

IMPACT OF TIME-RESTRICTED FEEDING ON CARDIOMETABOLIC HEALTH AND
PERFORMANCE AMONG FIREFIGHTERS

by

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LIST OF ABBREVIATIONS

Abbreviation	Description
ADF	Alternate-Day Fasting
AHA	American Heart Association
BMI	Body Mass Index
FF	Firefighter
FFM	Free-Fat Mass
FGT	Fire Grounds Test
GXT	Graded Exercise Testing
HDL	High Density Lipoproteins
HR	Heart Rate
IF	Intermittent Fasting
NFPA	National Fire Protection Association
ROS	Reactive Oxygen Species
RT	Resistance Training
SCD	Sudden Cardiac Death
SD	Standard Deviation
TRF	Time-Restricted Feeding
US	United States
VT	Ventilatory Threshold

I. INTRODUCTION

Firefighters (FF) experience physiological and psychological stressors such as disturbed sleep patterns, frequent snacking, smoke exposure, and intense physical exertion (Soteriades, Smith, Tsismenakis, Baur, & Kales, 2011) likely contributing to an increased risk of cardiometabolic diseases and sudden cardiac death (Donovan et al., 2009; Gordon & Lariviere, 2014; Soteriades et al., 2011). High obesity prevalence rates and low cardiovascular fitness levels increase FF risk for sudden cardiac death (Dobson et al., 2013; Donovan et al., 2009). Additionally, FF are susceptible to preventable risk factors for cardiometabolic disease collectively known as metabolic syndrome (i.e., increased blood pressure, high blood sugar levels, excess adipose tissue, high triglyceride levels, and low HDL levels). Proper dietary and exercise interventions can improve cardiometabolic markers of health such as blood pressure and lipid levels, which can lead to the reduced risk of cardiometabolic disease.

Although research exists examining FF health, performance, and exercise (Abel, Mortara, & Pettitt, 2011; Dennison, Mullineaux, Yates, & Abel, 2012; Smith, 2011), there is a need for research on dietary interventions that can improve cardiometabolic markers of health without hindering FF physical performance. Due to the stressful and sporadic nature of FF work shifts, poor dietary patterns are adopted, which consist of excessive sodium amounts, processed sugars, fatty snacks, and alcohol (Haddock et al., 2015; W.S. Poston et al., 2013). Extended hours of feeding and frequent snacking increase FF susceptibility for obesity and cardiometabolic disease. Additionally, like many Americans, FF lack proper education about healthy eating patterns. Yang, Farioli,

Korre, & Kales (2015) identified approximately 71% of FF do not have any specific dietary plan and more than 75% expressed interest in developing healthier eating habits.

Intermittent fasting (IF) extends the fasting period beyond a typical overnight fast and can potentially result in a reduction in energy intake (Tinsley et al., 2017). Moreover, time-restricted feeding (TRF) refers to a dietary intervention where all calories consumed daily are within a specific timeframe (i.e., 6-8 hours) and only water is ingested during the fasting period. There is growing evidence on TRF and benefits such as improving body composition and overall health without adversely affecting physical performance (Tinsley et al., 2017; Tinsley & La Bounty, 2015). Growing evidence demonstrates improvements in markers of cardiometabolic health such as body fat, blood pressure, adiponectin, and HDL-c while IF (McAllister, Pigg, Renteria, & Waldman, 2019). Research in animals suggests an importance of synchronizing TRF with daily circadian rhythms (Patterson & Sears, 2017). Ad libitum high-fat diet eating throughout the night and day extends the feeding cycle, leading to obese and metabolic dysfunction (Patterson & Sears, 2017). Human trials investigating the effects of prolonging the duration of an overnight fast (i.e., TRF protocol) have demonstrated dramatic reductions (i.e., 2.1% to 4.1% weight loss) in weight (LeCheminant, Christenson, Bailey, & Tucker, 2013; Carlson, et al., 2007; Stote et al., 2007). Aligning food intake with daytime hours and prolonging the overnight fasting window through TRF may improve health, reduce the risk for obesity and related diseases (Patterson & Sears, 2017), and possibly protect muscular strength (Tinsley et al., 2017). Due to the nature of FF, which requires muscular strength and endurance to perform physically demanding tasks, TRF may be an appropriate dietary intervention to lower adverse cardiometabolic risks and improve

physical performance. TRF may also be simpler to adhere to compared to other restrictive dietary regimens such as a ketogenic diet or vegetarian diet (Tinsley et al., 2017). This review examines the factors contributing to cardiometabolic health, FF performance, and the potential health benefits of a TRF intervention in FF.

II. REVIEW OF LITERATURE

Cardiometabolic Health

Cardiometabolic disease refers to conditions on a spectrum beginning with insulin resistance progressing to more severe conditions such as atherosclerosis and type 2 diabetes (Vincent et al., 2017). Cardiometabolic disease serves as an umbrella term with risk factors including overweight and obesity, dyslipidemia, and high blood pressure (Vasudevan and Ballantyne, 2005). To reduce cardiometabolic disease risk, high-risk individuals need to be identified and intervened with effective strategies for prevention (Guo, Moellering, & Garvey, 2013). Obesity and overweight affect more than one third of the world's population today, posing a major public health issue (Hruby & Hu, 2015; Mendy, Vargas, Cannon-Smith, & Payton, 2017; Stevens et al., 2012; Ng et al., 2014). According to the National Health and Nutrition Examination Survey, data between 2011 to 2012 indicated 78.6 million United States (US) American adults (34.9%) were obese (Ogden, Carroll, Fryar, & Flegal, 2015). Obesity, one of the top diseases globally, continues to rise (An, Jung, Ihm, Yang, & Youn, 2019) and exacerbates insulin resistance, resulting in cardiometabolic disease progression (Guo et al., 2013).

Cardiometabolic Disease and Firefighters

The American Heart Association (AHA) indicated nearly 70% of the US adult population is classified as overweight, and 35% are classified as obese (body mass index (BMI) ≥ 30 kg/m²) (Go et al., 2014). The AHA identified common risk factors for cardiometabolic disease including elevated serum cholesterol (≥ 240 mg · dL), hypertension ($> 120/80$ mm Hg), fasting plasma glucose (≥ 100 mg · dL¹), use of tobacco, and/or being physically inactive (Go et al., 2014). Additionally, Jokinen (2015)

found an association between obesity, diabetes, and male gender with cardiometabolic disease, suggesting obesity is linked to several other risk factors. Obesity and cardiometabolic disease rates among FF are high in the US (>75% and 45%, respectively) (Dobson et al., 2013; Gordon & Lariviere, 2014) due to several physiological and psychological stressors. The stressors FF experience many certain imbalances (i.e., hormonal and neurological) leading to obesity and greater risk for weight gain. Stressors include the following: poor sleeping patterns, frequent snacking, exposure to smoke, and intense physical exertion (Soteriades et al., 2011). Additionally, FF express the spectrum of risk factors to cardiometabolic disease known as metabolic syndrome including the following components: insulin resistance, excess adipose tissue, hypercholesterolemia, and hypertension (Heyn, Tagawa, Pan, Thomas, & Carollo, 2019) and have the highest occupational related risk of death due to cardiometabolic disease. Firefighting claims nearly 100 lives each year in the US (Washburn, LeBlanc, & Fahy, 1997; Fahy & Leblanc, 2002). Thus, U.S. FF have one of the highest occupational fatality rates (Fabio, Ta, Strotmeyer, & Schmidt, 2002). The leading cause of on-duty deaths is due to cardiometabolic disease (Kales, Stoeriades, Christoudias, & Christiani, 2003) and on-duty sudden cardiac death (Yang, Teehan, Farioli, Baur, Smith, & Kales, 2013; Sen, Palmieri, & Greenhalgh, 2016; Farioli, Christophi, Quarta, Kales, 2015; Mbanu et al., 2007). FF age and cardiac fitness are associated with cardiac fatality risk; however, young FF have been reported for sudden cardiac death as well, and deaths are suggested to correlate with lifestyle and metabolic factors (Sen et al., 2016). Stress and overexertion significantly increase the risk for on-duty cardiac death (Sen et al., 2016). The steady weight gain FF accumulate over their career contributes to their respective risk for

developing obesity and cardiometabolic disease (Yang et al., 2013) and averages to 1.2-3.4lbs/year gained (Poston, Haddock, Jahnke, Jitnarin, & Day, 2013). Excessive consumption of processed sugars, fatty snacks, sodium, and alcohol (Poston et al., 2013) are adopted due to FF sporadic and demanding schedules. According to Yang, Farioli, Korre, & Kales (2015), 70% of career FF do not follow any dietary plan; however, 75% express interest in learning more about healthy eating. Research examining how proper diet intervention can reduce cardiometabolic risk factors among FF and improve physical performance without hindering muscular strength and endurance is needed.

Fitness Metrics and Relevance to Cardiometabolic Health

Maximal Oxygen Consumption ($\dot{V}O_{2max}$)

Maximal exercise testing is used to assess $\dot{V}O_{2max}$ ($\text{ml}/\text{kg}^{-1}\cdot\text{min}^{-1}$), a clinical measure of the limits of cardiopulmonary function and is a strong indicator of cardio-fitness and health (Drew-Nord et al., 2011). Moreover, increases in $\dot{V}O_{2max}$ indicates increased stroke volume and blood to working muscles, which can result in improved physical performance. The estimated intensity FF have been shown to work at is between a $\dot{V}O_{2max}$ range of 33.6 - 49 $\text{ml}/\text{kg}^{-1}\cdot\text{min}^{-1}$ (Drew-Nord et al., 2011); however, FF are not meeting the cardiorespiratory fitness levels necessary to successfully complete a fire simulation test (roughly 42 $\text{ml}/\text{kg}^{-1}\cdot\text{min}^{-1}$) (Poston et al., 2011). Exercise at intensities beyond the cardiopulmonary system limits results in progressive dependence on oxygen-independent muscle metabolism (Drew-Nord et al., 2011) resulting in quicker fatigue. Cardiovascular functions are compromised and less efficient due to anaerobic metabolism dependence (Froelicher & Myers, 2006). Low cardiorespiratory fitness and heavy reliance on anaerobic metabolism is associated with an increased risk for adverse

cardiometabolic health (Carroll, Cooke, & Butterly, 2000; Earnest, Artero, Sui, Lee, Church, & Blair, 2013; Ekblom et al., 2015). Kelley et al. (2018) found an inverse association between $\dot{V}O_{2\max}$ and metabolic syndrome, which is associated with an increased risk for sudden cardiac death (Hess et al., 2017). Higher levels of cardiorespiratory fitness are linked to lower risk of metabolic syndrome (Lee et al., 2010; Sandbakk et al., 2016), sudden cardiac death (Hess et al., 2017), and cardiometabolic disease (Wijndaele et al., 2014; Knaeps et al., 2016). The physically demanding duties (i.e., victim rescues, hose deployment) FF perform can be detrimental to their health due to the high amounts of stress placed on the individual. Therefore, accurate cardiopulmonary assessment is critical to identify and treat cardiometabolic disease (Drew-Nord et al., 2011). Due to the risk of on-duty cardiac events or death, FF cardiopulmonary health should be assessed by way of a $\dot{V}O_2$ maximal test. Evidence suggests FF recruits report an average $\dot{V}O_2$ of $38.5 \text{ ml/kg}^{-1}\cdot\text{min}^{-1}$ necessary to complete a firefighting assessment course (Williams-Bell, Villar, Sharratt, & Hughson, 2009). Research has reported a minimum $\dot{V}O_2$ max of approximately $42 \text{ ml/kg}^{-1}\cdot\text{min}^{-1}$ should be required of FF (Storer et al., 2014; Adams et al., 2009; Dolezal, Barr, Boland, Smith, & Cooper, 2015). Fitness levels should be assessed to detect any potential cardiac compromise and to protect FF from life-threatening cardiac situations.

Body Composition

Obesity is associated with adverse cardiometabolic health, and more than 70% of US FF are classified as overweight or obese (Poston et al., 2011). Obesity is defined by the accumulation of body fat leading to negative effects on health (Wilson, D'Agostino, Sullivan, Parise, & Kannel, 2002; Hubert, Feinleib, McNamara, & Castelli, 1983).

Markers of oxidative stress such as elevated reactive oxygen species (ROS) and reduced antioxidant defense are associated with obesity and risk of cardiometabolic disease. Oxidative stress is believed to play a factor among diabetics (Huang et al., 2015). Specifically, ROS levels are elevated, and tissues are susceptible to oxidative stress, which in turn leads to diabetic complications (Asmat, Abad, Ismail, 2016). Obesity-related oxidative stress refers to a negative oxidative effect experienced by obese individuals. Skeletal muscle and mitochondrial respiratory function are impaired, resulting in the increases in mitochondria ROS production (Huang et al., 2015). Improvements to body composition can be noted through reductions in body mass index (BMI) (Ford, Hunt, Cooper, & Shield, 2010) and can reduce oxidative stress (Huang et al., 2015). Moreover, minimal reductions in BMI (~0.25 BMI) suggests improvements of metabolic health (i.e., reduced oxidative stress) (Huang et al., 2015; Ford et al., 2010). Body composition is a component of FF physical fitness and is strongly associates with cardiorespiratory fitness (Nogueira et al., 2015). Healthy eating habits and exercise will likely improve cardiorespiratory fitness and body composition among FF, while reducing their risk to cardiometabolic disease.

Muscular strength

Muscular strength is a critical performance factor FF need to meet the high physical demands of their job (Boyce et al., 2008). Adequate muscular strength is essential to carry out daily actives and avoid adverse cardiometabolic health risk (Ruiz et al., 2008; Ruiz et al., 2009; Artero et al., 2013). Resistance training (RT) leads to increased strength, lean body mass, and improved body composition (Roberts, Hevener, & Barnard, 2013), which is suggested to lower risk of cardiometabolic disease and

metabolic syndrome (Jurca et al., 2005; Tanasescu et al., 2002; Ruiz et al., 2008).

Regular RT interventions are critical to FF physical performance and lowering the risk of cardiometabolic disease (Wildman et al., 2008; Jurca et al., 2005; Tanasescu et al., 2002; Ortega, Silventoninen, Tynelius, & Rasmussen, 2012). Due to the dangerous and physically demanding nature of the profession, firefighting requires regular exercise training in order to meet and maintain the optimal occupational performance levels (Pawlak, Clasey, Palmer, Symons, & Abel, 2014). Muscular strength is necessary for FF to carry out on-duty tasks and meet the performance expectations.

Muscular endurance

Muscular endurance is inversely associated with cardiometabolic disease risk for men between the ages 21 to 66 years (Yang et al., 2019). More specifically, push-up capacity was found to be a simple, cost-effective muscular endurance measurement capable of estimating functional status for middle-aged men (Yang et al., 2019). Cross-sectional studies have found correlations between push-ups and cardiometabolic risk markers (Agostinis-Sobrinho, et al., 2017; Burns & Brusseau, 2016). FF who were able to complete more than 40 push-ups had a 96% reduction in cardiometabolic disease risk compared to those who were able to complete fewer than 10 push-ups (Yang et al., 2019). Additionally, FF who were able to perform 21- to 30- push-ups were associated with a lower risk for cardiometabolic disease outcomes compared to those who performed 0- to 10-push-ups (Yang et al., 2019). Therefore, push-up capacity testing could be a potential muscular endurance and cardiometabolic-risk assessment tool for FF, which can easily be implemented by tactical strength and conditioning facilitators or other FF-related professionals.

Firefighter Physical Performance

Impacts of Training on Firefighter Performance

According to the National Fire Protection Association (NFPA), a high proportion of FF in the US are not meeting the recommendations for health and fitness maintenance (NFPA, 2016). Various research indicates the prevalence of overweight, obesity, and poor fitness levels among FF (Fahs et al., 2009; Garver et al., 2005; Poston et al., 2011). The NFPA suggests fire departments provide health programs to enable FF to maintain the necessary levels of health and fitness to performance their duty (Andrew, Gallagher, & Herring, 2019). Additionally, the Fire Service Joint Labor Management Wellness Fitness Initiative recommends approximately a 60- to 90-minutes of allotted time for exercise during each FF work shift (Andrews et al., 2019). Exercise interventions provided by professional exercise specialists who have an exercise science degree and knowledge of the FF profession can aid physical performance and improve fitness levels (Andrew et al., 2019). Fire simulation tests or fire grounds tasks require both cardiovascular and muscular fitness, and FF training programs are recommended to target both components (Baur, Christophi, Tsismenakis, Cook, & Kales, 2011; Blair et al., 1996; Church, Kampert, Gibbons, Barlow, Blair, 2001). However, fire departments might lack exercise equipment necessary to implement effective training programs (Pawlak, Clasey, Palmer, Symons, Thorburn, & Abel, 2015). Pawlak et al. (2015) demonstrated fire departments have the means to enhance FF preparedness with basic fire equipment (i.e., full protective fire gear and self-contained breathing apparatus) and exercise programs using fire equipment can promote health, fitness, safety, and improved performance outcomes on fire grounds tasks (Pawlak et al., 2015). Moreover, circuit

training (with fire equipment) has been shown to elicit similar heart rate and blood lactate responses to smoke diving and fire suppression tasks (Abel et al., 2011) and further improve fire grounds tasks (Pawlak et al., 2015). Traditional strength and power training should be supplemented to optimize fitness components linked to FF tasks. Engaging in RT can result in improved health and quality of life over a wide range of individuals (Williams, Toluoso, Fedewa, & Esco, 2017). Generally, RT is used to increase muscular strength and can improve physical preparedness by focusing on improving 1-repetition maximum (1-RM) (Williams et al., 2017). Muscular strength is an essential component of FF and can be assessed by a 1-RM test. Muscular strength is important component of FF physical preparedness for their occupational demands (i.e., carrying heavy objects, climbing several flights of stairs). Therefore, improving 1-RM values results in increased physical performance among FF. In order to effectively prepare FF for the hazardous and physically demanding profession, appropriately structured exercise program is needed (Abel, Thomas, Trubee, & 2015).

Firefighter Physical Performance

FF require regular physical fitness assessments due to the physically demanding nature of their occupation (Siddall, Stevenson, Turner, & Bilzon, 2018). Cardiovascular and cardiorespiratory stress result from complex occupation tasks requiring FF to wear heavy, restricting equipment and clothing (Eglin, Coles, & Tipton, 2004; Sothmann et al., 1990; von Heimburg, Rasmussen, & Medbo, 2006), which increases the cardiorespiratory fitness levels necessary to meet the work demands. Specific levels of physical fitness are required to effectively perform tasks (Siddall et al., 2018). The combination of low-fat mass and cardiorespiratory capacity are essential for optimal FF physical performance

(Siddall et al., 2018). High levels of musculoskeletal strength are necessary for FF to perform on-duty tasks. Various on-duty tasks FF perform include hose dragging, short distance (< 200-350 m) sprints, long distance (> 350 m) runs, victim carries, procedures to clear a room, and ladder climbing all while wearing 35 kg of personal protective equipment (PPE) (Gavhed & Holmer, 1989; Gledhill & Jamnik, 1992). FF are faced with high thermal environments, which may exceed 100°C leading to increased metabolic demands and the accelerated depletion of muscle glycogen (Dimri, Malhorta, Gupta, Kumar, & Arora, 1980; Chevront, Kenefick, Montain, & Sawka, 2010). Exposure to heat/high thermal environments leads to impaired performance. Additionally, FF body compositions, paired with high thermal environments, inhibits the ability to dissipate heat through sweat and hinders tasks such as climbing ladders (Williford, Duey, Olson, Howard, & Wang, 1999). Therefore, training with FF equipment, mimicking the environment and on-duty tasks improves occupational performance (Pawlak, Clasey, Palmer, Symons, & Abel, 2015).

Impact of Diet Interventions on Fitness Metrics Related to Cardiometabolic Health

Improvements to dietary caloric intake and energy expenditure may be associated with improved physical performance due to the changes related to body composition (Heatherly et al., 2017). Diet interventions, such as low-carbohydrate diets, can favorably impact body composition, leading to reductions in percent body fat and increases in lean body mass (Heatherly et al., 2017). Additionally, dietary manipulations are suggested to enhance substrate utilization (i.e., free fatty acid availability via low-carbohydrate dieting) (Muoio, Leddy, Horvath, Awad, & Pendergast, 1994). Dietary manipulations may enhance oxidative potential leading to an increase in $\dot{V}O_{2\max}$ (Muoio et al., 1994).

The adaptations occurring during regular endurance training and exercise favor the fat oxidation ability at high workloads, which leads to increased maximal fat oxidation (Lima-Silva et al., 2010; Scharhag-Rosenberger, Meyer, Walitzek, & Kindermann, 2010). Moreover, recent studies have shown high fat, carbohydrate restricted diets and RT (Waldman et al., 2018) and intermittent fasting increase fat oxidation (Azevedo, Ikeoka, & Caramelli, 2013) promoting fat oxidation and possibly correlating to enhanced performance capabilities (Volek et al., 2015; Maher, Akhtar, & Tarnopolsky, 2010). Tinsley et al. (2015) demonstrates increases in 1-RM for leg press and increased bench press muscular endurance while following IF and resistance training. Additionally, IF dietary interventions could improve health-related biomarkers, decrease fat mass, and help maintain muscle mass when coupled with RT (Moro et al., 2016).

Diet Interventions Among Firefighters

Due to sporadic work shifts and unhealthy eating behaviors, FF diets consist of excess sodium, sugars, fatty snacks, and alcohol (Haddock, Day, Poston, Jahnke, & Jitnarin, 2015). Most FF studies are observational (Yang et al., 2015; Dobson et al., 2013), and 71% of FF are not practicing any specific dietary regimen (Yang, Farioli, Korre, & Kales, 2015). About 68% of FF lack sufficient nutrition information; however, 75% reported to be interested in learning about health eating behaviors (Yang et al., 2015). A higher percentage of FF classified at a normal weight are following some dietary plan compared to those classified as overweight or obese (Yang et al., 2015). Workplace oriented nutritional promotion approaches had positive outcomes within the FF community, suggesting the opportunity to implement a health promotion program to increase the rate of adoption for health eating patterns (Yang et al., 2015). Recent studies

have suggested an association between the Mediterranean style diet and improved cardiometabolic disease risk profiles among FF (Korre, Sotos-Prieto, & Kales, 2017). Dietary change is more likely to occur when the change strategy is accepted by the target group. Diet plans such as the Mediterranean diet are favorable due to the less restrictive nature compared to other diets that restrict certain favored food groups (Korre et al., 2017). However, little is known about dietary interventions among FF. Dietary interventions such as Paleo (Mozaffarian, 2017), carbohydrate-restriction (Volek et al., 2002; Volek et al., 2008; Griebet al., 2008), and Mediterranean (Yang et al., 2015) are associated with reduced cardiometabolic disease risk. Research is needed to further assess appropriate dietary interventions capable to reduce adverse cardiometabolic health risk factors and prevalence of cardiometabolic disease and sudden cardiac death risk among FF.

Characteristics of Time-Restricted Feeding

Many short-term weight loss dietary interventions can improve markers of cardiometabolic health by lowering risk factors of metabolic syndrome and cardiometabolic disease. Dietary restriction can reduce body fat for the obese. Intermittent fasting can decrease body weight, fat mass, and visceral fat mass (Varady, 2011). Growing evidence suggests a metabolic switch from glucose utilization to fatty acids-derived ketones occurs due to IF regimens such as TRF, which may result in the mobilization of fat through fatty acid oxidation (Anton et al., 2017). The shift in metabolism results in less fat storage and more utilization on fatty acid-derived ketones, which allows for muscle mass preservation (Anton et al. 2017). Moreover, IF can induce

optimal physiological function by activating signaling pathways, enhance performance variables, and slow processes of aging and disease (Anton et al., 2017).

Importantly, IF should not be confused with starvation (reduction up to 40% of daily caloric intake), instead, fasting or TRF allows for individuals to consume ad libitum energy (i.e., eating until satiated) intake during their feeding window (Moro et al., 2016). Typically, TRF consists of following the same eating pattern each day, with certain hours comprised for a fasting and feeding window. Additionally, alternative day fasting (ADF) is a method of fasting consisting of alternating between non-fasting days and fasting days (i.e., fasting every other day). Fasting diets have been shown to promote weight loss, improving blood lipids, reduce triglycerides, lower low-density lipoprotein (LDL) cholesterol, and blood pressure (Tinsley and La Bounty, 2015; Varady, 2011; Harvie et al., 2011). Fasting is classified as the voluntary abstinence from food and beverage intake for a period of time (fasting window). More commonly recognized as a religious or spiritual traditional practice, fasting windows ranged from 12 hours to 3 weeks (Moro et al., 2016). However, when referring to TRF, fasting windows are based on a daily schedule allowing a limited feeding window (i.e., 8 hour feeding window, 16 hours fasting window). Stote et al. (2007) found TRF to result in lower fat mass compared to consuming three meal per day post 8-weeks following a 20 hour fast/4 hour feeding protocol per day.

Growing evidence suggests TRF is a useful dietary intervention to improve overall health for the general population due to improvements to blood lipids (Bhutani, Klempelm, Kroeger, Trepanowski, & Varady, 2013; Klempel, Kroeger, & Varady, 2013; Varady, Bhutani, Klempel, & Lamarche, 2011), inflammatory markers (Faris, Kacimi,

Al-Kurd, Fararjeh, Bustanji, Mohammad, & Salem, 2012), and reduced fat mass (Varady, Bhutani, Church, & Klempel, 2009). Modified IF protocols (i.e., TRF) serve as a potentially practical dietary intervention based on studies demonstrating no negative effects to strength and muscle mass (Moro et al., 2016). Additionally, TRF allows individuals to consume ad libitum calories within the defined time of their window (Moro et al., 2016). For example, TRF with 8 hours feeding and 16 hour fasting window may be beneficial in trained individuals for improving health-related biomarkers, decreasing fat mass, and maintaining muscular strength (Moro et al., 2016). Additionally, ADF may have similar benefits due to the ad libitum nature of fasting days (individuals participating in TRF) while increasing adherence with normal feeding days (not fasting). Tinsley et al. (2017) found evidence suggesting TRF (with no limitations to energy intake) resulted in reduced caloric intake by approximately 650 kcal per day just by having a defined feeding window without decrements to lean tissue. Zuo et al. (2016) suggests a high protein, IF and low-calorie diet are associated with similar reductions in BMI and blood lipids for both obese men and women. Obesity and adverse cardiometabolic profiles link to diminished physical fitness and on-duty performance among FF. Dietary protocols such as TRF or ADF may result in BMI reductions and other benefits favorable to FF.

Cardiometabolic Health and Physical Performance Responses to Time-Restricted

Feeding

Research shows obese individuals benefit from an IF intervention due to the dramatic decreases in body mass and fat mass (Wilson, Deasy, Stathis, Hayes, & Cooke, 2018). Weight loss strategies focused on minimizing fat free mass (FFM) may be

advantageous for athletes and individuals who are attempting to decrease adipose tissue while preserving performance (Manore, 2015). Energy restriction nutritional approaches to reduce weight are characterized by fasting and feeding phases, and have gained attention recently for the potential benefits for athletes (Byrne, Sainsbury, King, Hills, & Wood, 2017; Harris, McGarty, Hutchison, Ells, & Hankey, 2018; Trepanowski et al., 2017; Trepanowski et al., 2017). Additionally, ADF has been shown to result in favorable body composition changes over a short-duration (4- to 6-weeks) (Wilson et al., 2018). A combination of diet and exercise will be more effective to improve cardiometabolic health for individuals; however, TRF is a method that can potentially reduce obesity rates among FF simply by decreasing the daily feeding window (i.e., timeframe when an individual consumes their daily caloric intake) (Wilson et al., 2018). Assuming the fasted diet is isocaloric, research shows that high-intensity exercise performance is maintained with no known detriments (Karli, Guvenc, Asian, Hazir, & Acikada, 2007). However, limited evidence exists on prolonged sustained or intermittent high-intensity training (Maughan, Fallah, & Coyle, 2010).

The FF lifestyle habits (i.e., frequent snacking, poor diets) may be favorably improved following an IF dietary intervention. Fasting can reduce total cholesterol, triglycerides, body fat, and body weight in obese individuals and may be an effective alternative to caloric reduction dietary interventions (Tinsley & La Bounty, 2015). Moreover, TRF has been hypothesized to allow less time for the following to occur decreased insulin sensitivity, increased carbohydrate metabolism, increased oxidant production, and increased inflammation (Waldman, Renteria, & McAllister, 2019). Contrarily, individuals following a TRF regimen allow more time for the following to

occur: increased gluconeogenesis and glycogenolysis, increased lipid metabolism, increased tissue repair, and increased mitochondrial biogenesis, which results in the improvements to insulin sensitivity, oxidative stress and inflammation markers, lipid panels, and body composition (Waldman et al., 2019). Additionally, reductions in body fat and increases in adiponectin and HDL-c have been found as a result from 28-day TRF protocol in metabolically healthy, active young men (McAllister et al., 2019). The recent findings suggest TRF can improve cardiometabolic health markers and serves as a potential benefit to FF performance.

Statement of Purpose: The purpose of the present investigation is to examine the effects of 8 weeks of time-restricted feeding on markers of cardiometabolic health and specific firefighter performance tasks in career male firefighters.

Hypothesis: Time-restricted feeding will benefit firefighter performance by ways of improving body composition and preserving both strength and aerobic performance.

Exercise Performance: Graded Exercise Testing, Firefighter Physical Performance Assessment, 1RM Muscular Strength Assessments, Vertec Vertical Jump Assessment (Power).

Significance: If Time-Restricted Feeding can improve markers of cardiometabolic health without hindering on-duty physical performance, this gives firefighters, and potentially other high stress occupations, a dietary intervention method to improve overall health and quality of life.

III. METHODS

Participants

Twenty apparently healthy professional, male FF were recruited from a local fire department (Lakeway, Texas, USA) for the proposed study (age = 35.4 ± 7.2 years; height = 179.03 ± 5.59 cm; weight = 87.24 ± 12.83 kg; body mass index [BMI] = 18.83 ± 6.47 ; years of fire service = 11.07 ± 34).

Selection Criteria

Participants were professional male FF who met the following inclusion criteria: free from (1) signs, symptoms or diagnosis of any cardiorespiratory and/or metabolic disorders, (2) any known blood disorders, (3) caffeinated supplements (pre-workouts, etc.) as well as alcohol and nicotine consumption 24 hours prior to all trials (4) dietary supplements such as creatine or testosterone boosters for at least two weeks prior to initiation. Additionally, participants qualified for the study by meeting the following training criteria: (1) participate in regular RT at least twice per week for the last six months, (2) have no current or previous injuries within the last year that can affect the results by preventing max effort in testing, job performance, or limit training, and (3) engage in at least 150-minutes of moderate-intensity exercise per week.

Protocol

Upon providing consent to participate, the participants were asked to complete a health history, physical activity readiness, and lifestyle evaluation questionnaire, which determined qualification for the study. The participants were assigned to either the normal diet (ND) (n = 4) or TRF group (n = 16) based on their preference. The TRF group followed a daily 14:10 hour fasting/feeding protocol. The ND group followed their

normal ad-libitum dietary patterns. Additionally, both groups (TRF and ND) followed a standardized training program for the duration of the 8-weeks to control the impact of training. The training program included exercises such as barbell bench press, dumbbell incline press, and dumbbell shoulder press, barbell bent over row, barbell back squat, pull-ups, and curl-ups. Three days of testing sessions was conducted both before and after the intervention. Session one, session two, and session three were performed for the post-testing following weeks six, seven, and eight, respectively. Each of the testing sessions lasted approximately 90-minutes. Session one occurred at the Lake Travis Fire Rescue Headquarters (Lakeway, Texas, USA). Session two occurred at the Lake Travis Fire Rescue Station 601 (Lakeway, Texas, USA). Session three was held at the training facility in Oak Hill (Austin, Texas, USA). At least two but no longer than seven days separated visits one, two, and three.

Session One – Anthropometrics & Graded Exercise Testing

Session one consisted of anthropometrics and a graded exercise treadmill test. Height, weight, and body fat percentage (by way of a handheld bioelectrical impedance analysis analyzer) were collected. A maximal graded exercise test (GXT) was performed on a treadmill. The GXT consisted of three-minute stages with stage one starting at a speed of 5.5 km/h (3.4 mph) and a one percent incline. Stage two increased in intensity to 7.5 km/h (4.6 mph) and three percent incline. Stages three, four, and five remained at a speed of 7.5 km/h (4.6 mph) but the incline increased by two percent each stage. The sixth stage increased speed to 9 km/h (5.5pmh) and an incline of 10 percent. Each following stage increased in speed by 2 km/h until volitional exhaustion (until the participant requested to stop due to fatigue or if they reached 90% of their maximal heart

rate). The GXT took roughly 21-minutes to complete. The participant was connected to a True One 2400 (Parvo Medics, Sandy, UT, USA) metabolic cart with headgear to collect pulmonary data (i.e., volume of oxygen consumption ($\dot{V}O_2$), volume of carbon dioxide expulsion ($\dot{V}CO_2$), and respiratory exchange ratio (RER). The participant also wore a chest H10 heart rate (HR) monitor (Polar Electro Inc., Bethpage, NY, USA) throughout the exercise testing to record HR. Absolute ventilatory threshold (VT) was quantified by graphing $\dot{V}O_2$ and $\dot{V}CO_2$ values (L/min x 1000) in Microsoft® Office Excel (Albuquerque, New Mexico, USA), then identifying the VT point in which there is a non-linear increase in the graphed values. Peak $\dot{V}O_2$ was quantified by averaging the last four 15-second $\dot{V}O_2$ (L/min) values of the GXT and multiplying the averaged value by 1000 then dividing by the participants weight in kg. The VT (% $_{Max}$) values were quantified by taking the absolute VT value divided by the Peak $\dot{V}O_2$ and then multiplying by 100 to equal the % $_{Max}$. Participants reported their rate of perceived exertion (RPE) at the end of every minute. Time to exhaustion and $\dot{V}O_2$ peak values were recorded once the test ended. In addition, ventilatory threshold was recorded.

Session two – Muscular Performance Testing

Session two consisted of a maximal standardized vertical jump test and muscular strength and endurance tests. The participants performed the maximal standardized vertical jump test and were asked to jump as high as possible. The participant's standing reach height was measured by having the participant stand underneath the Vertec™ (Unique Fitness Concepts, Vernon Hills, IL, USA). The participants reach height was recorded. The participant stood directly beneath the veins and squatted to a position where the knees were at a 90° angle and the hands by the sides and performed a counter

movement jump. The participants were instructed to jump straight up as high as possible, touch as many rungs on the Vertec™ as possible, and land with both feet. Three trials were performed to assess maximal jump height. Jump height was computed by subtracting the standing reach height from the max jump height [jump height = max jump height (in) – standing reach height (in)].

Following the vertical jump test, the participant performed a predicted 1-repetition maximal strength (1-RM) test for both the bench press and back squat. The participant performed a standardized warm-up set using the 45-lb barbell for ten repetitions for the exercises of bench press and back squats. Upon completion of the warm-up, the participant initiated the predicted 1-RM protocol for the bench press, followed by the back squat. One warm-up set was performed with 45-lb plates on each side of the barbell for five to ten repetitions, followed by one minute of rest. A second warm-up set was performed at a self-selected, 50-80% perceived 1-RM weight for three to five repetitions, followed by two minutes of rest. Finally, the estimated 1-RM took place with a load the participant could perform between two to ten repetitions. The load and repetitions completed were entered into the Bryzachi Prediction Equation to predict the 1-RM. The Bryzachi Prediction Equation is as follows:

$$1\text{-RM} = 100 \times \text{load rep} / (102.78 - 2.78 \times \text{rep})$$

Following the 1-RM testing, the participant performed muscular endurance testing for push-ups and inverted-rows. The participant performed as many as possible repetitions of standard push-ups until failure within a two-minute time period or until they reached 80 repetitions. The standard push-up starting position for the participants was to place the hands shoulder-width apart with the elbows and body straight. The total

number of push-ups completed within the two minutes were recorded. The participant needed to maintain cadence with a metronome set at 80 beats per minute (a pace of 40 repetitions per minute). The participant lowered their body towards the ground until their chin touched a five-inch tall prop positioned on the ground. The test was terminated for the following: the participant reached the maximum number of repetitions (80), performed three incorrect repetitions, failed to maintain the cadence with the metronome, or experienced joint/muscular pain.

Following the push-up test, the participant rested for two-minutes prior to performing the inverted row test (horizontal pull-up). The participant performed a series of repetitions for a two-minute time period, for a maximum of 80 repetitions. The start position began from the “down” position (knees bent at a 90° angle, feet and hands were shoulder width apart, back and head in a neutral position). The participants were instructed to hang from the bar with their arms straight and a pronated, overhand grip on the bar. With the knees bent and feet flat on the floor, the participant pulled their chest up to the bar. The bar needed to be adjusted to have the participant approximately 1” above the floor while in the initial position. Additionally, the bar was aligned with the participants sternum. The participant were informed to not prop their feet on anything other than the floor while the subject’s body had to remain in a straight and neutral position throughout the test, the arms needed to be fully extended at the bottom of the repetition, and the participant had to maintain the cadence of the metronome set at 80 beats per minute (pace of 40 repetitions per minute). The test was terminated for the following: the participant reached the maximum number of repetitions (80), performed

three incorrect repetitions, failed to maintain the cadence with the metronome, or experienced joint/muscular pain.

Session Three – Simulated Fire Grounds Testing

The third session was the FF performance test held at the training facility located in Oak Hill (Austin, Texas, USA). The standardized Lake Travis FF performance test includes nine specific tasks. The FF were asked to performance the following in series, in full gear, and as fast as possible:

- Dry Hose Deployment: 60-lb. 1.75-inch pre-connected dry hose deployment/drag; 200 feet.
- Charged Hose Deployment: 60-lb. 1.75 charged hose deployment/drag; 74 feet into a building.
- Low-Room Search: crawling search on hands and knees, examining the corners of the room; 80 feet.
- Roof Walk/Vent Task: 23-lb. chainsaw carry and roof walk- FF ascended and descended a 10-foot staircase and walked; 40-feet on the roof with the chainsaw.
- Forced Entry Task: involved a 4.5 kg sledgehammer on an 18.8 kg Keiser Sled (Fresno, California, USA) Keiser.
- Ladder Carry Task: 14-foot,13.6 kg aluminum ladder carry around a building; 250-feet.
- Stair Climb Task: 18 kg hose pack carry up three flights of stairs, followed by raising an 18 kg hose hoist attached to a rope up approximately 40-feet

vertically, and then carrying the hose pack back down the flights to the bottom of the stairs.

- Ceiling Breach: Ten full extension raises with a 20.4 kg barbell, which simulated a ceiling breach.
- Victim Removal: A 82 kg victim-dummy was dragged for a distance of 26 feet, which included one cone as an obstacle requiring the participant to turn around and return to “start” line.

The FF performance test lasted approximately seven-to-ten minutes. Air depletion was measured in pounds per square inch (PSI) was measured before and immediately after the fire grounds test. Prior to the start of the test, air tanks were filled to 4500 PSI, which was checked on the tank and on the extension piece connected to the air tank. Immediately post, the air tanks and the extension piece were checked for air depletion from the 4500 PSI level. Time to completion was recorded. An FF safety officer was present for all FF performance assessments. Each FF wore full turnout gear and the self-contained breathing apparatus (approximately 23.7 kg). Additionally, the participant also wore a chest H10 HR monitor throughout the exercise testing to record HR. Finger pricks were taken pre- and immediately post FF performance test to collect blood samples for lactate level analysis. Blood samples were collected via finger prick at prior to the test and two, four, six, and eight minutes after completion of FF performance test for lactate assessment. A Lactate Plus Meter lactate analyzer (Nova Biomedical Corporation, Waltham, MA, USA) was used to measure blood lactate. For finger prick sampling procedures, a self-retracting safety lancet was used to puncture the lateral aspect of an index or middle finger after cleaning the area with an alcohol swab. A small sample ~25

uL of blood were collected to analyze lactate levels. Gauze was provided to apply pressure to the puncture site. After all samples are collected, a band-aid was placed on the puncture site(s).

Dietary Intervention

The participants assigned to the fasting group were asked (1) to follow a 14:10 fasting-feeding TRF protocol and (2) to download the “Zero” smartphone app (Big Sky Health, Inc., San Francisco, CA, USA) to enter the times for initial and final food intake each day. Participants who were unable to download or preferred not to use the Zero app were asked to record the time of their first and last meal on a sheet provided. Zero app results and provided sheets were collected at the end of the study, and randomly (at least one per week) throughout the study to check compliance. Additionally, the participant was asked to download the “MyFitnessPal” smartphone app (Under Armor, Inc, Baltimore, MD, USA) to track diet. Participants were asked to record their dietary intake on My Fitness Pal for three full days before the intervention and three days during each week of post testing following the concept of a similar seven-day pre-post food recording protocol (Gabel et al., 2018). The same tests used during the pretest were completed during a posttest consisting of 3 visits.

Resistance Training Protocol

The participants were instructed to follow a standardized RT program on each of their on-duty workdays throughout the 8-week intervention. The standardized RT program consisted of circuit-based, FF specific, and traditional-style training. Exercise for the RT program included kettle bell movements, traditionally barbell movements (i.e., bench press, overhead press, and back squat), and FF specific movements such as farmer

carries, tire flips, standing hose pulls and full-extensions. The standardized RT program emphasized stressing the anaerobic energy systems in addition to mimicking movements typically performed during a simulated fire grounds test or real fire situation. Training compliance were assessed through a weekly survey in which the participants reported the percentage (i.e., 100%, 90%, 75%, or 50%) of the RT session they were able to complete for the respective week. Additionally, the participants were asked to provide feedback on random on-duty days to check for training compliance. In order to randomly check the participants compliance, the researchers emailed, and text messaged the participants on shift.

Statistical Analysis

This study used SAS 9.4 for all statistical analysis. Air depletion was quantified as a change in PSI from pre- to post-fire grounds test. Air depletion, time to completion, $\dot{V}O_{2max}$, blood cholesterol, body composition, and muscular strength, endurance, ventilatory threshold, and power measures were compared with a 2 x 2 (treatment x time) repeated measures ANOVA. Lactate post fire grounds test were analyzed by a 2 x 4 (treatment x time) repeated measures ANOVA. Fishers LSD post hoc test was run to compare means in the instance of a significant main effect ($p < 0.05$).

IV. RESULTS

GXT Test Variables

Descriptive Characteristics

All data were reported as mean \pm SD. Data for height, weight, age, percent body fat, and BMI can be seen in Table 1. Overall, weight, BMI and percent body fat did not significant change pre-post intervention (Table 1). The fasted group's weekly fasting times averaged 15.01 hours of fasting, which met the 14-hour fasting window requirement. Training compliance was checked weekly via exercise questionnaire. Data for training compliance can be seen in Table 2. All macronutrient changes during the study can be seen in Table 3. Overall, kcals and macronutrients (grams and percent averages) remained similarly matched across the intervention.

Ventilatory Threshold

With respect to changes in *absolute* VT (L/min; Figure 1) there was no significant treatment x time interaction ($F = 0.32$, $p = 0.57$). There was a main effect for treatment ($F = 5.64$, $p = 0.02$) and time ($F = 7.26$, $p = 0.01$). There was a significant difference between the normal and fasted diet groups as the fasted diet group had higher VT (L/min) values (mean of 2.6) compared to the normal diet (mean of 2.5) ($p = 0.02$) during the post test. There was a significant increase for time in both groups as VT (L/min) changed from pre (2.47 L/min) to post (2.58 L/min) ($p = 0.01$). Data for absolute VT (L/min) can be seen in Figure 1.

No significant treatment x time interaction was noted for *relative* VT ($\%_{\text{Max}}$) (Figure 2) ($F = 0.33$, $p = 0.57$). There was no main effect for treatment ($F = 0.02$, $p = 0.89$). However, there was a main effect for time ($F = 13.40$, $p < 0.01$) with significant

increases from pre to post intervention in both the normal and fasted diet groups. Mean VT %Max increased pre to post intervention from 65.87 to 69.73 for both groups ($p < 0.01$). Data for relative VT (%_{Max}) can be seen in Figure 2.

VO₂ Peak

No significant treatment x time interaction was noted for mean VO₂ peak (L/min; Figure 3) ($F = 2.03$, $p = 0.17$). There was no main effect for time ($F = 1.11$, $p = 0.30$). However, there was a main effect for treatment ($F = 7.21$, $p = 0.01$). The fasted group had significantly higher mean VO₂ peak values compared to the normal diet group ($p = 0.01$). The mean VO₂ peak value for the normal diet was 3.65, and the value for the fasted group was 3.80. Data for relative VO₂ peak can be seen in Figure 3.

Body Fat

In regard to mean percent body fat (Figure 4) there was no significant treatment x time interaction ($F = 0.38$, $p = 0.54$). There was no main effect for time ($F = 0.16$, $p = 0.69$). However, there was a main effect for treatment ($F = 31.5$, $p < 0.001$) with the normal diet group having significantly lower mean body fat compared to the fasted group during the post test. The mean body fat in the normal group was 14.27% compared to the fasted group's mean of 20.5%. Data for percent body fat peak can be seen in Figure 4.

Muscular Test Variables

Muscular Endurance

In terms of changes for inverted rows (repetitions; Figure 5) there was no significant treatment x time interaction ($F = 1.97$, $p = 0.17$). There was no main effect for time ($F = 0$, $p = 0.97$). However, there was a main effect for treatment ($F = 14.18$, $p < 0.01$) with the normal diet group performing significantly more repetitions (28.62)

compared to the fasted group (24.04; $p < 0.01$). Data for inverted rows can be seen in Figure 5.

No significant treatment x time interaction was noted for push-ups (repetitions; Figure 6) ($F = 3.92$, $p = 0.06$). There was a main effect for time ($F = 9.33$, $p < 0.01$) and treatment ($F = 16.97$, $p < 0.001$). There was a significant increase in the mean repetitions for push-ups pre to post intervention for both groups ($p < 0.01$). The mean repetitions for the push-up in the normal diet group was 37.15, and the mean value for the fasted group was 41.7. Data for push-ups can be seen in Figure 6.

Muscular Strength and Power

With respect to mean bench press max (Figure 7) there was no significant treatment x time interaction ($F = 0.33$, $p = 0.57$). There was no main effect for time ($F = 2.68$, $p = 0.12$). However, there was a main effect for treatment ($F = 5.39$, $p = 0.03$). The fasted diet group had higher mean post-test bench press max (230.2) compared to the normal diet groups' mean bench press max (202.6). Data for bench press can be seen in Figure 7.

In regard to mean power (Figure 8) there was no significant treatment x time interaction ($F = 0.71$, $p = 0.41$). There was no main effect for condition ($F = 0.08$, $p = 0.77$) or treatment ($F = 1.67$, $p = 0.21$). Data for mean power can be seen in Figure 8.

Fire Ground Test Variables

Time to Completion

With respect to fire ground completion time (Figure 9) there was no significant treatment x time interaction ($F = 0.87$, $p = 0.42$). There was no main effect for time ($F = 2.62$, $p = 0.09$). However, there was a main effect for treatment ($F = 7.16$, $p = 0.01$). The

normal diet group had faster mean fire grounds completion times (7.5 minutes) compared to the fasted diet group (8.3 minutes). Data for fire ground completion time can be seen in Figure 9.

Heart Rate

In terms of changes for mean heart rate (Figure 10) during the fire grounds test there was no significant treatment x time interaction ($F = 0.87$, $p = 0.42$). There was a main effect for time ($F = 627.65$, $p < 0.001$) as heart rates after the stair climb and immediately posttest was both significantly higher than pre- heart rate values (180.64, 179.93, and 96.95 respectively). There was a main effect for treatment ($F = 10.66$, $p < 0.01$) as the normal diet group had significantly higher mean heart rates (155.2) compared to the fasted diet group (148.9) during the fire grounds test. Data for mean heart rate can be seen in Figure 10.

Lactate

With respect to lactate (mmol/L) (Figure 11) there was a significant treatment x time interaction ($F = 2.54$, $p = 0.04$). Lactate values at two-minutes post fire ground test were significantly higher in the normal diet group compared to the fasted diet group ($p = 0.01$). Additionally, four minutes post, six minutes post, and eight minutes post were significantly higher in the normal diet group compared to the fasted group ($p < 0.01$, $p < 0.01$, $p < 0.001$, respectively). Data for lactate can be seen in Figure 11.

Air Depletion

No significant treatment x time interaction was noted for air depletion (PSI) for the extension (Figure 12) ($F = 0.88$, $p = 0.36$). There was a main effect for treatment ($F = 22.77$, $p < 0.001$) and for time ($F = 13.21$, $p < 0.01$). There was significant increase in air

depletion for both the normal diet and fasted diet groups post-intervention (2125.0 and 2418.8 PSI, respectively). The fasted diet group had significant more mean air depletion compared to the normal diet group (2316.1 and 1950.0 PSI, respectively). Data for air depletion can be seen in Figure 12.

V. DISCUSSION

The purpose for the present investigation was to examine the effects of an 8-week TRF and standardized training intervention on cardiometabolic health markers and performance variables in professional FF. The present study demonstrated TRF diet did not directly improve cardiometabolic health or performance markers. Both the normal diet and fasted diet groups improved performance on push-ups and ventilatory threshold. However, there were not improvements in muscular strength. The limited research on human subjects and TRF suggest TRF does not negative affect performance and may have favorable effects on body composition (Moro et al., 2016; Tinsley et al., 2017; Tinsley & La Bounty, 2015). The FF in the present study did not experienced significant improvements for body composition, which may likely be attributed to the lack of sensitivity and validity of the BIA (Langer et al., 2016).

Recent research suggest TRF may allow for physiological benefits such as improvements in insulin sensitivity, oxidative stress, inflammation, lipid panels, and body composition (Waldman et al., 2019). While TRF is theorized to be a potential practical nutrition strategy to combat cardiometabolic disease among high-stress occupations, more research is needed to determine the direct effects of TRF on cardiometabolic health and performance markers. The present study noted the 8-week, 14:10 fasting-feeding TRF protocol had no negative effects on performance. The improvements in performance outcomes (i.e., push-ups and VT) may be attributed to either TRF or the RT program; however, a larger scale study is needed to determine the effects of TRF among FF on cardiometabolic health markers and performance. It can be assumed the RT protocol

contributed to the improvements in performance as there were no detectable changes in body composition.

Ventilatory Threshold & Maximal Oxygen Consumption ($\dot{V}O_{2max}$)

In order for FF to work more efficiently and meet the physiological demands for their job, higher VO_{2peak} and high VT (as % VO_{2peak}) are necessary (Lemon & Hermiston, 1977). Research has suggested FF are better trained with VT occurring above 60% VO_{2peak} (Windisch et al., 2017). More specifically, FF able to exercise around 60 to 80% of VO_{2peak} are within the recommended range to allow better metabolic adaptations to occur as a result of the physical work demands (Bunc, Heller, Leso, Sprynarova, & Zdanowicz, 1987). Improvements in VT were observed from the GXT pre-post intervention and may be attributed to the standardized RT program. Specifically, the circuit training and anaerobic energy system focuses of the standardized RT program likely aided the FF in terms of the improvements for VT. Based off the VT improvements, FF are expected to have been more efficient with air utilization and may be working at higher VT %MAX percentages during the post-fire ground test (~69.7% VT%MAX), which indicated an improvement to FF fitness levels. Numerous studies have demonstrated FF experience high physical stress due to the physical demands and nature of the profession (Bilzon, Scarpello, Smith, Ravenhill, & Rayson, 2001; Del Sal et al., 2009; Elsner & Kolkhorst, 2008; O'Connell, Thomas, Cady, & Karawasky, 1986). Moreover, the primary focus when assessing FF performance in previous research has been with regard to completion time during fire simulation tests (Rhea, Alvar, & Gray, 2004; Williford, Duey, Olson, Howard, & Wang, 1999). However, a key factor for FF performance is the compressed air depletion from the SCBA, which when depletion is

low the fitness level of an FF is likely higher (Windisch, Seiberl, Schwirtz, & Hahn, 2017). While the FF improved their VT pre-post intervention, it is hard to make a strong distinction on whether the FF were working at a higher end of their respective %MAX. The FGT is a maximal effort test, which maybe it is hard to state they were working at a submaximal exercise level.

Implications for FGT Performance

High VO_{2peak} , high VT, and lower air depletion from the self-containing breathing apparatus (SCBA) are typically classified with higher fitness levels and are able to meet the job demands. When FF are “on air” from the SCBA they have recirculating compressed air for approximately 30 to 40 minutes; however, air tank depletion can rapidly occur before they have finished a simulated fire ground test. Moreover, FF with lower air tank depletion, quicker time to completion, and less physical strain during a fire ground test typically have higher fitness levels represented by VO_{2peak} (Windisch et al., 2017). Therefore, FF who are able to work at high VO_{2peak} values while not depleting their air tanks will be able to perform better during simulated fire testing or a real fire situation. Interestingly, air depletion was greater during the post-fire ground test compared to the pre-test trial for PSI air tank extension in our study. However, the air depletion readings directly from the SBCA air tank values were slightly lower during the post-trial compared to the pre-trial. It is important to note two different individuals filled the air tanks between FGT trails. While VT was improved, air tank depletion, time to completion, and VO_{2peak} values did not improve. Air tank PSI may not have improved due to the sensitivity of the air tank. A larger scale study is needed to examine the impact TRF may have on VO_{2peak} and air tank depletion.

Impact of Training

Performance variables among the FF were positively impacted by the intervention. Although tactical strength and conditioning is relatively new, research is growing on the most effective training strategies for FF. The strenuous nature of firefighting requires optimal physical fitness levels. Therefore, FF should engage in a regular RT program in order to meet the job demands. While traditional and undulating periodization models have been shown to improve FF performance, more attention is needed with respect to the stress placed on both anaerobic and aerobic energy systems (Abel et al., 2011). Circuit-based RT has been demonstrated to produce low cardiovascular stress while inducing the appropriate amount of anaerobic stress, which is similar to the stress experienced during specific FF tasks (Abel et al., 2011). The standardized RT program the FF followed for the 8-week intervention focused on a combination of traditional and hypertrophic - focused resistance training, anaerobic and aerobic energy system targeting workouts, and FF specific circuit-based workouts. Additionally, the program followed an undulating periodization model, which was performed on the on-duty days. Each week the FF trained for two sessions (i.e., session one was a non-circuit session and session 2 was a circuit session) with an occasional third training session every three weeks. The circuit training sessions focused on movements and exercises mimicking FF tasks performed on-duty or during a fire grounds simulated test such as a standing hose pull, tire flips, and farmer carries. Previous research on circuit-based RT among FF have been shown to yield heart rates averaging at an elevated percentage of the max heart rate (i.e., $\geq 75\%$ max-heart rate) (Abel et al., 2011). Circuit-based training may allow for the necessary physiological adaptations to occur for FF to

effectively meet their job demands (i.e., lifting and carrying heavy objects or victims from a fire). Both the normal diet and fasted diet groups improved performance, which may possibly be due to the RT program, which had the training sessions assigned each on-duty day during the 8-week intervention. However, a larger scale study is needed to further elucidate.

The standardized RT program served to target both anaerobic stress and traditional periodization. The data from this study support previous research regarding the importance for including circuit-based training in the physical training program to produce appropriate anaerobic stress and low cardiovascular stress (Abel et al., 2011). Additionally, the standardized RT program included non-circuit training sessions, which emphasized hypertrophy, strength, and power. The 8-week program was consistent of high-intensity cardiovascular exercise and movements, circuit-based training, and a range of training intensities to prepare FF for their on-duty tasks. Given FF may not typically follow such a planned periodized program, it is possible the improvements in VT and muscular endurance are attributed to the RT program. However, the improvements in VT and muscular endurance may also be due to improvements in body composition, although no reductions in body fat or changes in weight were noted. It is likely the lack of diverse methods used to assess body composition resulted in the lack of any significant pre-post change.

Muscular strength

Muscular strength is a critical performance factor needed for FF to meet job demands (Boyce et al., 2008). The FF in the normal diet and TRF groups did not increase one-repetition max for bench press from pre- to post-intervention. Previous research

suggests there is no negative effects from TRF on strength and muscle mass (Moro et al., 2016). Specifically, Moro et al. (2016) noted the TRF group was able to maintain muscular strength and lean muscle mass while following the 16/8 TRF protocol. However, there are mixed results in terms of hypertrophic adaptations and muscular strength while following TRF and participating in RT (Tinsley et al., 2017). The FF in the present study did not improve muscular strength. However, the normal diet and fasted diet groups were able to maintain muscular strength, which is consistent with previous research (Moro et al., 2016; Tinsley et al., 2017). Additionally, no differences were noted for caloric and macronutrient consumption among both the normal diet and fasted diet groups. It is important to note the present RT protocol was structured to improve FF specific tasks and not solely induce hypertrophic training adaptations. It is unclear whether TRF, or other fasting diets, can induce muscular hypertrophy.

Muscular Endurance

Significant improvements in muscular endurance were noted in both the normal diet and TRF groups pre-to-post intervention for push-ups completed. Previous research suggests FF who can complete greater than 20 push-ups are at a lower risk for cardiovascular-related events when compared to FF who could only complete less than 10 push-ups (Yang et al., 2019). The FF from the normal diet group performed within the desirable range in terms of average repetitions on the push-up test, while the fasted group performed above the desirable range (>40 repetitions) in both the pre- and post-test. The improvements for push-up capacity in the present study is likely attributed to the standardized RT program since no detectable changes in body composition were present. It is difficult to make strong distinctions on the effects of TRF on muscular endurance for

the present study; however, the increase in repetitions for push-ups may be due to the diet and RT. Previous research has demonstrated TRF does not negatively affect muscular endurance, which is consistent with the present findings (Moro et al., 2016; Tinsley et al., 2017; Tinsley & La Bounty, 2015).

Previous research has highlighted obesity to be a major concern among FF with more than 70% are considered overweight or obese (Walker SC Poston et al., 2011; Brown et al., 2016). Poor health profiles of FF are characterized by adverse cardiometabolic profiles, poor job performance, low cardiorespiratory fitness levels, and sudden cardiovascular-related events on duty (Fahy et al., 2012; Jahnke et al., 2013). The NFPA recommendations for health and fitness maintenance for FF are not being met. High levels of muscular endurance, along with muscular strength and cardiorespiratory fitness, are required in order to perform FF specific tasks while wearing PPE (~20-35 kg). Therefore, FF who have high push-up capacity are better prepared physically to meet the demands of the job. Push-up tests are a standard muscular endurance assessment utilized by the fire department. Additionally, push-up capacity testing is a simple, no-cost, and quick assessment tool, which can be used as a clinical assessment tool for evaluation of functional capacity and cardiovascular-related risks.

Impact of Fasting & Body Composition

Recent research demonstrated reductions in body fat among college aged, health individuals while following a four-week TRF protocol (McAllister et al., 2019). One idea behind TRF is to optimize meal timing (Waldman et al., 2019) and reduce the feeding window, frequent snacking habits, and poor eating patterns, which may allow more time for various physiological adaptations to occur such as weight loss and favorable body

composition changes. The 8-week TRF protocol did not directly impact health or performance outcomes; however, based on the current findings, the diet does not appear to hinder performance. For six weeks of the intervention, 15 of 16 FF averaged >14-hours fasting each week. For the entire eight weeks of the intervention, 14 of 15 FF averaged >14-hours fasting each week. While the majority met and exceeded the 14-hour fasting window, the fast may not have been enough of a positive physiological stressor to cause desirable adaptations such as favorable body composition changes, and improvements to cardiometabolic health markers (i.e., reduction in body fat) (McAllister et al., 2019; Waldman et al., 2019). Body composition did not change significantly from TRF, which is in contrast to previous work (McAllister et al., 2019; Moro et al., 2016). Moro et al. (2016) noted significant decreases in fat mass for the TRF group, which was measured by a dual-energy X-ray absorptiometry (DXA) body composition assessment method. The present study measured body fat pre-post via the bioelectrical impedance analysis (BIA) method. The BIA method may overestimate body fat percentage; however, research suggests it may be a suitable method when a DEXA is not available (Smee et al., 2019). The results from using the BIA method can be adversely affected in those who have higher amounts of fat free mass (Langer et al., 2016). The BIA method's validity is approximately $\pm 3.5\%$ and depends on the hydration status of the individual, the validity of the equations programmed into the analyzer, and body water distribution (ACSM, 2017). The standard error for the BIA is approximately between 4.6 to 6.4% fat, which is comparable to the BMI method (Jackson, Pollock, Graves, & Mahar, 1985; American College of Sports Medicine [ACSM], 2017). Additionally, given the logical constraints of other anthropometric assessment methods (i.e., BMI), the BIA has been suggested as an

alternative for assessing body composition among FF (Smee et al., 2019). The BIA was the more practical and cost-effective method to assess body composition for the present study due to having to set up a remote laboratory at the FF station. Although TRF may be a beneficial nutrition intervention for FF, reductions in body fat were not noted as a result of TRF, which may be due to the lack of more diverse methods for calculating body fat percentage. The improved performance variables may be due to either TRF or the RT protocol; however, more research is warranted.

Several limitations were present during the intervention. The dietary intervention relied on self-reported data. Each subject was asked to record their food consumed in MyFitnessPal. Additionally, subjects of the fasted group were asked to record daily fasting times in the Zero smartphone app. Given the nature of firefighting, subjects may have broken fasting times sooner than desired, or misreported fasting times and MyFitnessPal data. Subjects were asked to report food logs prior to the start of the intervention and during the weeks of the post testing visits. Subjects were also asked to report weekly fasting times to check for compliance and limit discrepancies. Another limitation could be noted with subjects who engaged in any additional training (i.e., resistance training or cardio) outside of the provided 8-week standardized resistance training program. The subjects were asked to report any additional training on a weekly survey, which checked compliance to the standardized RT program. Subjects were allowed to perform aerobic and additional RT as long as they reported it on the weekly surveys. A third limitation was noted during the post testing. Several of the subjects reported having lack of sleep the night before due to being on-duty and responding to a call. Performance during the post testing may have been affected due to stressors from

being on-call the day/night prior. While it is challenging to predict on-duty FF shift events (i.e., fire), the FF in the present study were asked to sign-up for the testing dates best suited for their schedules. Additionally, the sporadic work shifts the FF experiences may have led to possible inconsistencies for their RT session. The FF were instructed to perform the RT session on their on-duty days. Several FF informally stated responding to various emergency calls (i.e., fire calls) may have impacted their ability to complete RT sessions. The disruption to the RT sessions may have reduced potential for improvements in muscular strength and power. The fifth limitation was noted during the fire ground testing. Two different individuals refilled air tanks, which may have contributed to slight inconsistencies in filling the air tank PSI. Lastly, the study design was unbalanced as the fasting group (n = 16) was larger compared to the normal diet group (n = 4). During the sixth week, one subject dropped out of the study due to an injury, which was unrelated to the intervention.

Conclusion

While TRF did not directly improve health or performance variables, the diet did not hinder health or performance outcomes. The standardized RT program resulted in improvements for VT and muscular endurance. The improved performance variables may result in reduced risk for heart disease and SCD while optimizing occupational specific performance. In terms of the benefits offered from a TRF diet, recent research supports the clinical importance and practicality for TRF among high-stress occupations and combatting disease. However, the feeding-fasting window resulting in optimal stress to induce desirable adaptations is unclear. Additional examination for the various TRF fasting versus feeding window protocols among high-stress occupations is warranted.

Tables:

Table 1. Descriptive Characteristics

	Pre-Intervention	Post-Intervention
Height (cm)	179.03 ± 5.59	179.17 ± 5.69
Weight (kg)	87.24 ± 12.83	87.33 ± 12.54
Age (years)	35.4 ± 7.21	35.7 ± 7.17
Percent Body Fat	18.83 ± 6.47	19.68 ± 5.03
Body Mass Index [BMI]	26.88 ± 3.08	27.3 ± 3.09

Table 2. Training Compliance

%	Week							
	1	2	3	4	5	6	7	8
100%	15	16	15	10	9	8	13	4
90%	3	3	3	4	6	4	4	5
75%	0	0	0	1	0	0	0	1
50%	2	1	1	3	4	5	2	6
25%	0	0	0	0	1	2	1	1
0%	0	0	1	2	0	1	0	2

% Compliance is represented as the number of FF who completed a specific percent of the standardized resistance training program per each week. Note: Week nine, one subject was unable to partake due to injury not related to the present study.

Table 3. Macronutrient Breakdown

	Pre-Diet	Post-Session 1	Post-Session 2	Post-Session 3
K/cals	2128 ± 112	2030 ± 238	2130 ± 74	2124 ± 91
Carbs (g)	176 ± 29	198 ± 40	194 ± 9	191 ± 18
Carbs (E%)	35 ± 3	35 ± 2	36 ± 2	36 ± 2
Fats (g)	98 ± 6	99 ± 20	91 ± 7	91 ± 6
Fats (E%)	42 ± 2	41 ± 0.5	39 ± 3	40 ± 3
Protein (g)	117 ± 3	120 ± 7	127 ± 3	119 ± 7
Protein (E%)	23 ± 2	24 ± 2	24 ± 1	24 ± 1

Sessions one, two, and three were repeated post testing in which dietary food logs were collected from participants. E% is the macronutrient percentage of the respective macronutrient.

Illustrations:



Session 1: Blood collection, anthropometrics, & graded exercise testing



Session 2: Vertical jump, muscular strength, & muscular endurance testing



Session 3: Fire grounds testing

Illustration 1. Study Timing

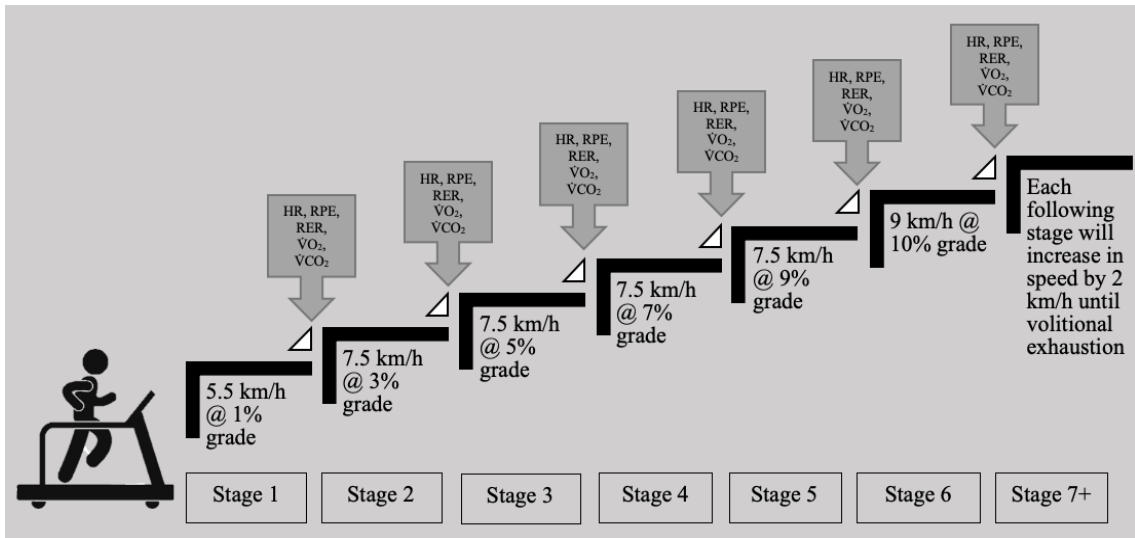


Illustration 2. Graded Exercise Test Protocol

Figures:

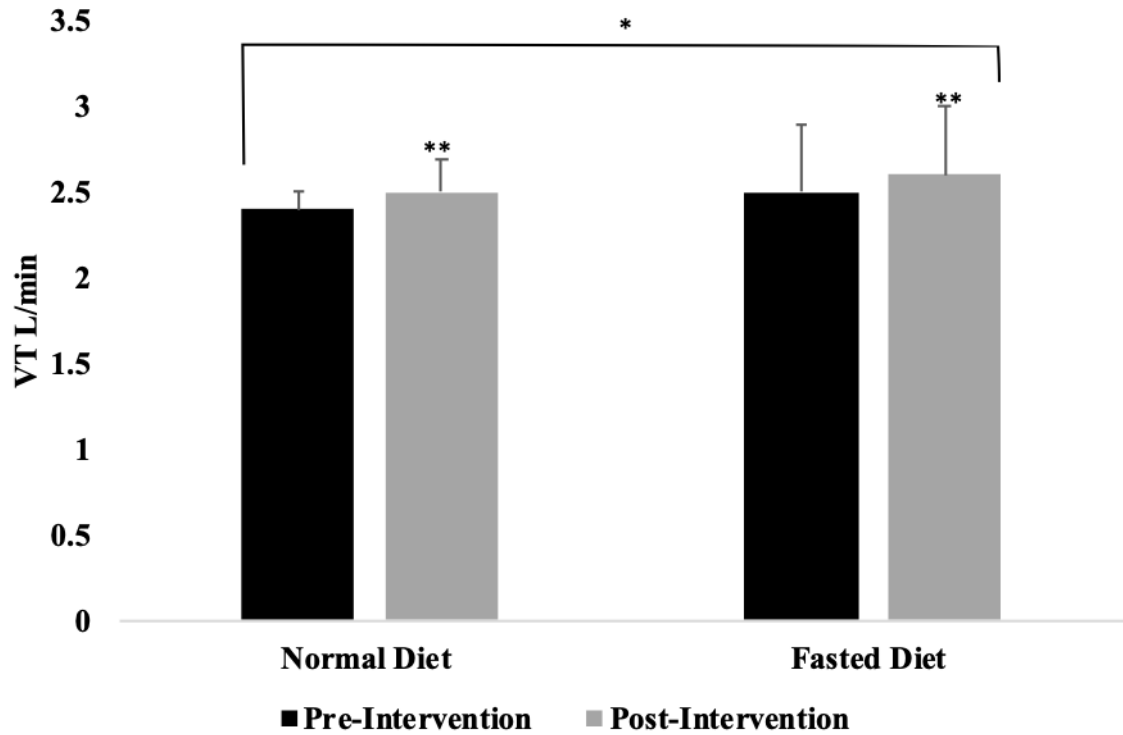


Figure 1. Ventilatory Threshold

Changes (mean \pm SD) for ventilatory threshold (VT) for both the normal and fasted diet groups. Each bar represents mean ventilatory threshold values in liters per minute (L/min; \pm SD). *Denotes significant differences found for treatment with the fasted diet group having higher VT (L/min) values compared to the normal diet group. **Denotes significant increases in VT (L/min) pre-to post-intervention for both groups.

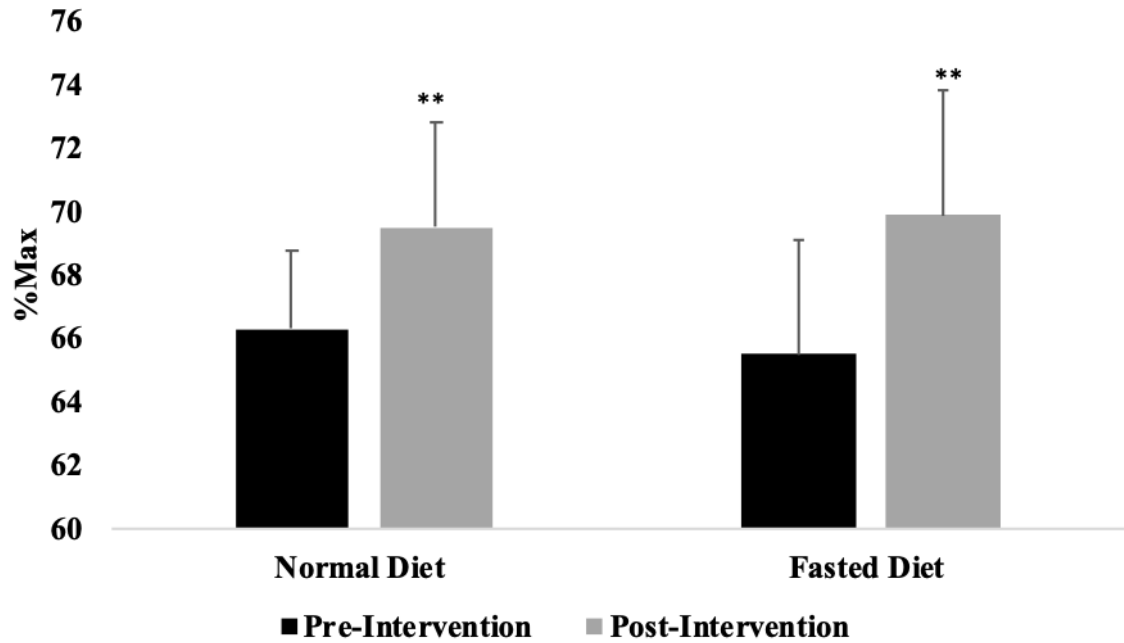


Figure 2. VT %Max

Changes (mean \pm SD) for ventilatory threshold as %Max for both the normal and fasted diet groups. Each bar represents mean ventilatory threshold %Max values (\pm SD).

**Denotes significant increase from pre-to post-intervention.

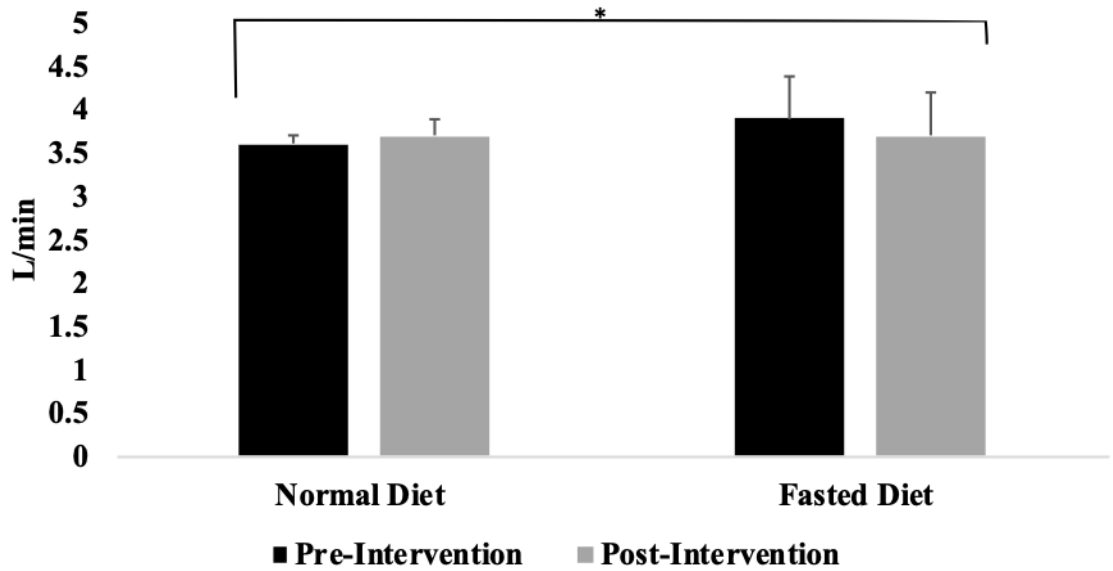


Figure 3. VO₂ Peak

Changes (mean ± SD) for VO₂ Peak (L/min) for both the normal and fasted diet groups.

Each bar represents mean VO₂ Peak values (± SD). *Denotes significant differences between treatments with higher VO₂ Peak (L/min) values in the fasted diet group compared to the normal diet group.

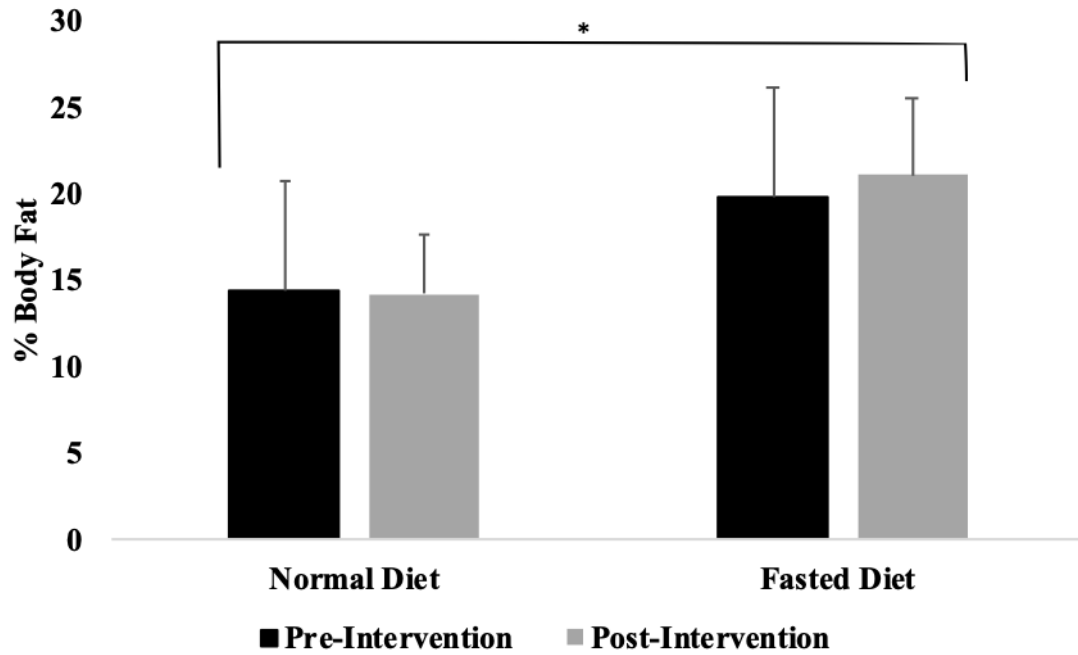


Figure 4. Percent Body Fat

Changes (mean \pm SD) for percent body fat for both the normal and fasted diet groups. Each bar represents mean percent body fat values (\pm SD). *Denotes significant differences between treatments with the fasted diet group have higher mean body fat compared to the normal diet group.

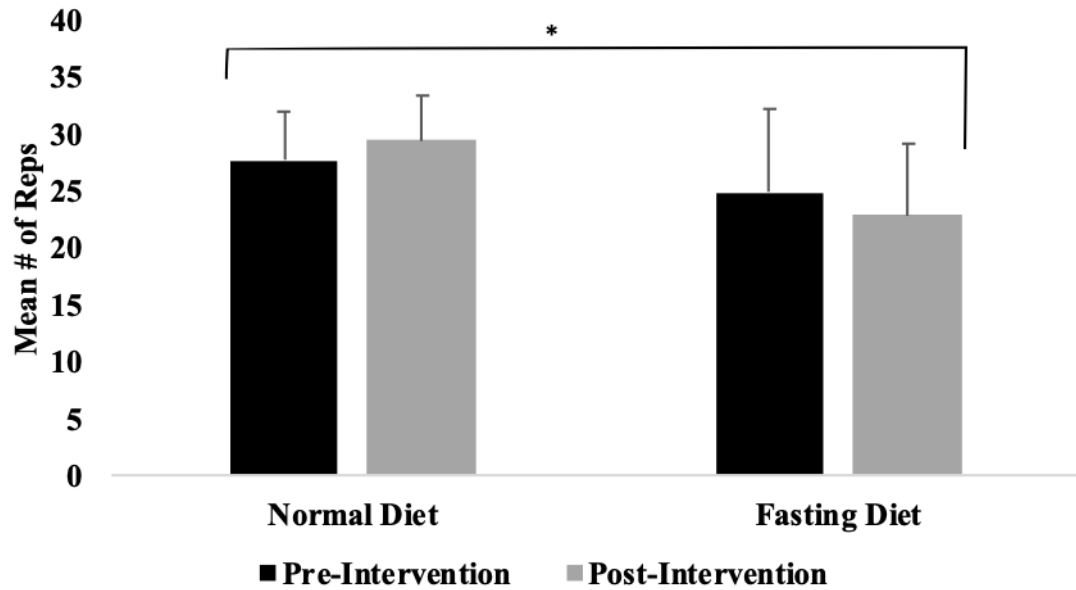


Figure 5. Inverted Rows

Changes (mean \pm SD) for mean repetitions of inverted rows for both the normal and fasted diet groups. Each bar represents mean number of repetitions for inverted rows (\pm SD). *Denotes significant differences between treatments with the normal diet group performing more repetitions compared to the fasted diet group.

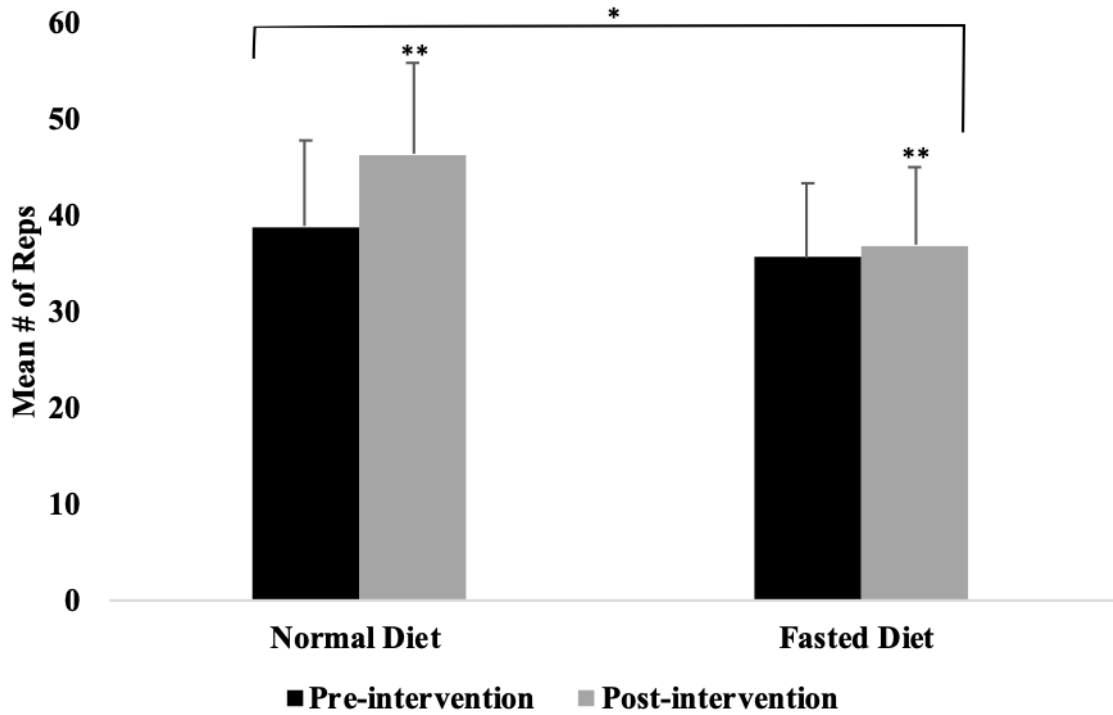


Figure 6. Push-Ups

Changes (mean \pm SD) for mean number of repetitions for push-ups for both the normal and fasted diet groups. Each bar represents mean number of repetitions for push-ups (\pm SD). *Denotes significant differences between treatments with the fasted group performing more push-ups compared to the normal diet group. **Denotes significant increases pre-to post-intervention for both groups.

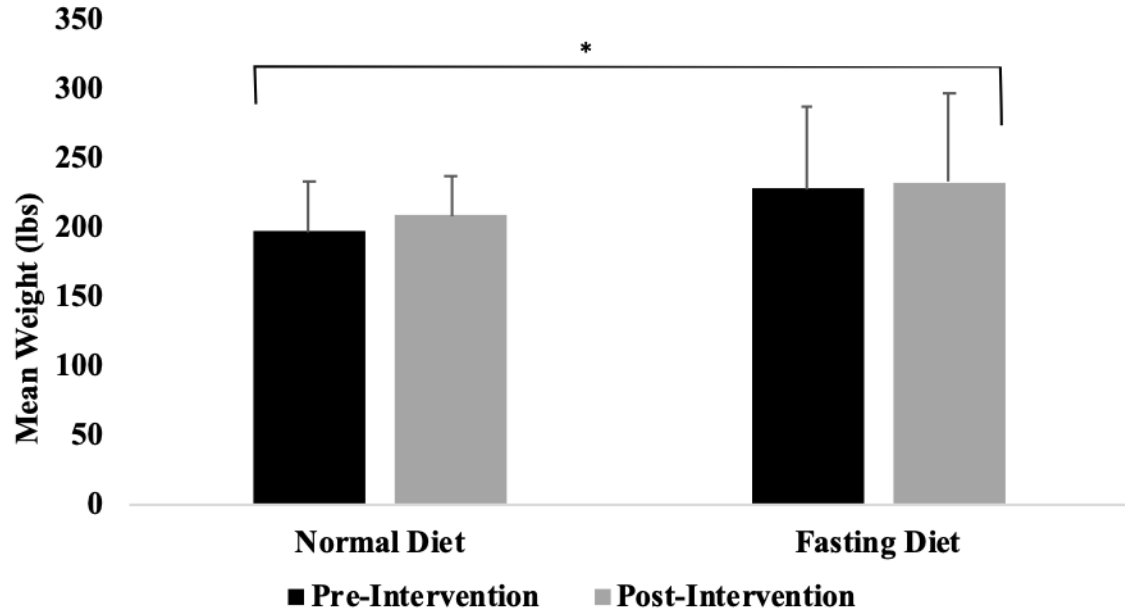


Figure 7. Bench Press

Changes (mean \pm SD) for mean bench press max weight for both the normal and fasted diet groups. Each bar represents mean bench press max weight (\pm SD). *Denotes significant differences between treatments with the fasted group having higher mean bench press values compared to the normal diet group.

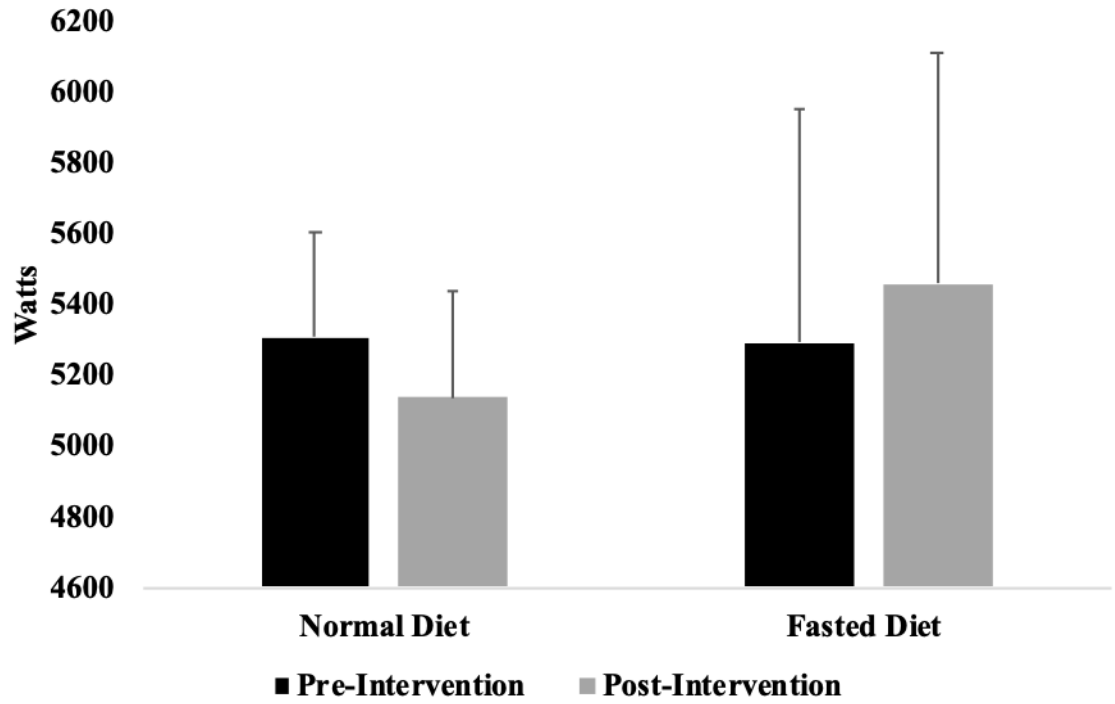


Figure 8. Power

Changes (mean \pm SD) for mean power (watts) for both the normal and fasted diet groups.

Each bar represents mean power (\pm SD). There was no main effect for time or treatment.

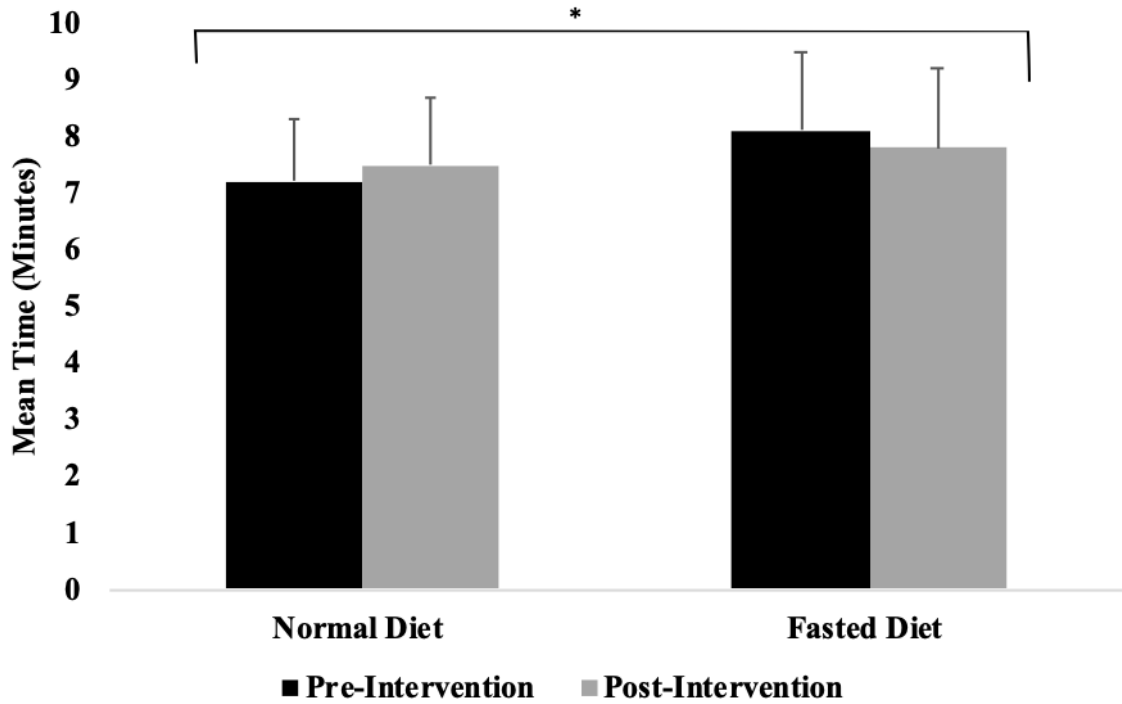


Figure 9. Fire Grounds Time to Completion

Changes (mean \pm SD) for fire grounds time to completion for both the normal and fasted diet groups. Each bar represents mean time to completion values (\pm SD). *Denotes significant differences between treatments with the normal diet group having faster completion times compared to the fasted diet group.

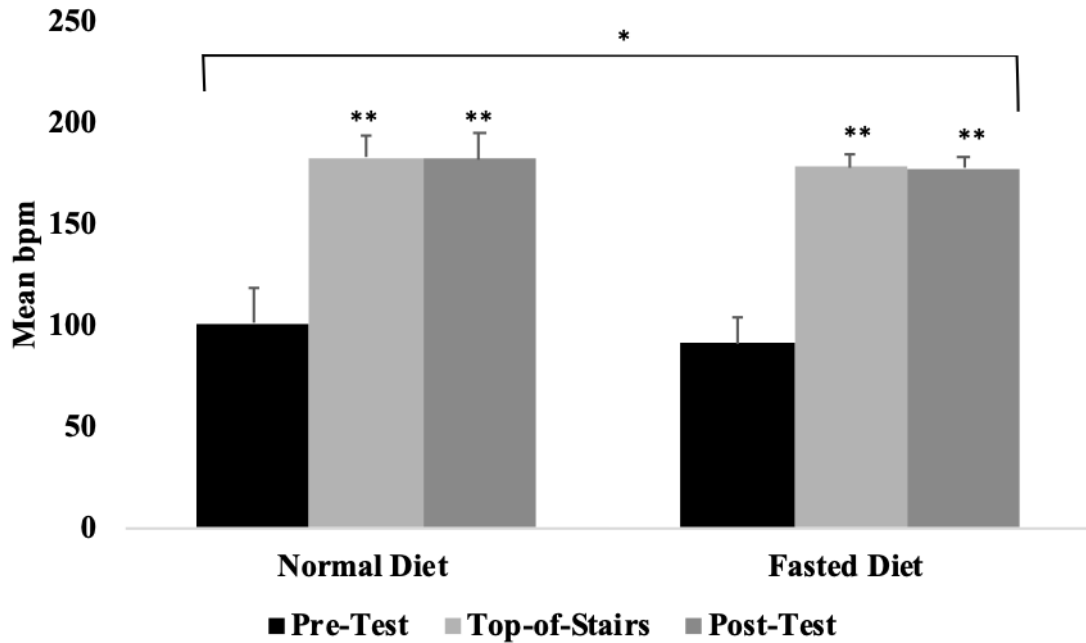


Figure 10. Heart Rate Response

Changes (mean \pm SD) for heart rate response (bpm) for both the normal and fasted diet groups. Each bar represents mean heart rate response values (\pm SD). **Denotes significant increases in mean heart rate at the top-of-stair and immediately post timepoints compared to the pre values (180.64, 179.93, and 96.95 respectively). *Denotes significant differences for treatments with the normal diet group having significantly higher mean heart rate values compared to the fasted diet group.

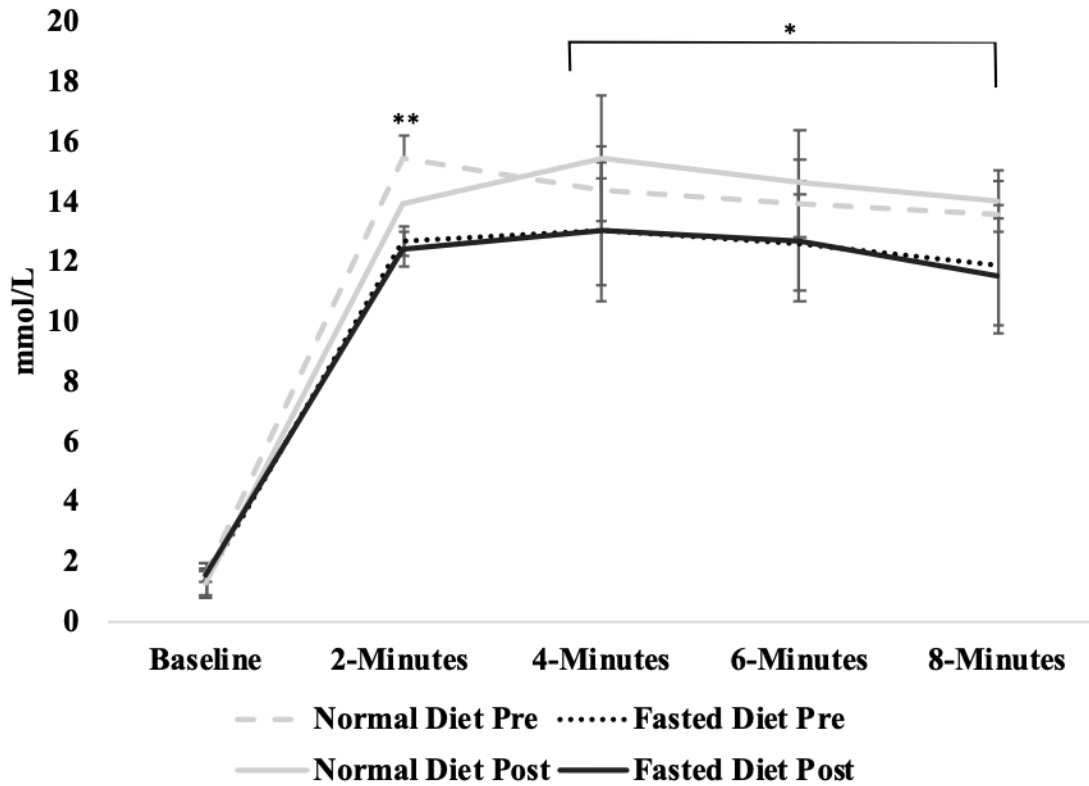


Figure 11. Lactate

Changes (mean \pm SD) for lactate values (mmol/L) for both the normal and fasted diet groups. **Denotes significant difference between treatments. Lactate values at two-minutes post fire ground test were significantly higher in the normal diet group compared to the fasted diet group. Additionally, four minutes post, six minutes post, and eight minutes post fire ground tests were significantly higher in the normal diet group compared to the fasted diet group. *Denotes significant differences for treatments with the normal diet group having higher lactate values compared to the fasted diet group.

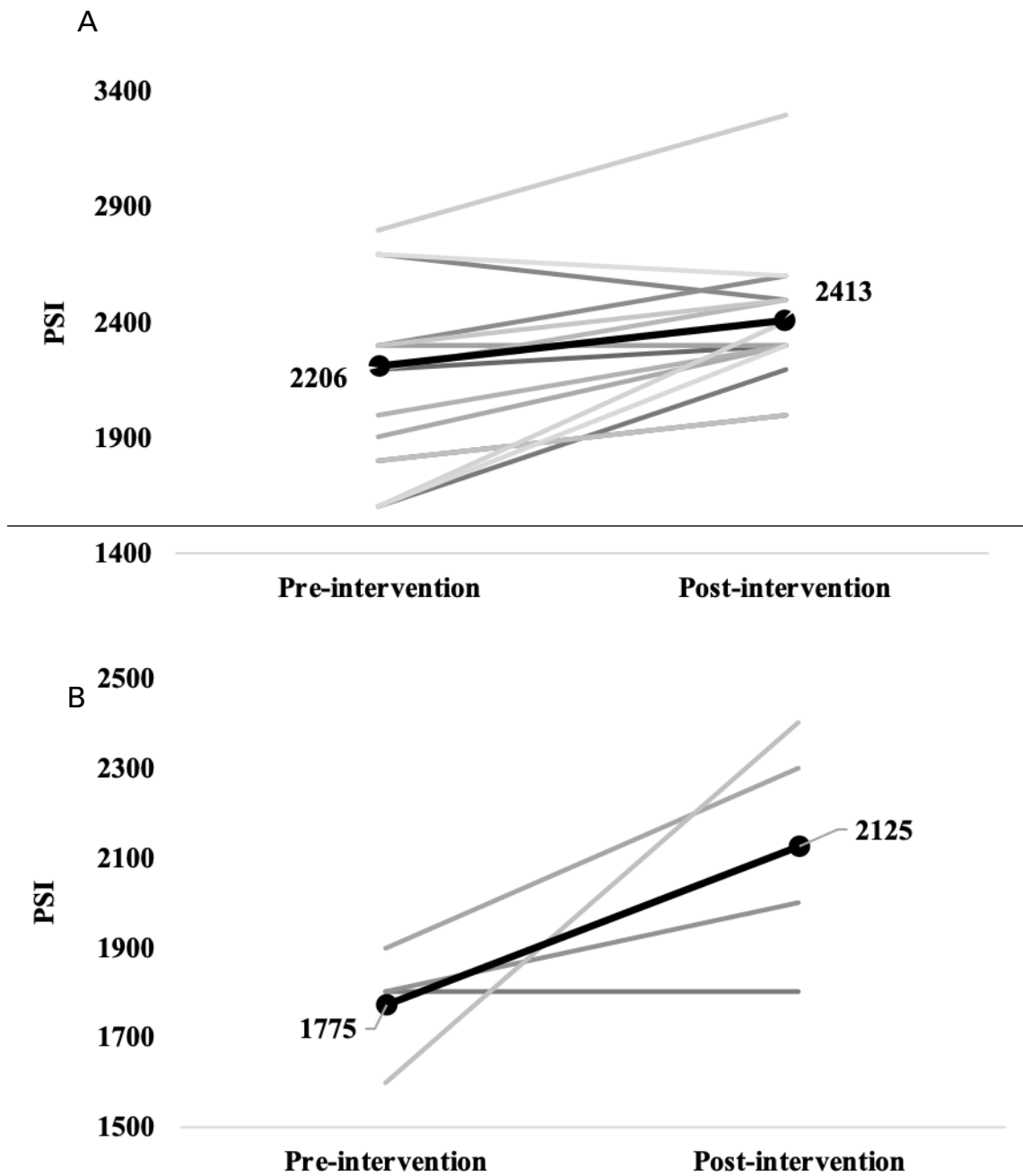


Figure 12. PSI Tank Extension Difference

Air tank PSI = pounds-per-square-inch. Individual air extension depletion responses for pre-to post-intervention. The bold line with the larger end markers represents the mean values.

