
			Upper	.885	.800	.470
TNF2	Pearson Correlation			.957**	.436	.064
	Sig. (2-tailed)			<.001	.241	.869
	N			9	9	9
	Bootstrap[c]	Bias		-.040	-.094	-.115
		Std. Error		.090	.452	.434
		95% Confidence Interval	Lower	.685	-.625	-.892
			Upper	.993	.949	.764
TNF3	Pearson Correlation			.478	.013	-.591
	Sig. (2-tailed)			.193	.973	.094
	N			9	9	9
	Bootstrap[c]	Bias		.070	-.041	.068
		Std. Error		.282	.444	.375
		95% Confidence Interval	Lower	-.059	-.893	-.942
			Upper	.962	.697	.472
TNF4	Pearson Correlation			1	.568	-.002
	Sig. (2-tailed)				.110	.996
	N			9	9	9
	Bootstrap[c]	Bias		0	-.057	-.078
		Std. Error		0	.361	.455
		95% Confidence Interval	Lower	1	-.423	-.966
			Upper	1	.976	.785
TNF5	Pearson Correlation			.568	1	.228
	Sig. (2-tailed)			.110		.556
	N			9	9	9
	Bootstrap[c]	Bias		-.057	0	.013
		Std. Error		.361	0	.432
		95% Confidence Interval	Lower	-.423	1	-.571
			Upper	.976	1	.962
PAT_Time	Pearson Correlation			-.002	.228	1
	Sig. (2-tailed)			.996	.556	
	N			9	9	9
	Bootstrap[c]	Bias		-.078	.013	0
		Std. Error		.455	.432	0

Correlations

				TNF5	SR5	VJ5	HG5
TNF5	Pearson Correlation			1	.330	-.672**	-.074
	Sig. (2-tailed)				.249	.009	.800
	N			14	14	14	14
	Bootstrap[c]	Bias		0	-.013	.021	.018
		Std. Error		0	.301	.191	.269
		95% Confidence Interval	Lower	1	-.334	-.925	-.577
			Upper	1	.791	-.163	.466
SR5	Pearson Correlation			.330	1	-.572*	-.155
	Sig. (2-tailed)			.249		.033	.598
	N			14	14	14	14
	Bootstrap[c]	Bias		-.013	0	.020	-.007
		Std. Error		.301	0	.216	.222
		95% Confidence Interval	Lower	-.334	1	-.846	-.606
			Upper	.791	1	.029	.254
VJ5	Pearson Correlation			-.672**	-.572*	1	-.143
	Sig. (2-tailed)			.009	.033		.626
	N			14	14	14	14
	Bootstrap[c]	Bias		.021	.020	0	-.015
		Std. Error		.191	.216	0	.270
		95% Confidence Interval	Lower	-.925	-.846	1	-.654
			Upper	-.163	.029	1	.370
HG5	Pearson Correlation			-.074	-.155	-.143	1
	Sig. (2-tailed)			.800	.598	.626	
	N			14	14	14	14
	Bootstrap[c]	Bias		.018	-.007	-.015	0
		Std. Error		.269	.222	.270	0
		95% Confidence Interval	Lower	-.577	-.606	-.654	1
			Upper	.466	.254	.370	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples