EXAMINING THE RELATIONSHIP BETWEEN VO_2 AND BLOOD LIPIDS IN DENTON FIREFIGHTERS

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ABSTRACT

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The purpose of this study was to examine the relationship between VO_2 and various blood lipids in Denton firefighters and to evaluate the correlation of these indices with the risk of cardiovascular diseases. Around 200 firefighters participated in this study over 5 years. Participants' VO_2 and blood lipid profiles were evaluated. Statistical evaluation was conducted using SPSS. A Within Subjects *t*-test evaluated correlations between VO_2, DEXA, and blood parameters including low density lipoprotein (LDL), high density lipoprotein (HDL), triglycerides, and total cholesterol. Results indicate that over the 5-year period, total cholesterol, LDL cholesterol, and triglycerides increased significantly whereas HDL cholesterol saw a non-statistical increase. A decrease in VO_2 may be associated with and play a role in the significant increases in blood lipids. There was no consistent correlation with body mass index (BMI) as it was found that BMI does not appear to be good indicator of risk for cardiovascular diseases in these firefighters.

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CHAPTER I

INTRODUCTION

FIREFIGHTER'S CVD RISK EVALUATION

Although a firefighter's job requires high energy and a high level of fitness, in firefighter pre-tests and post-tests, they have found decreased ventilatory threshold, an increase in total and body fat mass, increased visceral fat, and increased blood lipids including total cholesterol and low-density lipoproteins (LDL).[1] These shifts increase the risk for cardiovascular disease (CVD).[1,2,3] When compared to the average adult male, elevated levels of LDL and lower high density lipoprotein (HDL) are more prevalent in firefighters.[2] The American College of Sports Medicine proposes that there is a protective factor tied to exercise that offers benefits in reducing the risk for cardiovascular disease that is associated with high LDL, high total cholesterol, decreased HDL, and increased triglyceride levels.[1]

Data from a 14-day test that included both male and female firefighters, found that they averaged 70 hrs of physical activity per week.[1] Results from a 5-month observational study found increased triglycerides and LDL cholesterol even when fire suppression activities were included as part of a firefighter's job. This may indicate that lifestyle factors other than information on diet were not accurately gathered.[1] Firefighting is considered one of the most physically demanding jobs among all emergency services. Thus, firefighters are always expected to stay physically fit.[1]

Firefighters typically tend to live an unhealthy lifestyle, which can be attributed to their knowledge related to health and wellness and the influence of their peers.[5] They report being physically inactive when they are off-duty and tend to consume unhealthy foods, though more details of their diet need to be elucidated.[5] When compared with other emergency service personnel, firefighters tend to have the lowest health and wellness knowledge with the highest

level of social stigma regarding seeking advice from professionals. As a result, firefighters are at an increased risk for cardiovascular disease. Though many firefighters hear about modifiable risk factors, they appear not to practice these in their day-to-day life or will give in to the pressure of their peers. The physical activity pattern of firefighters, their health knowledge, years of experience, age, and family history of CVD risk factors can predict their attitude about their specific exercise pattern.[5]

Based on body mass index (BMI), more than 75% of the firefighters are overweight with 40% identified as obese.[6] This high prevalence of overweight/obese results in a decline in physical activity levels and decreases their ability to perform their on-job duties.[1,2,6] The number one mortality cause in firefighters over the past 38 years has been cardiac death.[6] These cardiovascular events were also a major cause of early retirement. Vigorous physical activity (VPA) and waist circumference or WC are the main predictors of cardiorespiratory fitness (CRF). When a firefighter increases their time spent in VPA, they have a higher CRF.[6]

Non-modifiable risk factors for CVD include gender, age, and family medical history whereas the modifiable factors include high total cholesterol, high triglycerides, high blood pressure, diabetes, overweight, or obesity.[1,2] Generally, one's risk for cardiovascular disease increases with age. There is an increase in morbidity and mortality with increased cardiovascular risk factors.[6] Healthy People 2020 aimed to improve cardiovascular health by emphasizing modifying the risk factors. BMI is a common tool used to assess risk, as it relates body fat to obesity or overweight risk.[6] A firefighter's job requires them to face extreme cardiovascular stress, which is a concern when evaluating for their cardiovascular fitness. Thus, they are at an increased risk for cardiovascular mortality or morbidity.[6] Reducing the overall risk of cardiovascular events,

exercise, and weight reduction are the initial steps to increase HDL and decrease LDL, total cholesterol, and triglycerides.[2]

Obesity is an important risk factor increasing the cardiovascular risk in firefighters along with poor diet and lack of exercise. There is very little knowledge of the diet pattern of firefighters, but their exercise pattern can be assessed.

Diet

The standard American diet is characterized by the consumption of high amounts of sugary beverages and red meat.[3] Meat and meat-related products are an important part of the American diet. According to the US Department of Agriculture or USDA, a typical individual consumed around 100.8 kgs of red meat and poultry in 2018. Studies show that higher consumption of meat is associated with a 42% higher risk of having coronary heart disease or CHD and a 19% increased risk of getting diabetes.[3] The standard American diet is associated with an increase in LDL, total cholesterol, and a reduction in HDL levels.[3] These studies support that a diet high in saturated fats is associated with risks of CVD. These findings confirm and strengthen support for the Mediterranean diet and the negative relationship between the standard American diet and cardiovascular outcomes.[3]

Prevention and Health Promotion

Firefighters usually experience hypotension soon after exercise or heavy physical activities, elevated body temperatures during fire suppression, and reduced sub-endocardial viability ratios.[3] These increase the risk for obesity and hypertension, increasing the overall cardiovascular risk.[3] Firefighters tend to remove their breathing apparatus during and after fire suppression work resulting in exposure to significant levels of carbon monoxide, a factor known to contribute to myocardial hypoxia.[3]

Education is an accepted essential, helpful step in shifting people toward healthier behaviors that could be used to improve the health and well-being of firefighters.[4] Culturally relevant preventions and strategies have been at the forefront in the workplace and can be applied to fire departments as well.[4] The primary prevention health strategies should always be culturally relevant and aim to improve the overall wellness of those being educated.[4] More effort should be placed on cardiovascular modifiable factors such as weight loss and maintenance to achieve an ideal BMI, quitting smoking, increasing fitness by incorporating physical activity at minimum recommendations, and maintaining healthy eating habits that align with the current dietary guidelines.[4]

In 2010, the American Heart Association defined ideal cardiovascular health as the presence of four important health behaviors, which included non-smoking, having a normal BMI, a consistent diet, and incorporating physical activity as recommended. Other health factors including total cholesterol < 200 mg/dL, untreated blood pressure < 120/ 80 mm Hg, and fasting glucose < 100 mg/dL are considered important in preventing heart disease and promoting cardiovascular health.[4]

Approximately half of all deaths in firefighting are not directly linked to fire hazards but to CVD, primarily heart attacks or cerebrovascular events from exertion, and strain due to job activities.[5,6,7] Many studies support that exercise programs for firefighters may improve overall health and fitness and reduce the risk of cardiovascular events.[7] There are short as well as long-term improvements reported from engaging in physical activity for firefighters.[7] Fifty percent of firefighters report daily physical activity, which is below recommendations for those not exercising, whereby a lack of physical activities increases the risk for ischemic heart disease.[7] Ischemic heart disease is a term used to describe cardiac problems due to the narrowing of the

heart arteries whose main function is to supply blood to the heart.[7] Thus, there is an emerging health danger for firefighters especially those not participating in regular exercise.[7]

The goal for a firefighter would be to maintain high cardiorespiratory fitness to reduce the risk of cardiovascular events.[7,8] Chronic physical activity results in several benefits including improvements in cardiovascular health, reduced blood pressure, improved endothelial function, stabilized blood lipids, and improved insulin resistance and antioxidant status, which could reduce oxidative stress that can lead to inflammation.[8] Studies confirm that improved aerobic exercise capacity and cardiorespiratory fitness provide several benefits including decreased susceptibility to depression and cancer as well as cardiovascular risk factors including heart failure, hypertension, and coronary artery disease or CAD.[8] Data indicates that several differences exist between firefighters who engage in physical activity and those who do not.[8] Firefighters with higher CRF had lower cholesterol, insulin, triglycerides, LDL, C-reactive protein, LDL to HDL ratio, and body fat percentages and had higher levels of HDL when compared to a low fitness group.[8] In contrast, firefighters with low CRF had all the risk factors that increase the risk of CVD. Thus, firefighters need to be educated and encouraged to participate in behaviors that increase cardiovascular fitness and reduce on-duty events.[8]

When compared with sedentary clerks and police officers, firefighters had significantly higher levels of physical activity.[9] Police officers had the highest risk of cardiovascular events of all groups as many had metabolic syndrome, around 2.75% more body fat, lower HDL levels, and a higher WC.[9] Although firefighters have been shown to have a better health profile compared to police officers and sedentary clerks, there is no clear evidence that the altered CVD risk affords an overall health benefit or is derived from their on-duty activities, diet, and exercise patterns.[9] Increasing physical activity beneficially affects cardiorespiratory fitness where many favorable

effects have been recorded related to CVD profiles.[10] Physical activity has been proven to be beneficial regardless of the BMI.[10]A priority should be given to the frequency, duration, and intensity of the physical activity. Maintaining the CRF and improving physical activity should be a priority in the U.S. Fire Service.[10]

Researchers are lamenting the obesity epidemic in the U.S. and other Western nations and have recognized the health risks and costs associated with increasing obesity rates.[11] Although obesity is associated with CVD risk, obesity also increases the risk for osteoarthritis, work-related disabilities, sleep apnea, and diabetes.[11] Firefighters are more at risk for problems related to obesity-related conditions as on-the-job activities put them under additional stress that can trigger cardiac events.[11] Similar to the general population, firefighters have been reported to gain weight on average as they age.[11] Recent findings suggest that over time, about 12% of firefighters lost weight, 50% of firefighters gained weight, and around 38% of firefighters maintained their current weight.[11] Obesity is also associated with cardiomegaly, a disorder that increases the risk for sudden cardiac events.[11]

Typically, combined interventions are considered the most effective means to improve the cardiovascular health of emergency personnel, including firefighters. Thus, fire and other emergency agencies need to consider multiple intervention strategies and avoid solely focusing on one intervention like diet alone.[12] A program that evaluates blood profiles that reflect dietary behavior along with an assessment of strength and cardiac function would provide strong overall information on firefighter fitness and risk for heart disease.[12]

PURPOSE OF THE STUDY

This study will evaluate data associated with firefighter CVD risk that was collected as a part of a larger study that assessed firefighter fitness and possible changes in fitness over 5 years.

The measurements were collected in the Institute of Women's Health and the Speech, Language, and Hearing Clinic at Texas Woman's University. Participants answered questions on a standard Health Questions and performed physiologic assessments, which included a submaximal exercise test to estimate cardiorespiratory fitness, the electrical activity of the heart electrocardiograph (ECG), muscular strength, endurance, flexibility, lung function, body composition, bone density, vision, and hearing tests. Data from fasting blood samples were collected from each firefighter. Blood data and the results from physical evaluations over 4 years were evaluated. As an incentive to improve health, a firefighter could receive financial benefits based on the improvement or maintenance of a healthy performance.

A VO_2 test was used to estimate aerobic capacity, which measures the ability of the body to use oxygen and is a way to assess fitness. Heart responses were monitored through an ECG. Muscle endurance and strength tests determined strength, endurance, and flexibility. The pulmonary test evaluated lung function by spirometry. The test evaluates several parameters associated with lung, volume, and forced expiration. Body composition and BMI were determined by dual-energy x-ray absorptiometry (DXA). A standard blood test was used to identify blood glucose, total cholesterol, triglycerides, HDL, LDL, very low-density lipoproteins (VLDL), Hemoglobin A1C (HbA1C), Systolic blood pressure (BP), Diastolic BP and total cholesterol, HDL ratio. The DEXA scan was used to measure bone density and bone loss and evaluate body composition.

Data and Statistical A**nalysis**

Statistical evaluation was conducted through the use of SPSS. A Within Subjects *t*-test evaluated correlations between VO_2, and DEXA and blood parameters including LDL cholesterol, HDL cholesterol, triglycerides, and total cholesterol. A *t*-test was used for this study where the

means of the different groups were compared to check if they were statistically significant. A *t*-test is appropriate to use when a study has a random sample from a statistical "population" and used to compare the mean of the sample to another value. The independent variables of this study were time, VO_2, and BMI whereas the dependent variables were total cholesterol, LDL cholesterol, triglycerides, and HDL cholesterol. Paired samples t-test was used to compare the LDL cholesterol, total cholesterol, triglycerides, HDL cholesterol, BMI, and VO_2 values of each year with first year in Denton firefighters.

Expected Results

A healthy value for total cholesterol is considered to be less than 200 mg/dL, with LDL less than 100 mg/dL, triglycerides less than 150 mg/dL, and HDL greater than 40 mg/dL. A normal VO_2 range for people between 30-40 years of age is 31 ml oxygen/ kg of body weight/minute for women and 42 ml oxygen/kg of body weight/minute for men. A value above this would be considered at risk for metabolic and cardiovascular diseases. We expected to see a positive correlation between total cholesterol, triglycerides, LDL, and an inverse relationship between HDL that would correlate with their CRF as a reflection of their physical stress related to their job that contributes to a lower aerobic fitness as evidenced by low VO_2 score.

CHAPTER II

REVIEW OF THE LITERATURE

LITERATURE OVERVIEW

VO_2 max is the maximum amount of oxygen the body can use during any physical activity. It is the best indicator of aerobic or cardiorespiratory fitness. Improvement in aerobic endurance is directly proportional to the duration, intensity, and frequency of physical training. A study focusing on the relationship between high aerobic capacity vs low aerobic capacity on blood lipid levels of men hypothesized that high aerobic capacity in males would improve their blood lipid levels.

Seventeen non-smoking healthy males ranging from 20-30 years old, participated in a study evaluating the relationship between exercise and blood lipid profiles. The participants had not been involved in any physical activity 6 months prior taking part in the study. The participants were assigned randomly to the H group, the high-intensity exercise group, or the L group, the low-intensity exercise group. There were no dietary restrictions except for a 12-hour refrainment from exercise, food, or alcohol consumption before the blood draws. Both groups of participants rode on a peddle cycle ergometer at 50 rpm, 3 days per week, for 18 consecutive weeks. Each participant in the H group rode for around 25 mins at 80-85% VO_2 max whereas the L group did the activity for about 50 mins at 45% VO_2 max. Oxygen intake was measured using the indirect calorimetry method.

At the beginning of the study, both the high-intensity and the low-intensity groups had a caloric expenditure of 300 kcals and by the end of the study, the energy expenditure was about 350 kcals. By the end of the training, the heart rate for the high-intensity group during exercise was about 95-96% of max whereas the heart rate for the low-intensity groups was about 70-71%.

Before the training, after 3-weeks, and at the end of the study (18 weeks), the subjects had their blood drawn to measure total cholesterol, HDL, LDL, and triglycerides. During exercise and throughout the training period, heart rate was monitored continuously using an ECG. The participant's body density was measured using hydrostatic weighing.

After 18 weeks, both the high-intensity and low-intensity exercise groups had statistically significant increases in their aerobic capacity. The high-intensity training group increased VO_2 max by about 18.7% and 19.6% whereas the low-intensity training group increased by about 15.1% and 17.2%. The data on body composition showed that there were no statistical differences in body weight. There were statistically significant reductions in the percent body fat where the body fat loss for both the training groups was approximately 1.3 – 1.4 kilograms. There were no statistically significant changes in triglycerides, total cholesterol, HDL, and LDL, for both the high-intensity and the low-intensity exercise group. Though it was not statistically significant, there was a slight reduction in LDL cholesterol and total cholesterol levels, and a slight increase in HDL cholesterol.

Improvements in the VO_2 max in both the exercise training groups were compared to those using training intensities of greater than 50% of VO_2 max. The VO_2 max of the low-intensity groups improved their cardiovascular fitness, which could be attributable to an increase in heart rate by around 6-10 beats per minute (bpm). Results from this study concluded that the minimum threshold to improve cardiovascular fitness or aerobic capacity requires working at a minimum of 45% of VO_2 max, having training sessions of 50 min/session, and maintaining the exercise for at least 3 weeks. This combination will lead to a reduction of body fat mass and an increase in total lean mass following continuous training sessions.

The increased percentage of lean body mass can be the result of increased total blood volume. The main purpose of this study was to measure the impact of high and low-intensity

exercise on blood lipid levels. Though it was found that exercise intensity did not significantly impact blood lipids, there were changes in lipid values. The dietary habits of the participants were not analyzed during the study even though it is known that diet can impact lipoprotein levels. The participants reported that they did not try to change or alter their diet for exercise training. It has been noted that exercise does not alter nutrient intake or the ratio of any nutrients. Therefore, it is not likely that diet had any impact on the study results.[13]

Aerobic exercise is typically recommended to improve blood lipid levels and reduce the risk of CVDs. Elevated blood lipids are known to be a major risk factor for mortality and morbidity contributing to cardiovascular events. Though there have been several studies focused on the effect of aerobic exercise or exercise in general on blood lipid levels, these studies have been done primarily in adults rather than focusing on men. In a meta-analysis of studies that examined the impact of aerobic exercise on blood lipids in men, computerized sources including Medline, dissertation abstracts, and Sport Discus were evaluated. Apart from these sources, expert reviews of the current reference list and hand-searches were also done. The participant inclusion criteria included randomized controlled trials (RCT), men above 18 years of age, having been involved in aerobic activity for more than 8 weeks, and other studies published in various journals.

The lipoproteins assessed in the meta-analysis included HDL, LDL, total cholesterol, and triglycerides. Ninety-five percent confidence intervals were applied to the data sets. A total of 3,750 studies were evaluated for inclusion in the meta-analysis of which 59 were selected to meet the evaluation criteria. Of the 59 studies, 10 studies were excluded as blood lipid or lipoprotein data could not be retrieved. Of the final 49 studies, 29 were conducted in the United States, 3 in the United Kingdom, Finland and Switzerland, 2 in Canada, and 1 each in Denmark, New Zealand,

Nigeria, Sweden, Belgium, Israel, Netherlands, Germany and Slovenia. Forty-seven studies used a parallel group study whereas 2 used a crossover study design.

Ten of the studies analyzed the blood lipids in the supine position whereas 9 other studies assessed the participants in the sitting posture. Eight studies assessed the blood lipids and lipoproteins twice during each testing session. Participant fasting before assessment ranged from 10-14 hours.

The training mode was primarily jogging or a combination of jogging and walking. Around 20 groups across 12 studies used jogging as their main training mode whereas 20 other studies used a combination of both. Seven study groups used walking as their primary exercise whereas 1 group used stair climbing or cross-country skiing as their main activity. The 19 remaining studies used different combinations including cycling, swimming, calisthenics, stair climbing, jogging, walking, and gymnastics as their primary physical activity.

The results from this analysis found a significant reduction in triglycerides and total cholesterol as well as LDL cholesterol. Additionally, there was a significant increase in HDL cholesterol. These results were stable and significant for most of the studies analyzed, confirming the credibility of the data. Secondary outcome measures identified significant reductions in BMI body weight, and percent body fat and an increase in oxygen consumption.

Overall, this study suggested that aerobic activities help improve blood lipids and lipoproteins including HDL cholesterol, LDL cholesterol, total cholesterol, and triglycerides. The impact of exercise induced a significant beneficial impact on blood lipids in men. Many such studies have not been done exclusively on men thus it is unknown if it is true for the male population. Although the improvements were more significant for triglycerides with a reduction of 9%, total cholesterol decreased by 2%, and HDL cholesterol increased by 3%. These changes

would be beneficial in reducing the risk of cardiovascular diseases including CAD. To reduce the risk of CAD, a reduction of at least 1% in total cholesterol is effective. Triglycerides are independent risk factors for CAD though lowering it reduces CAD risk.

Lowering LDL cholesterol is an important target for lipid-improving therapies. In this study, there was no statistically significant reduction in LDL cholesterol induced by aerobic exercises though there was a 2% reduction observed. The reduction observed in this study would be biologically important as a 1% reduction in LDL cholesterol could reduce the cardiac risk by approximately 2%.

Results from this study suggest the need for future studies focusing on the effect of aerobic activity on lipoproteins and lipids in men that would include information on dropout, dietary components, drugs, race, ethnicity, tobacco use, alcohol, and history of physical activity and the time of blood draws post physical activity. Future studies should also concentrate on the dose-response relationship between aerobic activity and changes in blood lipids and lipoproteins including triglycerides, HDL, LDL, and total cholesterol.[14]

United States national recommendations for physical activity include walking as an important form of physical activity to maintain the health-related quality of life or HRQoL. The HRQoL identifies a person's mental and physical health. Its deterioration is seen in women associated with menopause. Studies indicate that the transition to menopause commonly leads to weight gain primarily as fat.

Women who engage in no to very low physical activity have a higher risk for developing hypertension, a risk factor for cardiovascular diseases and coronary artery disease. Nordic walking has increasingly become a form of exercise and a mode of rehabilitation. Nordic walking is designed to use poles mimicking cross-country skiing. This is considered an effective form of

exercise as it engages the upper body muscles increasing energy consumption and making it more efficient in energy use as compared to walking.[15]

A study evaluated the impact of moderate endurance activity on specific parameters related to general health and menopause.[15] A 12-week Nordic walking program evaluated its impact on health parameters including VO_2 max, blood levels of HDL cholesterol, LDL cholesterol, triglycerides, total fat mass, total cholesterol, BMI, and WC in menopausal, premenopausal, and postmenopausal women. The premenopausal women were grouped as having their menstrual cycle less frequently than every 60 days. The menopausal transition was grouped by a menstrual cycle of 60- 365 days. The postmenopausal women were grouped by having a last menstrual period that exceeded 365 days or a year before the exam.

One hundred and sixty-eight women participated in this study. The criteria for this research included age older than 30 years, being a non-smoker, and being in good health as confirmed by a general physician. The participants were divided into three groups: G1 being premenopausal, G2 for perimenopausal, and G3 being postmenopausal. The G1 group had 65 participants, whereas the G2 and G3 had 53 participants each.[15]

All participants in the study performed a 12-week Nordic walking program consisting of three 90-minute sessions per week. The average pulse rate was 100 –140 beats/min. As a part of the study, participants were to continue the same nutrient intake during the study and were advised not to increase their fat intake. Blood samples were collected and analyzed for triglycerides, total cholesterol, LDL cholesterol, and HDL cholesterol were stored as per the manual from the WHO and MONICA. The samples were evaluated within 3 hours of collection.

VO_2 max analysis indicated significant changes in all three groups from pre- to post-exercise. As a result of Nordic walking, there was an increased VO_2 max while there was a

decrease in VO_2 max associated with age. There was a significant decrease in BMI due to the training session for the study groups. There was also a significant increase in HDL cholesterol and a decrease in LDL cholesterol as a result of Nordic walking. The changes in HDL and LDL cholesterol contributed to a significant decrease in total cholesterol. Further WC and blood triglycerides also dropped after a 12-week Nordic walking program.

Total fat mass and BMI typically increase during the transition period from perimenopause to menopause although it is statistically insignificant. Incorporating Nordic walking as a part of daily routine led to a significant decrease in WC, total fat mass, BMI, LDL cholesterol, total cholesterol, and an increase in HDL cholesterol. The results indicate that Nordic walking is an excellent form of aerobic activity and is useful in preventing the risk of coronary heart disease and CVD in women. It was shown that appropriately chosen moderate endurance training led to a statistically significant increase in VO_2 max in premenopausal, perimenopausal, and postmenopausal women. The study indicates that Nordic walking combined with proper dietary and lifestyle habits would influence the HRQoL significantly in perimenopausal women.[15]

Among the different physical activities, aerobic exercise has gained importance in CVD prevention. Out of all forms of exercise, walking and running have been the most popular activities used for developing cardiovascular fitness. A study analyzed the effects of moderate to high-intensity aerobic exercise activities on blood lipid profiles of young healthy females in an 8-week study. [16]

In a study on 27 young women, the inclusion criteria included mean age of 20.5 years with no prior health issues and no orthopedic, neurological, or metabolic issues that might impact the study results.[16] The effect of aerobic activity on blood lipids was evaluated. This study was part of preparing the participants for a 4000 m cross-country run. The participants were informed to

maintain their regular dietary habits and lifestyle. Anthropometric, body composition and blood samples for the lipid levels were taken before and after the study. The training program for all participants was based on the running velocity of an initial run that measures and maximum heart rate values. The program lasted for 45 to 60 minutes performed 3 times weekly, including a 10-minute warm-up. Apart from the warm-up, the main exercise portion of the training had three activity zones. Zone 1 was a slow long-distance run lasting for about 45 minutes at 60-80% of heart rate max. Zone 2 was a 35–45-minute run at a heart rate of 81-90% max while zone 3 was a run with many intervals at a heart rate of 91-100%. The participants wore a Suunto belt heart rate monitor to control the training intensity. To initially assess the VO_2 max of the aerobic exercise, a 20-meter multistage shuttle run test was used. Blood HDL cholesterol, triglycerides, total cholesterol, LDL cholesterol, and total cholesterol/HDL ratio were evaluated. Blood draws occurred between 7 – 8 AM to avoid the effects of a circadian rhythm on blood lipid levels. The levels of HDL cholesterol, triglycerides, total cholesterol, and LDL cholesterol were all determined.[16]

Initial VO_2 max was around 43.9 ± 3.7 mL O_2/kg/min with a final value around 45.56 ± 3.63 mL O_2/kg/min. The running velocity and shuttle run increased by 8%.[16.]

Overall, total cholesterol did not change while other blood lipids did improve. LDL cholesterol levels were decreased from 2.52 to 2.27 mmol/L. HDL cholesterol increased from 1.29 to 1.59 mmol/L. The total cholesterol to HDL ratio significantly improved while plasma triglyceride levels also had a significant increase.[16]

The study concluded that an 8-week training program consisting of aerobic activity in young females will improve their blood lipids, their aerobic capacity, and their cardiovascular fitness, even while consuming a low-energy diet of around 1000 kcals/week.[16,17.] The increase in

TG was said to be due to the moderate and low duration exercise whereas high intensity and a longer duration would cause the TG to decrease about 50%. Thus, engaging in a high intensity and a longer duration training program would help the young females reduced their triglycerides.

A study focusing on the benefits of aerobic exercise on blood lipids and lipoproteins evaluated the impact of exercise in older adults. Most studies related to cardiovascular health have focused on middle-aged adults at risk for CVD. Older adults evaluated for the relationship between exercise and lipid profiles in a 12-week RCT with a follow-up. The participants were recruited from an elderly living community using exercise facilities. [18]

Thirty-two healthy Caucasian women between the age range of 67-85 years were recruited for this study of which 10 women were highly conditioned with an age range from 65-84 years. These conditioned elderly women were active in many sports competitions with endurance in various activities. They had been training for about 11.2 years and were used as the baseline for comparison. Sedentary individuals were randomly selected to participate in either walking or calisthenics, a type of strength training. The sedentary group exercised 5 days a week for 30-45 minutes per day for a total of 12-weeks. The walking group maintained their heart rate at 60% max while the calisthenic group maintained their heart rate close to normal or resting. LDL cholesterol, HDL cholesterol, triglycerides, total serum cholesterol, VO_2 max, dietary intake, and skinfold tests were evaluated at baseline, after 5-weeks, and after 12-weeks. With activity in the sedentary group, serum HDL cholesterol increased, and triglycerides decreased while there were no significant changes in total plasma cholesterol and LDL cholesterol. Overall, the 12-week aerobic exercise program had a positive impact on VO_2 max in the subjects with a 12.6% improvement but did not significantly impact energy intake, diet quality, body weight, or other blood lipids or lipoproteins.[18]

The benefits of exercise or aerobic activity to achieve cardiovascular endurance are not limited to healthy adults, or children but also have an important role in people with diabetes mellitus. People with type 2 diabetes are at increased risk for various chronic diseases including CVD. Other risk factors include increased abdominal fat stores, hypertension, hyperglycemia or high blood glucose levels, and dyslipidemia. Low-grade inflammation is typically seen in people with type 2 diabetes, which is attributed to adipocyte-derived interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF- α), and the CD163 or sCD163, which is a type of soluble haptoglobin receptor.

Aerobic exercise has many benefits for people with type 2 diabetes from improving body composition and weight to improving insulin sensitivity while reducing inflammation and blood lipids. Exercise intensity and duration play an important role in influencing blood lipid levels and systemic inflammation. In recent times, high-intensity interval training (HIIT) has been gaining popularity for its benefits on cardiovascular health. Although more people are choosing HIIT, moderate aerobic activity is the most common level of exercise.

Many studies have evaluated the benefits of HIIT and moderate continuous training (MCT); however, most were not RCTs or were short. Thus, the main aim of this study was to examine the impact of MCT combined with resistance training (RT), or HIIT with RT on the blood lipid levels and inflammatory levels. This study was a randomized control trial done for one year with a control group. The participant inclusion criteria were adults diagnosed with type 2 diabetes mellitus with an age range of 30-75 years with no major complications from diabetes and a BMI less than 48 kg/m^2. The researchers were blinded to assure participant randomization. The control group followed an instructed standard exercise with no specific ones. The other groups, the MCT and HIIT, had three physical activity sessions weekly and were monitored with a heart rate band. The exercise sessions of both groups were matched for their energy expenditure.

Both groups participated in their training session for 1 year in 3 phases. Heart rates were calculated using the Karvonen formula at allocated intensities. Phase 1 was identical for both groups with the participants cycling at a moderate intensity while increasing the duration from 15 to 25 minutes by the end of the session. The participants in the MCT group had an additional training phase where they exercised at 60% heart rate max. The HIIT training groups performed 2-minute cycling bouts at a heart rate of 70% max in phase 2 of the exercise training followed by exercising for a minute at a 60% heart rate max and then increasing to 80%. During phase 3, weeks 9 to 52, participants in the HIIT training group rode for 1 minute at a heart rate of 90% max followed by a resting phase at 60% max. Both groups then performed a whole-body strength training exercise after their aerobic exercises, which included chest press, seated row, leg press, shoulder press, leg lunge, and plank. [19,20]

Blood draws followed an overnight fast to analyze the serum blood lipids including triglycerides, LDL cholesterol, HDL cholesterol, and total cholesterol. Plasma inflammatory biomarkers including TNF- α, IL-6, sCD163, and C-reactive protein (CRP) were analyzed. Inflammatory and blood lipid profiles were examined at baseline and 1 year. Long-term HIIT activities with resistance training improved the LDL cholesterol, total cholesterol, and IL-6 in type 2 diabetes. MCT training resulted only in a change in IL-6 and did not impact the blood lipid profile. Overall, there was no difference in any of the inflammatory biomarkers between the moderate training with resistance training group versus the HIIT with resistance training group. Weight loss was associated with a decrease in TNF- α and IL-6 when compared to those who did not lose weight.

After a year of training at two different intensities, individuals with type 2 diabetes mellitus favorably benefited as plasma levels of IL-6 were reduced which would decrease systemic

inflammation. Only HIIT was effective in reducing LDL cholesterol and total cholesterol. HIIT would be a better choice than MCT if a type 2 diabetic wants to achieve the long-term benefits of affecting blood lipids and inflammatory biomarkers.[19,20.]

The effect of aerobic activity has been gaining popularity for reducing CVD across the population. Aerobic exercise is not only prescribed for healthy patients but also for people with a high risk for cardiovascular diseases. Exercise performed at high intensity is increasing in popularity as people are choosing it for its health benefits rather than moderate-intensity aerobic exercises. Although exercise at high intensity provides greater health benefits, these intensive activities could trigger sudden cardiac events and myocardial infarction in vulnerable people. Current research guidelines indicate that exercise programs for cardiac patients should target a heart rate of 50-90% max.

In a study focusing on the benefits of high vs moderate-intensity aerobic exercise on cardiovascular fitness in people with a higher risk of CVDs, 4846 participants exercised at a heart rate of around 85-95% max in both healthy and coronary heart disease participants. The participants were referred for cardiac exercise-based rehabilitation and were evaluated for 7 years. The average age was 57 years. Subjects had many different cardiac diagnoses including angioplasty, coronary heart surgery, myocardial infarction, and heart failure. High-intensity training was done at a heart rate of 85-95% max as interval training whereas the moderate-intensity training sessions were done at a heart rate of 60-70% max. All training sessions for both groups were 1 hour long. The exercise included biking, aerobic sessions, walking, cross-country, and treadmill running. There was a 10-minute warm-up before the exercise sessions, active pauses between the sessions, and a cool down all at 50-60% max heart rate.

The overall results of the study included a fatal cardiac arrest and two non-fatal cardiac events primarily in the high-intensity exercise training group. Results indicated that high and moderate exercise intensity decreases cardiac events.

It was found that there was a greater improvement in cardiac risk factors associated with high-intensity exercise training when compared to moderate-intensity exercise. Compared with the moderate exercise group, the high-intensity group, at a VO_2 max greater than 60%, had improved aerobic capacity, diastolic blood pressure, and blood glucose levels but there was no impact on blood lipid levels or systolic blood pressure. The study concluded that there was a dose-dependent effect in the high-intensity exercise group that may help improve cardiorespiratory fitness in patients with coronary heart disease or other cardiac conditions. The high-intensity training groups appeared to obtain greater cardiovascular benefits than the moderate-intensity training group.[21]

FIRST RESPONDER HEALTH

First responders have always been at increased risk for many chronic health diseases with cardiovascular disease being the most common. Most first responders have a busy lifestyle that includes stress at work, hectic work schedules, erratic, or a lack of sleep, all of which contribute to an increased risk for chronic health conditions. Contrary to what many believe, first responders have low levels of physical activity daily, which then becomes a risk factor. A study on 487 police officers evaluated the relationship between exercise and risk factors for CVD including blood pressure, total body fat percent, heart rate, WC, waist-to-hip ratio, and serum lipid levels of cholesterol, LDL cholesterol, HDL cholesterol, and triglycerides.

The research study was intended to examine the relationship between blood lipids and physical fitness in police officers. The belief was that there would be a positive and significant

inverse relationship between physical fitness levels and blood lipids including total and LDL cholesterol, triglycerides, and higher HDL cholesterol.

VO_2 was monitored via a treadmill test. The speed and grade of the treadmill gradually increased until the officer reached 85% of the predicted heart rate. Sit and reach measurements were useful to measure the hamstring flexibility. Upper-body muscle capacity was examined by push-ups where participants did push-ups until they were tired or could not move forward. Vertical jumps were used to measure lower-body muscle power. Grip strength was measured with a grip dynamometer. The grip strength was taken for both hands as a measurement of the upper body strength. A 60-second sit-up test measured abdominal muscular endurance. A single-repetition maximum bench press was used to measure relative and absolute upper body strength.

Initially, 140 police officers had improved total cholesterol with time whereas 66 officers had very high total cholesterol. The number of officers with elevated LDL cholesterol remained steady throughout evaluation with only 30% in those at desirable levels. Those with desirable HDL cholesterol improved for the study while those with low HDL cholesterol remained steady. While the number of participants with normal and high triglycerides remained stable over 1 year, the number with very high triglycerides dropped by 90%.[21]

There was a significant positive relationship between HDL cholesterol, VO_2, hand grip strength, push-ups, and bench press in male officers. The female police officers had a significant relationship between sit-ups and HDL cholesterol. HDL cholesterol increased as VO_2 max levels increased. There were also negative significant correlations between the VO_2 max, sit-ups, and triglycerides in male officers while the female officers had a negative relationship between triglycerides and VO_2 max, hand-grip strength. These correlations suggest that the higher the VO_2 max, sit-ups, and hand grip strength, the lower blood triglyceride levels in male and female police

officers. Aerobic activity along with resistance training exercises should be considered an important part of cardiovascular fitness targeted at reducing blood lipid levels and improving overall cardiorespiratory health in first responders and the general public. Along with physical activity, dietary and lifestyle changes should also be incorporated by police officers to help them respond to stressors that may impact their health.[21]

Like other first responders, firefighters also experience stress that when coupled with a lack of sufficient physical activity, poor dietary and lifestyle choices, long work hours, and lack of sleep may negatively impact their health both short- and long-term. As CVD is the top concern for firefighters, wellness and fitness programs need to promote health. Around 39% of cardiovascular deaths in firefighters are attributable to coronary heart disease. Risk factors commonly seen in firefighters include hypertension and smoking. The goal of this study was to evaluate changes in cardiorespiratory fitness following aerobic training sessions in firefighters.[22]

Forty firefighters serving for 15 years or more were recruited to participate in this study. Participants were divided into two groups: A and B. The A group received aerobic walking training for 3 months, 4 times weekly. Group B was trained anaerobically for 3 months, with 2 sessions per week. Blood pressure, VO_2 max, and heart rate were measured before the training sessions. The Bruce protocol was used to identify their VO_2 max. The other variables measured before the study for both groups included systolic and diastolic blood pressure, minute ventilation, and heart rate.[22]

The average mean blood pressure and heart rate values were decreased significantly whereas the minute ventilation and VO_2 max were increased significantly in the A group after the training session. In group B, the heart rate and blood pressure changes were not statistically significant but VO_2 max and minute ventilation increased significantly after training. There was

significant improvement in systolic and diastolic blood pressure, heart rate, and minute ventilation in group A with no change in group B.[22]

Overall, this study indicates that aerobic training can improve CRF in firefighters. Though anaerobic exercises tend to be beneficial, no statistical significance was found on these variables when compared to the aerobic training group. Aerobic activities are less difficult to perform and can be performed frequently compared to anaerobic excercise.[22]

HYPOTHESIS

A low VO_2 will be associated with high blood triglycerides, LDL, total cholesterol, and low HDL cholesterol, increasing overall risk for CVDs.

CHAPTER III

METHODS AND MATERIALS

STUDY METHODS

The clinical portion of the study was done in the Institute for Women's Health in the Woodcock Building at Texas Woman's University. This study was approved by the Institutional Review Board at Texas Woman's University- Denton (Protocol #19799), and informed consent was signed by all participants.

Participants

Over 5 years, 215 participants were recruited from the Denton Fire Department. The participants consisted of men and women ranging in age from 20-56 years. Participation in this study was voluntary and each participant had the right to withdraw from the study at any time without penalty. If individual results were found to be less than satisfactory, the participants would be recommended for nutrition counseling or exercise to improve their fitness level or nutritional status without impacting their employment. They were asked to complete a health history questionnaire, a demographic questionnaire, and a customer satisfaction survey. These questionnaires took approximately 15 minutes to complete. The purpose of the health history questionnaire was to identify individuals requiring physician clearance before participation. The medical history questionnaire was used to optimize safety during exercise testing and participation in the program. The demographic questionnaire was used to characterize the participants in the program. The customer satisfaction survey assessed any problems or concerns the participants may have had. The responses from this survey were used to make necessary changes to improve the program.

STUDY DESIGN

The total time for all testing to be completed was approximately 2-4 hours. All the test procedures were conducted as per the criteria established by the American College of Sports Medicine for medical examination, physician supervision, and exercise testing and prescription. The National Fire Protection Association Standard on Comprehensive Occupational Medical Programs for Fire Departments 2018 states that when evaluations for body composition, aerobic capacity, muscular strength, endurance, and flexibility are evaluated in one sitting, the following sequence of testing should be followed: 1. body composition, 2. aerobic capacity, 3. muscular strength, 4. muscular endurance, and 5. flexibility. In addition to these tests, hearing, vision, and lung function were assessed. They were allowed to sign up for optional assessments for resting metabolism, power tests, blood sample collection, and nutritional analyses.

Participant Testing

During the VO_2 test or the treadmill test, an ECG was in place while on the treadmill. A 10-lead ECG was attached to the body and used to detect any irregularities in the heartbeat. BP was recorded before and after the exercise. The test started with a 3-minute warm-up, which was done at low speed with no incline. After the warm-up, the speed and the incline alternating were increased each minute. The test continued until the participants completed 10 minutes or stopped when they believed they could not continue. The participants were instructed to push the stop button on the treadmill anytime they felt they could not continue. During the test, the participants were asked to rate how they felt on a scale from 1 to 20. The numbers were recorded each minute along with the heart rate at the end of the test. After the exercise was done, there was a 3-minute cool-down where they would run on the treadmill at the lowest speed with no incline to reduce the

risk of muscle cramps and lactate build-up in the muscles. The final ECG was provided to each participant.

The participant's wellness checkup was done by a nurse practitioner who conducted a mini-health assessment. The participants previously provided fasting blood tests that included hemoglobin, hematocrit, platelets, RBC, WBC, total cholesterol, HDL cholesterol, LDL cholesterol, and triglycerides, along with other measurements. The lab results were collected and kept with the participant's records. A DEXA was used to measure the body composition of the firefighter. The DEXA scan works by sending x-rays to the bones and other tissues. Typically, the soft tissues and bones absorb the signals differently which can be used to differentiate body fat mass, lean mass, and bone health in the body. The participants were to lie motionless on the DEXA machine for around 6-7 minutes while scanned to check and quantify their body fat mass, along with their risk for osteoporosis and bone loss.

DATA ANALYSIS

The IBM Statistical Package for the Social Sciences or SPSS was used for all statistical evaluation. Results are reported as the mean ± standard deviation. Results were deemed significant if the *p*-value was ≤ 0.05. Though many tests were performed, the ones evaluated here were VO_2, DEXA for body composition, and blood tests to measure LDL cholesterol, HDL cholesterol, total cholesterol, and triglycerides.

CHAPTER IV

RESULTS/DISCUSSION

STUDY RESULTS

The purpose of this study was to examine the relationship between VO_2 and blood lipids in Denton firefighters. The results of the statistical analysis of blood lipids from the samples follow in Tables 4.1-4.4:

Table 4.1. Effect of the Independent Variables VO_2 and BMI on LDL

Parameter	Estimate	*t* value	Std. Error	Sig Value
Time	2.833	3.472	.816	<.001
VO_2	-.240	-3.163	.076	.002
BMI	-.043	-.105	.410	.916

Following a minimum of a 10 hour fast, whole blood was isolated, and plasma was used for lipoprotein determination. LDL cholesterol concentration versus VO_2, time and BMI were compared.

Table 4.2. Effect of the Independent Variables VO_2 and BMI on Total Cholesterol

Parameter	Estimate	*t* value	Std. Error	Sig Value
Time	2.406	2.632	.914	.009
VO_2	-.264	-3.145	.084	.002
BMI	.079	.171	.079	.864

Following a minimum of a 10 hour fast, whole blood was isolated, and plasma was used for lipoprotein determination. Total cholesterol concentration versus VO_2, time and BMI were compared.

Table 4.3. Effect of the Independent Variables VO_2 and BMI on Blood Triglycerides

Parameter	Estimate	*t* value	Std. Error	Sig Value
Time	2.985	2.553	1.169	.011
VO_2	-.349	-3.181	.110	.002
BMI	2.520	4.138	.609	<.001

Following a minimum of a 10 hour fast, whole blood was isolated, and plasma was used for lipoprotein determination. Triglyceride concentration versus VO_2, time and BMI were compared.

Table 4.4. Effect of the Independent Variables VO_2 and BMI on HDL

Parameter	Estimates	*t* value	Std. Error	Sig Value
Time	.052	.222	.234	.825
VO_2	.028	1.247	.023	.213
BMI	-.411	-3.149	.130	.002

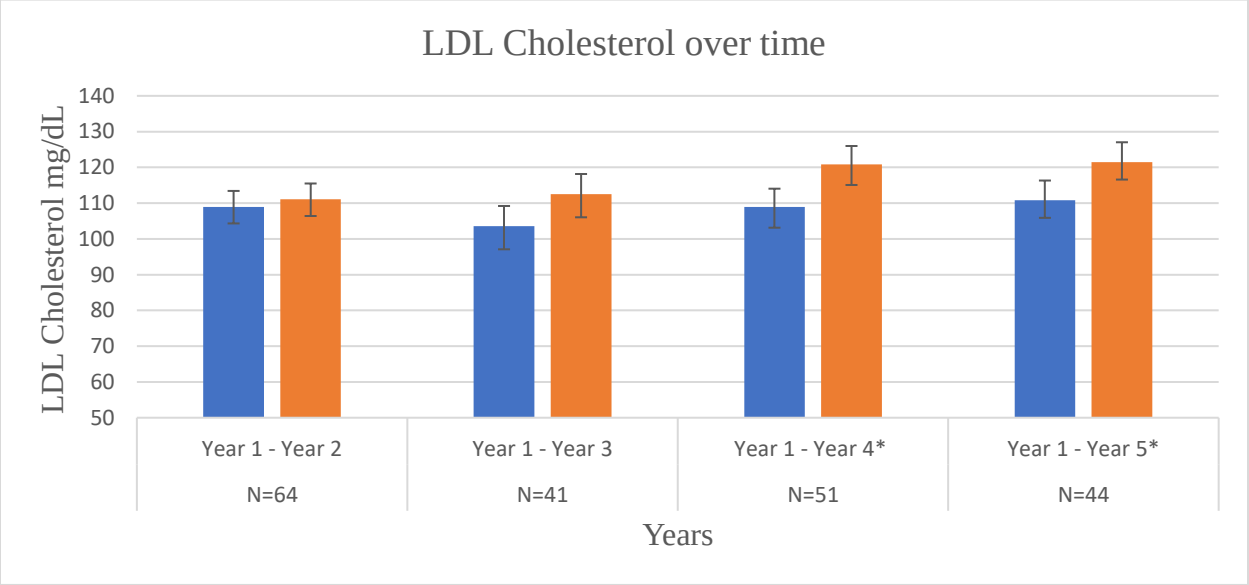
Following a minimum of a 10 hour fast, whole blood was isolated, and plasma was used for lipoprotein determination. HDL cholesterol concentration versus VO_2, time and BMI were compared.

Throughout evaluation, there was an increase in LDL levels (see Table 4.1) over 5 years. The *p*-value of time <.001 indicates a statistically significant increase of LDL over time. The estimate for the VO_2 at -.240 indicated that the VO_2 decrease, and blood LDL levels increase had a statistically significant correlation. The estimated value of BMI is -.043 indicates that as BMI increased, the LDL value decreased over time, though the change was not statistically significant with a *p*-value of .916. From Table 4.2, the estimate for the time at 2.406 indicates that over time, there was a statistically significant increase in the total blood cholesterol levels over 5 years with a value *p*-value of .009. VO_2 has an estimated value of -.264 indicating an inverse relationship whereas the VO_2 decreased, the total cholesterol increased at a statistically significant *p*-value of

<.002. The BMI estimate value of .079 indicated that as the BMI increased, the total cholesterol also increased, through with a *p*-value of .864, a change which was not statistically significant.

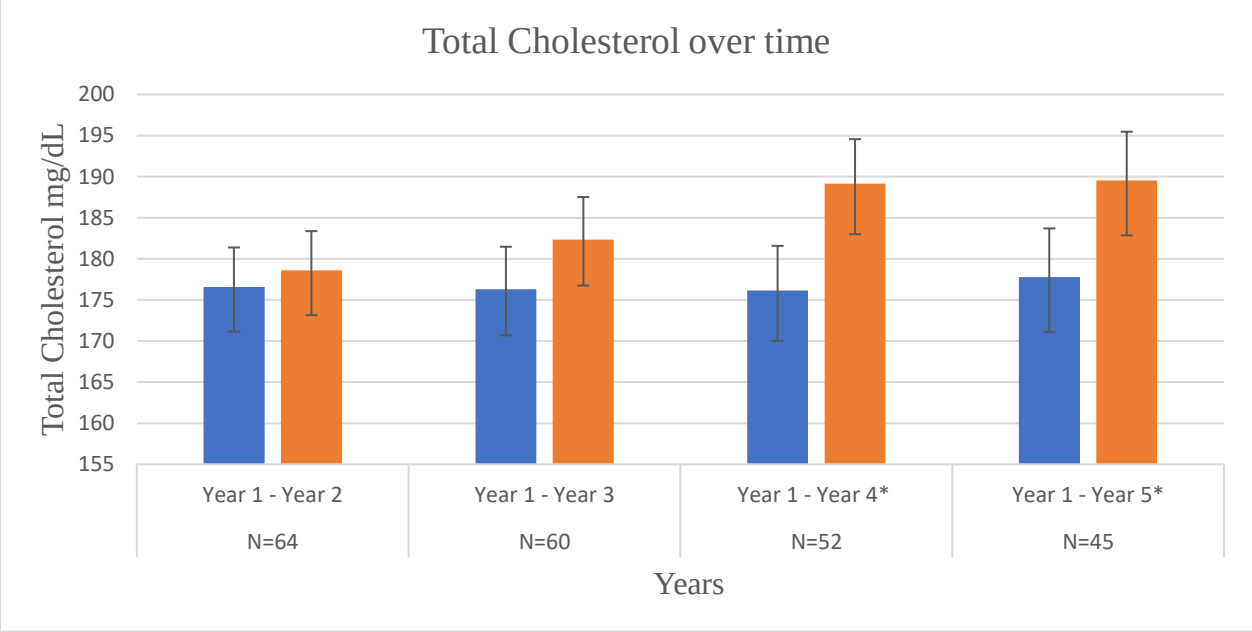
Table 4.3 data indicates that blood triglycerides increased over time with a *p*-value of <.011 indicating the level of statistical significance. The VO_2 had an estimate of -.349 indicating that the blood triglycerides increased as the VO_2 decreased with a statistically significant *p*-value of <.002. The BMI estimate of 2.520 indicated that as the BMI increased, blood triglycerides significantly increased with a *p*-value of <.001. The data in Table 4.4 indicated that though HDL blood levels improved over 5 years, with a *p*-value of .825, the change was not statistically significant. As VO_2 improved, the HDL cholesterol showed a statistically significant increase with a *p*-value of 0.213. With BMI increasing over time, HDL cholesterol levels decreased with the decrease being significant with a *p*-value <.0.002.

Figure 4.1. LDL Cholesterol Over Time



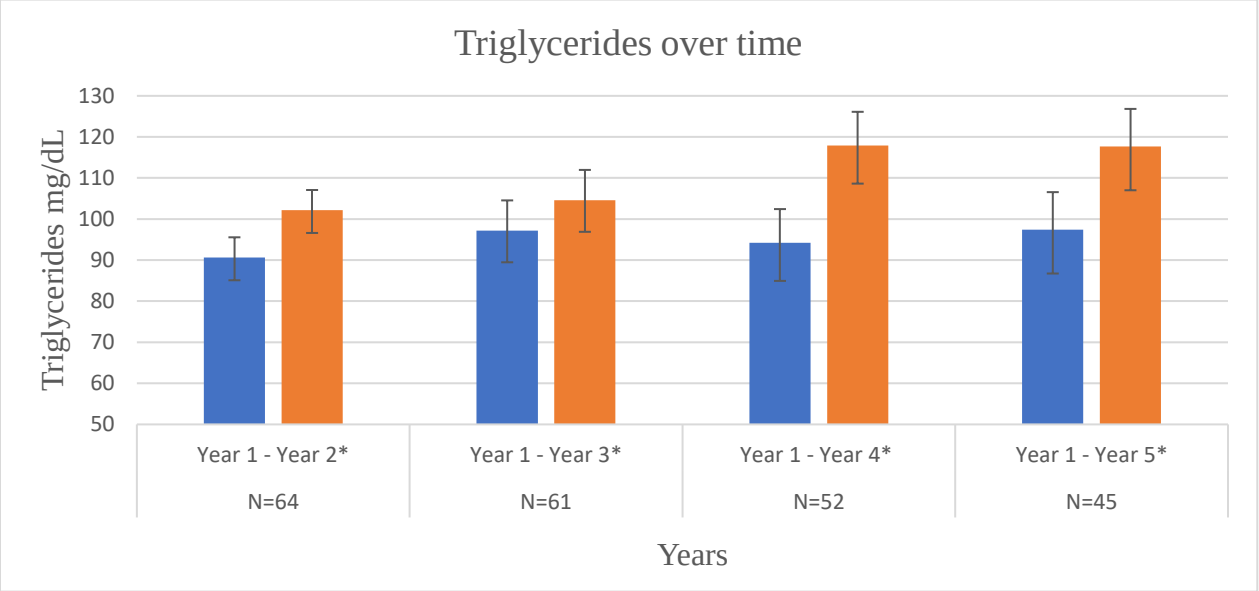
LDL Cholesterol over time. Fasting blood draws were done to analyze the LDL cholesterol concentration. Years indicated with * were statistically different than year 1 with $p \leq 0.05$.

Figure 4.2. Total Cholesterol Over Time



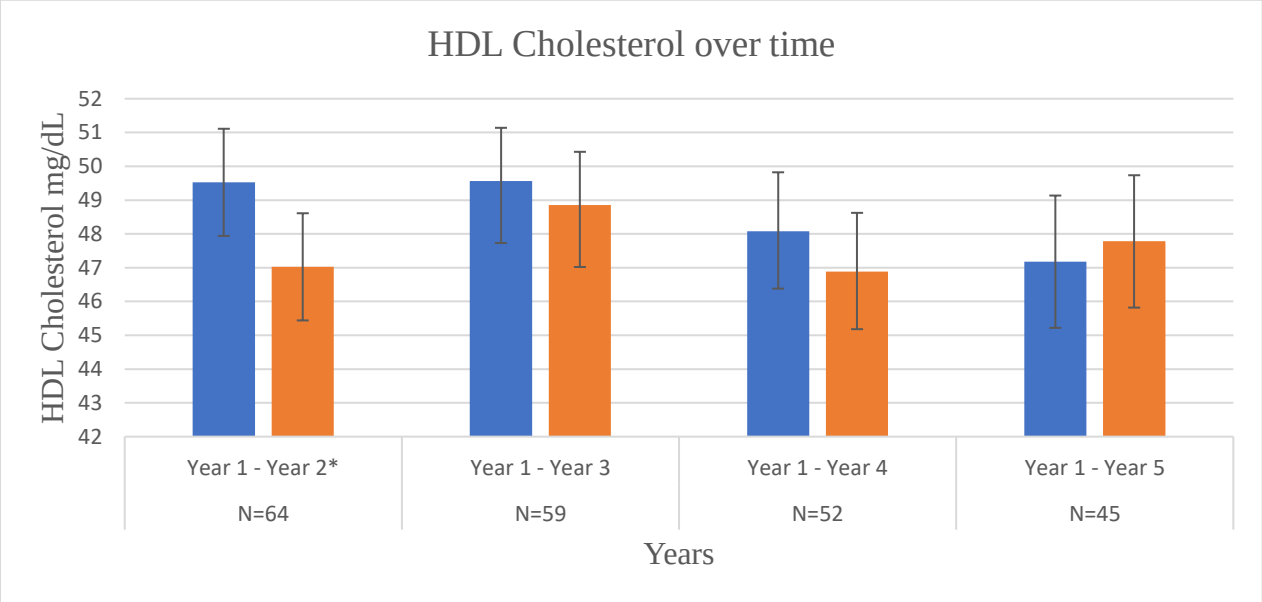
Total Cholesterol over time. Fasting blood draws were done to analyze the total cholesterol concentration. Years indicated with * were statistically different than year 1 with $p \leq 0.05$.

Figure 4.3. Triglycerides Over Time



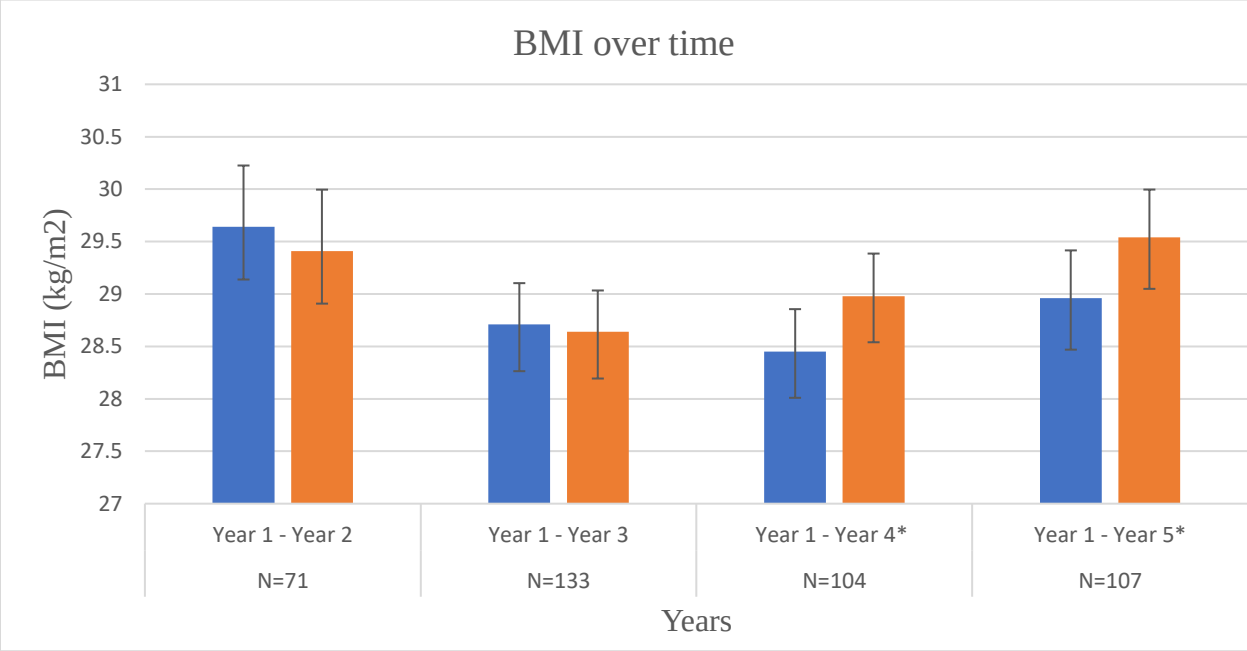
Triglycerides over time. Fasting blood draws were done to analyze the triglycerides concentration. Years indicated with * were statistically different than year 1 with $p \leq 0.05$.