REFERENCES

- Abel, M. G., Mortara, A. J., & Pettitt, R. W. (2011). Evaluation of circuit-training intensity for firefighters. *The Journal of Strength & Conditioning Research*, 25(10), 2895-2901.
- Abel, M. G., Palmer, T. G., & Trubee, N. (2015). Exercise program design for structural firefighters. *Strength and Conditioning Journal*, 37(4), 8-19. doi: 10.1519/ssc.0000000000000123
- Adams, J., Roberts, J., Simms, K., Cheng, D., Hartman, J., & Bartlett, C. (2009). Measurement of functional capacity requirements to aid in development of an occupation-specific rehabilitation training program to help firefighters with cardiac disease safely return to work. *Am J Cardiol*, 103, 762-765.
- Agostinis-Sobrinho, C., Abreu, S., Moreira, C., Lopes, L., Garcia-Hermoso, A., Ramirez-Velez, R., Correa-Bautista, J. E., ... Santos, R. (2017). Muscular fitness, adherence to the southern European Atlantic diet and cardiometabolic risk factors in adolescents. *Nutr Metab Cardiovasc Dis*, 27(8), 695-702. doi: 10.1016/j.numecd.2017.04.008
- An, S. J., Jung, M. H., Ihm, S. H., Yang, Y. J., Young, H. J. (2019). Effects of physical activity on the cardiometabolic profiles of non-obese and obese subjects: Results from the Korea National Health and Nutritional Examination Survey. *PLoS ONE*, 14(3). <http://doi.org/10.1371/journal.pone.0208189>
- Andrews, K. L., Gallagher, S., & Herring, M. P. (2019). The effects of exercise interventions on health and fitness of firefighters: A meta-analysis. *Scandinavian Journal of Medicine & Science in Sports*. <https://doi-org.libproxy.txstate.edu/10.1111/sms.13411>
- Anton, S. D., Moehl, K., Donahoo, W. T., Marosi, K., Lee, S., Mainous, A. G., Leeuwenburgh, C., & Mattson, M. P. (2017). Flipping the metabolic switch: Understanding and applying health benefits of fasting. *Obesity*, 26(2), 254-268. doi: 10.1002/oby.22065
- Artero, E. G., Lee, D., Lavie, C. J., Espana-Romero, V., Sui, X., Church, T. S., & Blari, S. N. (2013). Effects of muscular strength on cardiovascular risk factors and prognosis. *J Cardiopulm Rehabil Prev*, 32(6), 351-358. doi: 10.1097/HCR.0b013e3182642688
- Asmat, U., Abad, K., & Ismail, K. (2016). Diabetes mellitus and oxidative stress – A concise review. *Saudi Pharmaceutical Journal*, 24(5), 547-553. doi: 10.1016/j.jsps.2015.03.013

- Azevedo, F. R., Ikeoka, D., & Caramelli, B. (2013). Effects of intermittent fasting on metabolism in men. *Revista da Associacao Medica Brasileria*, *59*(2), 167-173. <http://doi.org/10.1016/j.ramb.2012.09.003>
- Baur, D. M., Christophi, C. A., Tsismenakis, A. J., Cook, E. F., & Kales, S. N. (2011). Cardiorespiratory fitness predicts cardiovascular risk profiles in career firefighters. *J Occup Environ Med*, *53*, 1155-1160.
- Bhutani, S., Klempel, M. C., Kroeger, C. M., Trepanowski, J. F., & Varady, K. A. (2013). Alternate day fasting and endurance exercise combine to reduce body weight and favorably alter plasma lipids in obese humans. *Obesity*, *21*, 1370-1379. doi: 10.1002/oby.20353
- Blair, S. N., Kampert, J. B., Kohl, W. H., Barlow, C. E., Macera, C. A., Paffenbarger, R. S., & Gibbons, L. W. (1996). Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *JAMA*, *276*, 205-210.
- Boyce, R. W., Ciulla, S., Jones, G. R., Boone, E. L., Elliott, S. M., & Combs, C. S. (2008). Muscular strength and body composition comparison between the Charlotte-Mecklenburg fire and police departments. *Int J Exerc Sci*, *1*(3), 125-135
- Burns, R. D., & Brusseau, T. A. (2016). Muscular strength and endurance and cardio-metabolic health in disadvantaged Hispanic children from the U. S. *Prev Med Rep*, *5*, 21-26. doi: 10.1016/j.pmedr.2016.11.004
- Byrne, N. M., Sainsbury, A., King, N. A., Hills, A. P., & Wood, R. E. (2017). Intermittent energy restriction improves weight loss efficiency in obese men: The MATADOR study. *Int J Obes*.
- Carroll, S., Cooke, C. B., & Butterly, R. J. (2000). Physical activity, cardiorespiratory fitness, and the primary components of blood viscosity. *Med Sci Sports Exerc*, *32*(2), 353-358.
- Cheuvront, S. N., Kenefick, R. W., Montain, S. J., & Sawka, M. N. (2010). Mechanisms of aerobic performance impairment with heat stress and dehydration. *Journal of applied physiology*, *109*(6), 1989-1995.
- Church, T. S., Kampert, J. B., Gibbons, L. W., Barlow, C. E., & Blair, S. N. (2001). Usefulness of cardiorespiratory fitness as a predictor of all-cause and cardiovascular disease mortality in men with systemic hypertension. *Med Sci Sports Exerc*, *88*, 652-656
- Dennison, K. J., Mullineaux, D. R., Yates, J. W., & Abel, M. G. (2012). The effect of fatigue and training status on firefighter performance. *The Journal of Strength & Conditioning Research*, *26*(4), 1101-1109.

- Dimri, G., Malhotra, M., Gupta, J. S., Kumar, T. S., & Arora, B. (1980). Alterations in aerobic-anaerobic proportions of metabolism during work in heat. *European journal of applied physiology and occupational physiology*, 45(1), 43-50.
- Dobson, M., Choi, B., Schnall, P. L., Wigger, E., Garcia-Rivas, J., Israel, L., & Baker, D. B. (2013). Exploring occupational and health behavioral causes of firefighter obesity: A qualitative study. *American journal of industrial medicine*, 56(7), 776-790.
- Dolezal, B. A., Barr, D., Boland, D. M., Smith, D. L., & Cooper, C. B. (2015). Validation of the firefighter WFI treadmill protocol for predicting vo2 max. *Occupational Medicine*, 65(2), 143-146. <https://doi.org/10.1093/oc-cmed/kqu189>
- Donovan, R., Nelson, T., Peel, J., Lipsey, T., Voyles, W., & Israel, R. G. (2009). Cardiorespiratory fitness and the metabolic syndrome in firefighters. *Occupational medicine*, 59(7), 487-492.
- Drew-Nord, D. C., Myers, J., Nord, S. R., Oka, R. K., Hong, O., & Froelicher, E. S. (2011). Accuracy of peak vo2 assessment in career firefighters. *J Occup Med Toxicol* 6(25). <http://doi.org/10.1186/1745-6673-6-25>
- Earnest, C. P., Artero, E. G., Sui, X., Lee, D. C., Church, T. S., & Blair, S. N. (2013). Maximal estimated cardiorespiratory fitness, cardiometabolic risk factors, and metabolic syndrome in the aerobics center longitudinal study. *Mayo Clin Proc*, 88(3), 259-270. doi: 10.1016/j.mayocp.2012.11.006
- Eglin, C. M., Coles, S., & Tipton, M. J. (2004). Physiological responses of fire-fighter instructors during training exercises. *Ergonomics*, 47, 483-494.
- Ekblom, O., Ekblom-Bak, E., Rosengren, A., Hallsten, M., Bergstrom, G., & Borjesson, M. (2015). Cardiorespiratory fitness, sedentary behavior and physical activity are independently associated with the metabolic syndrome: Results from the SCAPIS pilot study. *PLoS One*, 10(6).
- Fabio, A., Ta, M., Strotmeyer, S., Li, W., & Schmidt, E. (2002). Incident-level risk factors for firefighter injuries at structural fires. *J Occup Environ Med*, 44, 1059-1063. doi: 10.1097/00043764-200211000-00012
- Fahs, C. A., Smith D. L., Horn, G. P., Aglovlasis, S., Rossow, L. M., Echols, G., ... Fernhall, B. (2009). Impact of excess body weight on arterial structure, function, and blood pressure in firefighters. *American Journal of Cardiology*, 104(10), 1441-1445. doi: 10.1016/j.amjcard.2009.07.009
- Fahy, R., & LeBlanc, P. (2003). On-duty deaths 2002. *National Fire Protection Association Journal*, 97, 56-63.

- Farioli, A., Christophi, C. A., Quarta, C. C., & Kales, S. N. (2015). Incidence of sudden cardiac death in a young active population. *Journal of the American Heart Association*, 4(6). doi: 10.1161/JAHA.115.001818
- Faris, M. A., Kacimi, S., Al-Kurd, R. A., Fararjeh, M. A., Bustanji, Y. K., Mohammad, M. K., & Salem, M. L. (2012). Intermittent fasting during Ramadan attenuates proinflammatory cytokines and immune cells in health subjects. *Nutr Res*, 32, 947-955. doi: 10.1016/j.nutres.2012.06.021
- Ford, A. L., Hunt, L. P., Cooper, A., & Shield, J. P. H. (2009). What reduction in BMI SDS is required in obese adolescents to improve body composition and cardiometabolic health? *Arch Dis Child*, 95, 256-261. doi: 10.1136/adc.2009.165340
- Froelicher, V. F., & Myers, J. (2006). *Exercise and the heart* (5th ed.). Philadelphia: Saunders Elsevier.
- Garver, J. N., Jankovitz, K. Z., Danks, J. M., Fittz, A. A., Smith, H. S., & Davis, S. C. (2005). Physical fitness of an industrial fire department vs a municipal fire department. *Journal of Strength and Conditioning Research*, 19(2), 310-317
- Gavhed, D. C., & Holmér, I. (1989). Thermoregulatory responses of firemen to exercise in the heat. *European journal of applied physiology and occupational physiology*, 59(1-2), 115-122.
- Gledhill, N., & Jamnik, V. (1992). Characterization of the physical demands of firefighting. *Canadian journal of sport sciences= Journal canadine des sciences du sport*, 17(3), 207-213.
- Go, A. S., Mozaffarian, D., Roger, V. L., Benjamin, E. J., Berry, J. D., Blaha, M. J., Dai, S., Ford, E. S., & Fox, C. S. (2014). Heart disease and stroke statistics—2014 update: a report from the American Heart Association. *circulation*, 129(3), e28.
- Gordon, H., & Larivière, M. (2014). Physical and psychological determinants of injury in Ontario forest firefighters. *Occupational medicine*, 64(8), 583-588.
- Guo, F., Moellering, D. R., & Garvey, W. T. (2013). The progression of cardiometabolic disease: Validation of a new cardiometabolic disease staging system applicable to obesity. *Obesity*, 22(1), 110-118. doi: 10.1002/oby.20585
- Haddock, C. K., Day, R. S., Poston, W. S., Jahnke, S. A., & Jitnarin, N. (2015). Alcohol use and caloric intake from alcohol in a national cohort of U.S. career firefighters. *J Stud Alcohol Drugs*, 76(3), 360-366.

- Harris, L., McGarty, A., Hutchison, L., Ells, L., & Hankey, C. (2018). Short-term intermittent energy restriction interventions for weight management: A systematic review and meta-analysis. *Obes Rev Off J Int Assoc Study Obes*, *19*, 1-13.
- Harvie, M. N., Pegington, M., Mattson, M. P., Frystyk, J., Dillon, B., Evans, G., Cuzick, J., ...Howell, A. (2011). The effects of intermittent or continuous energy restriction on weight loss and metabolic disease risk markers: A randomized trial in young overweight women. *Int J Obes*, *35*(5), 714-727. doi: 10.1038/ijo.2010.171
- Heatherly, A. J., Killen, L. G., Smith, A. F., Waldman, H. S., Hollingsworth, A., Seltmann, C. L., & O'Neal, E. K. (2017). Effects of ad libitum Low Carbohydrate High-Fat Dieting in Middle-Age Male Runners. *Medicine and science in sports and exercise*.
- Hess, P. L., Al-Khalidi, H. R., Friedman, D. J., Mulder, H., Kucharska-Newton, A., Rosamond, W. R., Lopes, R. D., ... Al-Khatib, S. M. (2017). The metabolic syndrome and risk of sudden cardiac death: The atherosclerosis risk in communities' study. *J Am Heart Assoc*, *6*(8). doi: 10.1161/JAHA.117.006103
- Heyn, P. C., Tagawa, A., Pan, Z., Thomas, S., & Carollo, J. J. (2019). Prevalence of metabolic syndrome and cardiovascular disease risk factors in adults with cerebral palsy. *Developmental Medicine & Child Neurology*. doi: 10.1111/dmcn.14148
- Hruby, A., & Hu, F. B. (2015). The epidemiology of obesity: A big picture. *Pharmacoeconomics*, *33*(7), 673-689. <http://doi.org/10.1007/s40273-014-0243-x>
- Huang, C. J., McAllister, M. J., Slusher, A. L., Webb, H. E., Mock, J. T., Acevedo, E. O. (2015). Obesity-related oxidative stress: The impact of physical activity and diet manipulation. *Sports Medicine*, *1*(32). <https://doi.org/10.1186/s40798-015-0031-y>
- Hubert, H. B., Feinleib, M., McNamara, P. M., & Castelli, W. P. (1983). Obesity as an independent risk factor for cardiovascular disease: A 26-year follow-up of participants in the Framingham heart study. *Circulation*, *67*, 968-977. <http://doi.org/10.1161/01.CIR.67.5.968>
- Jokinen, E. (2015). Obesity and cardiovascular disease. *Minerva Pediatr*, *67*(1), 25-32.
- Jurca, R., Lamonte, M. J., Barlow, C. E., Kampert, J. B., Church, T. S., & Blair, S. N. (2005). Association of muscular strength with incidence of metabolic syndrome in men. *Med Sci Sports Exerc*, *37*(12), 5107-5112.
- Karli, U., Guvenc, A., Aslan, A., Hazir, T., & Acikada, C. (2007). Influence of Ramadan fasting on anaerobic performance and recovery following short time high intensity exercise. *Journal of Sports Science & Medicine*, *6*(4), 490-497.