Figure 4.4. HDL Cholesterol Over Time



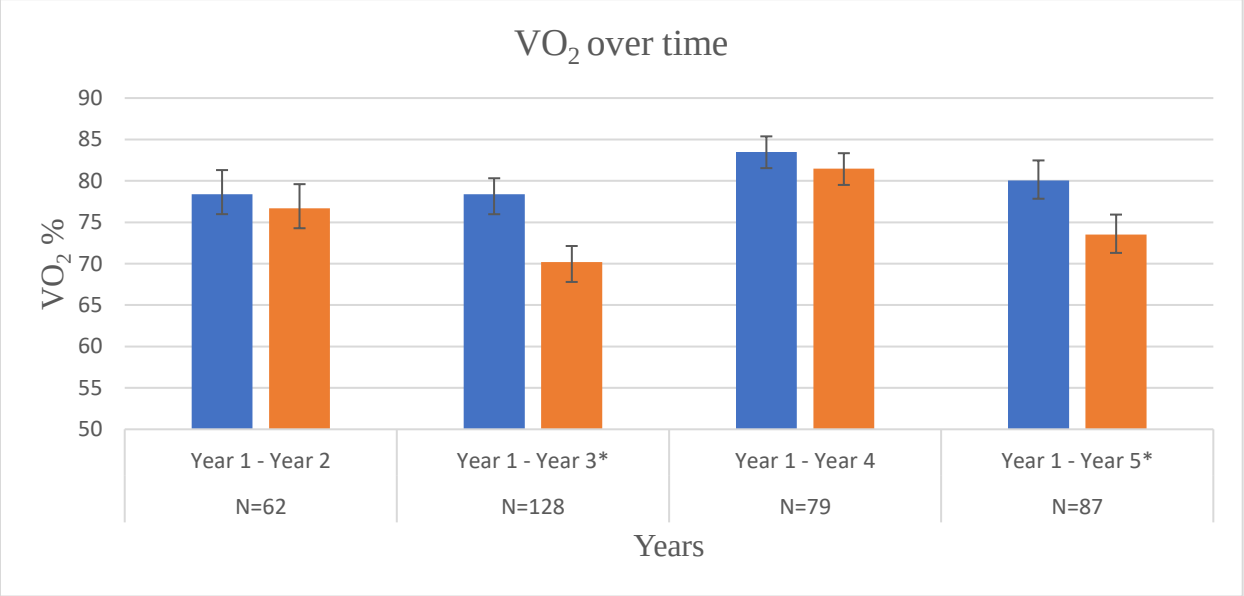
HDL Cholesterol over time. Fasting blood draws were done to analyze the HDL cholesterol concentration. Years indicated with * were statistically different than year 1 with $p \leq 0.05$.

Figure 4.5. BMI Over Time



BMI over time. BMI was calculated. Years indicated with * were statistically different than year 1 with $p \leq 0.05$.

Figure 4.6. VO_2 Over Time



VO_2 over time. A treadmill test with a steady increase in speed or incline was used to calculate VO_2. Years indicated with * were statistically different than year 1 with $p \leq 0.05$.

Figures above reflect changes in blood lipids with time. When successive years were contrasted with year 1, for Figures 4.1-4.6 only those individuals that were tested in both years were included in the statistical evaluation. Figure 4.1 evaluates LDL cholesterol over 5 years where there was a significant increase in years 4 and 5 compared to year 1. While years 2 and 3 did not have a significant increase over year 1, alarmingly is the progressive increase with time. Importantly, what appears to be rebound in year 5 could be of clinical importance. In Figure 4.2, reflecting the change in total cholesterol, year 2 with a p value of .602 and year 3 with a *p*-value of .157 did not differ from year 1. The total cholesterol increases in years 4 and 5 increased significantly with p values of .002 and .022 respectively. As exhibited in Figure 4.3, firefighter triglycerides from years 2-5 were significantly greater than year 1. In Figure 4.4, HDL cholesterol saw a significant decrease from year 1 to year 2 both with a rebound in year 3, years 3, 4 and 5 were not significant than year 1. Year 3 saw an increase, followed by a non-significant decrease in year 4 and an increase in year 5. Though there are health benefits associated with increased HDL, it is unknown if the small changes will be significant enough to implement a health benefit.

Figure 4.5 shows that BMI did change with a lower non-significant average BMI in years 2 and 3 followed by a significant increase in years 4 and 5 over year 1. Figure 4.6 shows a significant decrease in VO_2 by year 3 that rebounded in year 4but than decreased again in year 5.

DISCUSSION

Over 5 years, total cholesterol, LDL cholesterol, and blood triglycerides showed a significant progressive increase whereas, while HDL cholesterol increased, it was not significant. It has been shown that increases in total and LDL cholesterol along with increased triglycerides, leads to increased cardiovascular disease risk.[5] Unfortunately, these increases in LDL and triglycerides were not offset by the beneficial nonstatistical increase in HDL. Taken in total, the

findings indicate that the risk for CVD progressively increased for these firefighters over time. Total cholesterol, LDL cholesterol, and blood triglyceride levels increased as VO_2 decreased. Unfortunately, improved VO_2 in years 4 and 5 from year 3 did not result in improved LDL, total cholesterol and triglycerides indicating the relative permanence of these types of changes once induced. This data indicated that these types of changes are not likely to be easily reversed without concerted effort on the part of the individuals. In year 3, when VO_2 was lower, so too were HDL levels. As VO_2 began to rebound, a positive non-statistical change in HDL was noted. As BMI decreased, there was a non-statistical increase in LDL cholesterol. The consequence of this type of shift, with a non-statistical increase in LDL with decreased BMI would tend to indicate a consistent increased risk for CVD.[5] When looking at correlations between BMI, total cholesterol, and blood triglycerides, the blood lipids showed a significant increase that correlated with increased BMI. When compared further, HDL cholesterol increased as BMI decreased. However, as BMI began to increase in year 5, HDL levels began dropping indicating the benefit of lower BMI and higher VO_2 and the impact on HDL is not retained if improved BMI and VO_2 are not maintained. Overall, the study found that the increased aerobic exercise, which increases the VO_2, could improve cardiorespiratory fitness by marginally increasing HDL, though the small improvement in VO_2 did not appear to beneficially impact total cholesterol, LDL cholesterol, triglycerides.

Having higher LDL cholesterol levels can induce lipid accumulation within the arterial walls and when combined with calcium plaque, can eventually lead to permanent narrowing of the blood vessels. A clot, if formed in the narrowed arterial space, could trigger a heart attack or a stroke. Lipid deposition in the arterial wall induced by LDL cholesterol has led to it being referred to as “bad” cholesterol. HDL particles pick up cholesterol in the blood and return it to the liver

where it is then broken down or used for the synthesis of other compounds. In the current study, it was found that over 5 years, the LDL cholesterol of the participants increased significantly. A potential cause for increased lipids seen in firefighters could be tied to the changes in behavior attributed to the COVID-19 pandemic. During the pandemic, many firefighters worked odd hours, got the vaccination, or were infected with COVID, which changed their overall health. Most firefighters, similar to the American population, gained weight as reflected in the increase in BMI in years 4 and 5 over year 3 (prior to COVID), which could have been as muscle mass or total body fat, with fat negatively impacting their lipid levels.[44] It was found that as VO_2 increased, LDL cholesterol decreased significantly by year 5.

As indicated previously, aerobic exercise is effective in reducing LDL cholesterol levels and promoting health.[5] VO_2 is a measure of the aerobic exercise capacity as it is the maximum amount of oxygen a person can utilize during strenuous activity. The general tendency is the higher the value of VO_2 as an estimate of cardio fitness, the lower the LDL cholesterol. In Figure 4.1, LDL was measured over time. When each year was compared with the first year, the firefighters only had a significant increase in LDL cholesterol levels in years 4 and 5 only. They had a non-significant increase in the 2nd and 3rd years. Many studies have previously explored the benefits of aerobic exercise on LDL cholesterol and found that it is significantly reduced with a longer duration and higher intensity aerobic activity.[23,24,25] Most of these studies had statistically significant results which is in agreement with our study. Different types of Chinese exercise on blood lipids was studied in middle-aged and elderly population where it was found that the aerobic exercises combined with resistance training, in the form of martial arts, improved blood lipids significantly.[26] In our study, though optional nutrition counseling was available to the participants starting from year 4, there was no major impact as LDL in years 4 and 5 significantly increased.