- Kelley, E., Imboden, M. T., Harber, M. P., Finch, H., Kaminsky, L. A., & Whaley, M. H. (2018). Cardiorespiratory fitness is inversely associated with clustering of metabolic syndrome risk factors: The ball state adult fitness program longitudinal lifestyle study. *Mayo Clin Proc Innov Qual Outcomes*, 2(2), 155-164. doi: 10.1016/j.mayocpiqo.2018.03001
- Klempel, M. C., Kroeger, C. M., & Varady, K. A. (2013). Alternate day fasting increases LDL particle size independently of dietary fat content in obese humans. *Eur J Clin Nutr*, 67, 783-785. doi: 10.1038/ejcn.2013.83
- Klement, R. J., Frobel, T., Albers, T., Fikenzer, S., Prinzhausen, J., & Kämmerer, U. (2013). A pilot case study on the impact of a self-prescribed ketogenic diet on biochemical parameters and running performance in healthy and physically active individuals. *Nutrition and Medicine*, 1(1).
- Knaeps, S., Lefevre, J., Wijtzes, A., Charlier, R., Mertens, E., & Bourgois, J. G. (2016). Independent associations between sedentary time, moderate-to-vigorous physical activity, cardiorespiratory fitness and cardio-metabolic health: A cross-sectional study. *PLoS One*, 11(7). <http://doi.org/10.1371/journal.pone.0160166>
- Lee, J., Kim, S. U., & Kang, H. S. (2010). Low cardio/respiratory fitness as an independent predictor of metabolic syndrome in Korean young men. *Eur J Appl Physiol*, 108(4), 633-639.
- Lima-Silva, A. E., Bertuzzi, R. C., Pires, F. O., Gagliardi, J. F., Barros, R. V., Hammond, J., & Kiss, M. A. (2010). Relationship between training status and maximal fat oxidation rate. *J Sports Sci Med*, 9(1), 31-35.
- Maher, A. C., Akhtar, M., & Tarnopolsky, M. A. (2010). Men supplemented with 17beta-estradiol have increased beta-oxidation capacity in skeletal muscle. *Physiol Genomics*, 42(3), 342-347. doi: 10.1152/physiolgenomics.00016.2010
- Manore, M. M. (2015). Weight management for athletes and active individuals: A brief review. *Sports Med*, 45, 83-92.
- Maughan, R. J., Fallah, J., & Coyle, E. F. (2010). The effects of fasting on metabolism and performance. *British Journal of Sports Medicine*, 44(7), 490-494. doi:10.1136/bjism.2010.072181
- Mbanu, I., Wellenius, G. A., Mittleman, M. A., Peeples, L., Stallings, L. A., & Kales, S. N. (2007). Seasonality and coronary heart disease deaths in United States firefighters. *Chronobiol Int*, 24(4), 715-726. doi: 10.1080/07420520701535787

- McAllister, M. J., Pigg, B. L., Renteria, L. I., & McAllister, M. J. (2019). Time-restricted feeding improves markers of cardiometabolic health in physically active college-age men: A 4-week randomized pre-post pilot study. *Nutrition Research*. doi: 10.1016/j.nutres.2019.12.001
- Mendy, V. L., Vargas, R., Cannon-Smith, G., & Payton, M. (2017). Overweight, obesity, and extreme obesity among Mississippi adults, 2001-2010 and 2011-2015. *Preventing Chronic Disease, 14*. doi: 10.5888/pcd14.160554
- Mier, C. M., & Gibson, A. L. (2004). Evaluation of a treadmill test for predicting the aerobic capacity of firefighters. *Occup Med, 54*(6), 373-378. doi: 10.1093/occmed/kgh008
- Moro, T., Tinsley, G., Bianco, A., Marcolin, G., Pacelli, Q. F., Battaglia, G., Palma, A., ... Paoli, A. (2016). Effects of eight weeks of time-restricted feeding (16/8) on basal metabolism, maximal strength, body composition, inflammation, and cardiovascular risk factors in resistance-trained males. *Journal of Translational Medicine, 14*, 290. doi: 10.1186/s12967-016-1044-0
- Muoio, D. M., Leddy, J. J., Horvath, P. J., Awad, A. B., & Pendergast, D. R. (1994). Effect of dietary fat on metabolic adjustments to maximal vo2 and endurance in runners. *Medicine and Science in Sports and Exercise, 26*(1), 81-88.
- National Fire Protection Association. (2016a). *Protection association. Fourth needs assessment of the U. S. Fire Service. Conducted in 2015 and including comparisons to the 2001, 2005, and 2010 needs assessment surveys*. Quincy, MA: National Fire Protection Association, Fire Analysis and Research Division.
- Ng, M., Fleming, T., Robinson, M., Thomson, B., Graetz, N., Margono, C., ... Gakidou, E. (2014). Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: A systematic analysis for the global burden of disease study 2013. *The Lancet, 384*(9945), 766-781. [http://doi.org/10.1016/S0140-6736\(14\)60460-8](http://doi.org/10.1016/S0140-6736(14)60460-8)
- Nogueira, E. C., Porto, L. G. G., Nogueira, R. M., Wagner, M. R., Fonseca, Lunardi, C. C., & Oliverira, R. J. (2016). Body composition is strongly associated with cardiorespiratory fitness in a large Brazilian military firefighter cohort: The Brazilian firefighter study. *Journal of Strength and Conditioning Research, 30*(1), 33-38. doi: 10.1519/JSC.0000000000001039
- Ogden, C. L., Carroll, M. D., Fryar, C. D., & Flegal, K. M. (2015). Prevalence of obesity among adults and youth: United States, 2011-2014. *NCHS Data Brief, 219*, 1-8.
- Ortega, F. B., Silventoinen, K., Tynelius, P., & Ramussen, F. (2012). Muscular strength in male adolescents and premature death: Cohort study of one million participants. *BMJ, 345*.

- Patterson, R. E., & Sears, D. D. (2017). Metabolic effects of intermittent fasting. *Annu Rev Nutr*, 37, 371-393. doi: 10.1146/annurev-nutr-071816-064634
- Pawlak, R., Clasey, J. L., Palmer, T., Symons, T. B., & Abel, M. G. (2015). The effect of a novel tactical training program on physical fitness and occupational performance in firefighters. *Journal of Strength and Conditioning Research*, 29(3), 578-588. doi: 10.1519/JSC.0000000000000663
- Poston, W. S., Haddock, C. K., Jahnke, S. A., Jitnarin, N., Tuley, B. C., & Kales, S. N. (2011). The prevalence of overweight, obesity, and substandard fitness in a population-based firefighter cohort. *J Occupl Environl Med*, 53(3), 266- 273
- Poston, W. S., Haddock, C. K., Jahnke, S. A., Jitnarin, N., & Day, R. S. (2013). An examination of the benefits of health promotion programs for the national fire service. *BMC Public Health*, 13, 805. doi:10.1186/1471-2458-13-805
- Roberts, C. K., Hevener, A. L., & Barnard, R. J. (2013). Metabolic syndrome and insulin resistance: Underlying causes and modifications by exercise training. *Comprehensive physiology*, 3(1), 1-58.
- Ruiz, J. R., Sui, X., & Lobelo, F. (2008). Association between muscular strength and mortality in men: Prospective cohort study. *Br J Sports Med*, 337.
- Ruiz, J. R., Sui, X., & Lobelo, F. (2008). Muscular strength and adiposity as predictors of adulthood cancer mortality in men. *Cancer Epidemiology Biomarkers Prev*, 18, 1468-1476.
- Sandbakk, S. B., Nauman, J., & Zisko, N. (2016). Sedentary time, cardiorespiratory fitness, and cardiovascular risk factor clustering in older adults – the generation 100 study. *Mayo Clin Proc*, 91(11), 1525-1534.
- Scharhag-Rosenberger, F., Meyer, T., Walitzek, S., & Kindermann, W. (2010). Effects of one-year aerobic endurance training on resting metabolic rate and exercise fat oxidation in previously untrained men and women. Metabolic endurance training adaptations. *Int J Sports Med*, 31(7), 498-504. doi: 10.1055/s-0030-1249621
- Sen, S., Palmieri, T., & Greenhalgh, D. (2016). Cardiac fatalities in firefighters: An analysis of the U.S. Fire Administration Database. *Journal of Burn Care & Research*, 37(3), 191-195. doi: 10.1097/BCR.0000000000000225
- Siddall, A. G., Stevenson, R. D. M., Turner, P. J. F., & Bilzon, J. L. J. (2018). Physical and physiological performance determinants of a firefighter simulation test. *Journal of Occupational and Environmental Medicine*, 60(7), 637-643. doi: 10.1097/JOM.0000000000001313

- Smith, D. L. (2011). Firefighter fitness: improving performance and preventing injuries and fatalities. *Current sports medicine reports*, 10(3), 167-172.
- Soteriades, E. S., Smith, D. L., Tsismenakis, A. J., Baur, D. M., & Kales, S. N. (2011). Cardiovascular disease in US firefighters: a systematic review. *Cardiology in review*, 19(4), 202-215.
- Sothmann, M. S., Saupe, K. W., Jasenof, D., Blaney, J., Fuhrman, S. D., Woulfe, T., Raven, P. B., ... Davis, P. O. (1990). Advancing age and the cardiorespiratory stress of fire suppression: Determining a minimum standard for aerobic fitness. *Journal of Human Performance*, 3(4).
http://doi.org/10.1207/s15327043hup0304_1
- Stevens, G. A., Singh, G. M., Lu, Y., Danaei, G., Lin, J. K., Finucane, M. M., Bahalim, A. N., ... Ezzati, M. (2012). National, regional, and global trends in adult overweight and obesity prevalence's. *Popul health Metr*, 10(1), 22. doi: 10.1186/1478-7954-10-22
- Storer, T. W., Dolezal, B. A., Abrazado, M. L., Smith, D. L., Batalin, M. A., Tseng, C. H., & Cooper, C. B. (2014). Firefighter health and fitness assessment: A call to action. *J Strength Cond Res*, 28(3), 661-671. doi: 1519/JSC.0b013e31829b54da
- Tanasescu, M., Leitzmann, M. F., Rimm, E. B., Willett, W. C., Stampfer, M. J., & Hu, F. B. (2002). Exercise type and intensity in relation to coronary heart disease in men. *JAMA*, 288(16), 1994-2000.
- Thomas, T. R., Feiock, C. W., & Araujo, J. (1989). Metabolic responses associated with four modes of prolonged exercise. *J Sports Med Phys Fitness*, 29, 77-82.
- Tinsley, G. M., Forsse, J. S., Butler, N. K., Paoli, A., Bane, A. A., La Bounty, P. M., Morgan, G. B., & Grandjean, P. W. (2017). Time-restricted feeding in young men performing resistance training: A randomized controlled trail. *European Journal of Sports Science*, 17(2), 200-207. <http://doi.org/10.1080/17461391.2016.1223173>
- Tinsley, G. M., & La Bounty, P. M. (2015). Effects of intermittent fasting on body composition and clinical health markers in humans. *Nutrition Reviews*, 73(10), 661-674. doi: 10.1093/nutrit/nuv041
- Trepanowski, J. F., Kroeger, C. M., Barnosky, A., Klempel, M. C., Bhutani, S., Hoddy, K. K., Gabel, K., ... Varady, K. A. (2017). Effects of alternate day fasting on weight loss, weight maintenance, and cardio protection among metabolically healthy obese adult: A randomized clinical trial. *JAMA intern Med*, 177, 930-938.

- Trepanowski, J. F., Kroeger, C. M., Barnosky, A., Klempel, M. C., Bhutani, S., Hoddy, K. K., Rood, J., ... Varady, K. A. (2017). Effects of alternate-day fasting or daily calorie restriction on body composition, fat distribution, and circulating adipokines: Secondary analysis of a randomized controlled trial. *Clin Nutr*, *37*, 1871-1878.
- Varady, K. A. (2011). Intermittent versus daily calorie restriction: Which diet regimen is more effective for weight loss? *Obes. Rev.*, *12*, 593-601. doi: 10.1111/j.1467-789x.2011.00873.x
- Varady, K. A., Bhutani, S., Church, E. C., & Klempel, M. C. Short-term modified alternate-day fasting: A novel dietary strategy for weight loss and cardioprotection in obese adults. *Am J Clin Nutr*, *90*, 1138-1143. doi: 10.3945/ajcn.2009.28380
- Varady, K. A., Bhutani, S., Klempel, M. C., & Lamarche, B. (2011). Improvements in LDL particle size and distribution by short-term alternate day modified fasting in obese adults. *Br J Nutr*, *105*, 580-583. doi: 10.1017/S0007114510003788
- Vasudevan, A. R., & Ballantyne, C. M. (2005). Cardiometabolic risk assessment: An Approach to the prevention of cardiovascular disease and diabetes mellitus. *Clin. Cornerstone* *7*, 7-16. doi: 10.1016/S1098-3597(05)80063-8
- Vincent, G. E., Jay, S. M., Sargent, C., Vandelanotte, C., Ridgers, N. D., & Ferguson, S. A. (2017). Improving cardiometabolic health with diet, physical activity, and breaking up sitting: What about sleep? *Front Physiol*, *8*, 865. doi: 10.3389/fphys.2017.00865
- Volek, J. S., Fernandez, M. L., Feinman, R. D., & Phinney, S. D. (2008). Dietary carbohydrate restriction induces a unique metabolic state positively affecting atherogenic dyslipidemia, fatty acid partitioning, and metabolic syndrome. *Progress in lipid research*, *47*(5), 307-318.
- Von Heimburg, E. D., Rasmussen, A. K., & Medbo, J. L. (2006). Physiological responses of firefighters and performance predictors during a simulated rescue of hospital patients. *Ergonomics*, *49*, 111-126.
- Waldman, H. S., Krings, B. M., Basham, S. A., Smith, J. E. W., Fountain, B. J., & McAllister, M. J. (2018). Effects of a 15-day low carbohydrate, high-fat diet in resistance trained men. *Journal of Strength & Conditioning Research*, *32*(11), 3103-3111. doi: 10.1519/JSC.0000000000002282
- Waldman, H. S., Renteria, L. I., & McAllister, M. J. (2019). Time-restricted feeding for the prevention of cardiometabolic diseases in high-stress occupations: A mechanistic review. *Nutrition Reviews*, *nuz090*. doi: 10.1093/nutrit/nuz090

- Washburn, A. E., LeBlanc, P. R., & Fahy, R. F. (1998). 1997 firefighter fatalities. *National Fire Protection Association Journal*, *92*, 50-62.
- Wijndaele, K., Orrow, G., Ekelund, U., Sharp, S. J., Brage, S., Griffin, S. J., & Simmons, R. K. (2014). Increasing objectively measured sedentary time increases clustered cardiometabolic risk: A 6-year analysis of the ProActive study. *Diabetologia*, *57*(2), 305-312. doi: 10.1007/s00125-013-3102-y
- Wildman, R. P., Muntner, P., Reynolds, K., McGinn, A. P., Raipathak, S., Wylie-Rosett, J., Sowers, M. R. (2008). The obese without cardiometabolic risk factor clustering and the normal weight with cardio metabolic risk factor clustering: Prevalence and correlates of 2 phenotypes among the US population (NHANES 1999-2004). *Arch Intern Med*, *168*(15), 1617-1624. doi: 10.1001/archinte.168.15.1617
- Williams-Bell, F. M., Villar, R., Sharratt, M., & Hughson, R., L. (2009). Physiological demands of the firefighter candidate physical ability test. *Medicine and Science in Sports and Exercise*, *41*, 653-662. doi: 10.1249/MSS.0b013e31818ad117
- Williams, T. D., Toluoso, D. V., Fedewa, M. V., & Esco, M. R. (2017). Comparison of periodized and non-periodized resistance training on maximal strength: A meta-analysis. *Sports Medicine*, *47*(10), 2083-2100.
<http://doi.org.libproxy.txstate.edu/10.1007/s40279-017-0734-y>
- Williford, H. N., Duey, W. J., Olson, M. S., Howard, R., & Wang, N. (1999). Relationship between firefighting suppression tasks and physical fitness. *Ergonomics*, *42*(9), 1179-1186.
- Wilson, R. A., Deasy, W., Stathis, C. G., Hayes, A., & Cooke, M. B. (2018). Intermittent fasting with or without exercise prevents weight gain and improves lipids in diet-induced obese mice. *Nutrients*, *10*(3), 346. doi: 10.3390/nu10030346
- Wilson, J. M., Lowery, R. P., Roberts, M. D., Sharp, M. H., Joy, J. M., Shields, K. A., Partl, J., Volek, J. S., & D'Agostino, D. (2017). The Effects of Ketogenic Dieting on Body Composition, Strength, Power, and Hormonal Profiles in Resistance Training Males. *Journal of Strength and Conditioning Research*.
- Wilson, P. W., D'Agostino, R. B., Sullivan, L., Parise, H., & Kannel, W. B. (2002). Overweight and obesity as determinants of cardiovascular risk: The Framingham experience. *Arch Intern Med*, *162*(16), 1867-1872.
- Yang, J., Christophi, C. A., Farioli, A., Baur, D. M., Moffatt, S., Zollinger, T. W., & Kales, S. N. (2019). Capacity and future cardiovascular events among active adult men. *JAMA*, *2*(2). doi: 10.1001/jamanetworkopen.2018.8341

- Yang, J., Farioli, A., Korre, M., & Kales, S. N. (2015). Dietary preferences and nutritional information needs among career firefighters in the United States. *Global advances in health and medicine, 4*(4), 16-23.
- Yang, J., Teehan, D., Farioli, A., Baur, D. M., Smith, D., & Kales, S. N. (2013). Sudden cardiac death among firefighters ≤ 45 years of age in the United States. *The American Journal of Cardiology, 112*(12), 1962-1967.
<http://doi.org/10.1016/j.amjcard.2013.08.029>
- Zuo, L., He, F., Tinsley, G. M., Pannell, B. K., Ward, E., & Arciero, P. J. (2016). Comparison of high-protein, intermittent fasting low-calorie diet and health healthy diet for vascular health of the obese. *Front Physiol, 29*(7). doi: 10.3389/fphys.2016.00350