Studies have indicated that providing nutrition counseling has been impactful in reducing the blood lipids significantly.[27]

Over the 5 years, the firefighters experienced a significant increase in total cholesterol levels. Total cholesterol is primarily a reflection of the total LDL (bad cholesterol) and HDL cholesterol (good cholesterol) in the blood.[4] A person is considered at an increased risk for developing chronic heart disease if total blood cholesterol levels exceed 240 mg/dL.[5] The American Medical Association recommends that people limit their cholesterol intake to 300 mg per day to decrease the risk of heart disease. Aerobic capacity as evaluated by the VO_2 test, typically is associated with a decrease in total cholesterol. However, though there were declines in VO_2 in year 3 and increases in year 4, total cholesterol continued to increase with time. It must be noted that the firefighters were not pushed to their VO_2 maximum and could stop at any point. Many elected to stop at a point that was not near their maximum capacity but reflected their desire to simply stop the run, a duration that seems to get shorter year-by-year. Conversely, even when BMI decreased, serum total cholesterol increased becoming significant in years 4 and 5. Figure 2 shows total cholesterol over time which has been increasing over the years. When compared to year 1, years 2 and 3 showed a non-significant increase whereas years 4 and 5 saw a significant increase. Although the nutrition counseling was available to the participants, the total cholesterol increased significantly indicating that beneficial lifestyle changes had not been implemented. Studies suggest that nutrition education or counseling is effective in reducing total cholesterol levels significantly.[28,29] These studies were done in a controlled setting where the changes in response to nutrition education were tracked unlike our study where changes were not closely tracked. In a study similar to ours, the impact of physical activity on blood lipids was evaluated. The difference was that the study used self-reported and accelerometer-based assessment of

physical activity in older adults.[30] Weak correlations were found between physical activity and total cholesterol. A few limitations of the study was that the data was self-reported which has been shown to cause self-reporting bias and other being the position of the monitor worn which might cause significant errors in the results.

Though an increased BMI is associated with increased risk for many chronic diseases like cardiovascular with an increased risk for hypercholesterolemia, BMI is not considered a reliable indicator of body fat distribution.[7] People, in this case firefighters, may have a high BMI attributable to more body fat, but it may also be attributable to an increase in muscle mass. This difference in firefighters may explain why we did not have any statistically significant changes in BMI in our study. Most of the studies discussed in the literature review did not correlate CVD risk with BMI possibly due to its misinterpretation of body fat.[8] Methods that accurately identify the location of body such as DEXA can better identify CVD risk as it better identifies adipose tissue location. A DEXA can measure body composition, differentiating between body fat bone and lean mass. This more accurate information on total body fat mass and its location would be more able to predict the risk for CVD.

When BMI vs time was evaluated, years 2 and 3 had a non-significant decrease whereas years 4 and 5 saw a significant increase. Studies suggest that when physical training is combined with nutrition education, people tend to lower their blood lipids significantly.[31,32] Even after the nutrition counseling had been an option in years 4 and 5, there was a significant increase in BMI over time, indicating that food associated behaviors had not been applied. Increased BMI in firefighters is not a novel as obesity has been on the rise for decades. The obesity epidemic has been studied exclusively where many studies find that with time, people, mainly in the Western world gain weight attributable to factors that include socioeconomics or psychological

influence.[33,34,35,36] It has been demonstrated that COVID-19 resulted in weight gain or increase in the BMI in the population. During COVID-19, people lost jobs, had psychological and physical stress and had other issues leading to weight gain.[37]

Over 5 years, the firefighter's blood triglyceride levels increased significantly. Triglycerides tend to be impacted by lifestyle factors like exercise, sleep, simple carbohydrate intake, smoking, and alcohol use rather than just the saturated fat content, or extra calories people consume in their diet.[10] During the pandemic, many people, especially the front-line workers, had to work odd hours and in extreme situations, which might have taken a toll on their health with non-beneficial changes resulting in progressive increases in blood triglyceride levels over these years. Hypertriglyceridemia is associated with having high blood triglycerides and manifests with symptoms that include abdominal and chest pain or might be sometimes asymptomatic as well.[11] Aerobic exercise is an effective means of reducing blood triglyceride levels. The data herein identified decreases in VO_2 in years 3 and 5. These decreases in VO_2 could have been a causative factor or related to triglyceride increases. Though BMI remained unchanged from year 1 to year 5, the firefighters continued to see a progressive increase in their blood triglycerides. Figure 3 showed that triglycerides increased over time when compared to year 1. The diet or lifestyle patterns of the firefighters was not assessed, that may have had a role in the significant increase in triglycerides with time. A study found that calorie restriction along with exercise regimen results in a significant triglycerides reduction.[38] Though nutrition counseling was available for the firefighters, it largely went unused and the lifestyle changes were not tracked. Physical activity has always been beneficial in controlling the blood lipids. Several studies indicate that high intensity aerobic activity helps reduce blood triglyceride levels.[39,40,41] Many aerobic exercises have been shown to improve aerobic performance. Yijinjing, a traditional Chinese exercise that is considered

to be both aerobic and resistance training, has been found to reduce triglycerides significantly.[42] The VO_2 associated exercise did not push the firefighters to their max as they could control the duration and was evaluated only as a single point in time. It is likely reason that we did not see beneficial triglycerides changes.

High-density lipoproteins or HDL cholesterol are known as the "good" cholesterol due to its ability to remove cholesterol deposited in the arterial walls in a process called reverse transport.[3] HDLs are the smallest and densest lipoproteins in the plasma due to their higher protein content.[4] HDL levels are inversely associated with cardiac events where increases in HDL concentrations lead to or are associated with reductions in the risk of chronic diseases. Over 5 years, the firefighters saw a non-significant increase in blood HDL levels. Aerobic exercises like water aerobics, Zumba, running, hiking, dancing, swimming, and others have been promoted as a means to promote heart health.[12] Exercise reduces elevated lipids by improving and maintaining their blood concentrations. As VO_2 increases, HDL cholesterol also tends to increase though this was not exhibited in this study. The BMI had a negative correlation with HDL where, as the BMI increased, the levels of HDL tended to decrease. Figure 4 shows that firefighter HDL cholesterol dropped significantly in year 2 when compared to the year one. Year 3 showed an increase, year 4 showed a decrease whereas in year 5 a slight increase was noted. All these changes were non-significant. VO_2 was plotted against the time where it showed a significant decrease in years 3 and 5 but a non-significant increase in years 2 and 4. A study conducted on 40 firefighters concluded that they had an improved heart rate and minute ventilation.[22] This study was similar to our study where the firefighters who had a low VO_2 saw a significant increase in blood lipids. Many studies similar to our study have evaluated different exercise regimens people across all age groups. These studies have concluded that aerobic activity done for a longer duration, helps increase HDL

cholesterol levels significantly.[43] These studies reinforce our understanding of the benefits of aerobic exercise and its potential benefits on blood lipids. The marginal increase in HDL cholesterol seen in year 5 could be due to several factors which could include the use of nutrition counseling. Suggested dietary changes could impact HDL cholesterol whereby, incorporating the Mediterranean diet and replacing animal foods with plant foods have been proven to be beneficial in maintaining healthy blood lipid range.[44,45]

Figure 6 shows VO_2 over the years. When compared to year 1, there was a non-significant decrease in year 2, a significant decrease in year 3, a non-significant increase in year 4 and a significant decrease in year 5. Many people report being physically inactive outside of their work-related duties leading to an overall reduction in aerobic capacity. The growing obesity epidemic could also be a reason for being physically inactive.[46,47] There could be other reasons for the decrease in their aerobic capacity like being overweight. Many firefighters had an increase in their body weight which could have led to reduced exercise, lowering their aerobic capacity as studies suggest that people who are overweight or obese tend to see a decrease in their VO_2 over time.[48] Another possibility could be the age of the firefighters. Aging has been linked to lower aerobic capacity as people tend to decrease their VO_2 from 20-29 years of age.[49]

The hypothesis that a low VO_2 would be associated with high blood triglycerides, LDL, total cholesterol, and low HDL, increasing the overall risk for cardiovascular disease was unfortunately found to be true. The Denton firefighters who had higher estimated values for VO_2 had a decrease in the levels of total cholesterol, triglycerides, LDL cholesterol, and an increase in HDL cholesterol. However, as this was a minimal number of firefighters, they did not offset the negative pattern generally identified. The results relating to the VO_2 testing were all statistically significant identifying the relationship between aerobic exercise and triglycerides, total

cholesterol, and LDL cholesterol while agreeing with the positive correlation between aerobic exercise and HDL cholesterol. The sole evaluation herein evaluated the relationship between VO_2 and BMI and lipids indicators of CVD. The role of diet in firefighters was not evaluated. The firefighters should be advised to limit their daily intake of meat, full-fat dairy, processed food, fried foods, and ready-to-eat foods. They should focus on consuming more plant-based foods, increasing their overall intake of fruits, vegetables, whole grains, and low-fat dairy. Increasing their intake of good fats such as those found in nuts, seeds, vegetable oils like sunflower, safflower, olive oil, and avocadoes, and whole grains such as quinoa, brown rice, whole wheat, oats, and fish, which would help them lower their total cholesterol, LDL cholesterol, triglycerides while increasing exercise would increase their HDL cholesterol.[40]

STRENGTHS

A strength of this study was having multiple dependent variables where four blood lipids could provide an overall picture of the relationship between aerobic exercise and each blood lipid. Another strength was that longitudinal data was collected over 5 years allowing for the identification of developmental trends in firefighters that increase their risk for heart disease.

Limitations

Many firefighters did not participate during 2020 due to the COVID pandemic and as such, the data collected in that year was limited. The firefighter's diet and other lifestyle factors are not known which could also impact their blood lipids as well. For future studies, a questionnaire may be functional where questions could target the lifestyle factors that contribute to heart disease. Future studies should also consider the impact of diet and its role as the potential cause of increased blood lipids. Psychological factors could also assess indices that might impact their diet and lifestyle as well.

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