

THE RELATIONSHIP BETWEEN ISOKINETIC MUSCLE STRENGTH AND  
CARDIOVASCULAR RISK FACTORS IN OVERWEIGHT AND OBESE  
FIREFIGHTERS

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## ABSTRACT

Andrew James Tweedell: The Relationship between Isokinetic Muscular Strength and Cardiovascular Risk Factors in Overweight and Obese Firefighters  
(Under the direction of Eric Ryan)

Firefighters display sub-standard fitness despite strenuous occupational duties, and are at risk for cardiovascular disease (CVD). Muscular strength may provide a protect effect, independent of cardiorespiratory fitness (CRF). The purpose of the present study was to examine the relationship between CVD risk factor profiles and isokinetic muscular strength in overweight firefighters, prior to and after accounting for CRF. A CVD risk factor profile was created using blood pressure, blood lipids, and body fat, while peak torque (PT) was measured during a slow (60°/sec) and fast (240°/sec) isokinetic muscle action of the leg extensors in 43 overweight and obese (BMI>25) career firefighters. No relationship was found between CVD risk factor profiles and slow ( $r=-0.10$ ,  $P=0.51$ ) or fast ( $r=-0.14$ ,  $P=0.37$ ) isokinetic PT, even when accounting for CRF ( $P>0.05$ ). These finding suggest there is no protective effect of muscular strength from CVD risk factors in this sample of overweight and obese firefighters.

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## LIST OF ABBREVIATIONS

BF%	Body Fat Percentage
BMI	Body Mass Index
BM	Body mass
BIS	Bioimpedance Spectroscopy
CRF	Cardiorespiratory Fitness
CVD	Cardiovascular Disease
HDL	High Density Lipoprotein
LDL	Low Density Lipoprotein
MVIC	Maximal Voluntary Isometric Contraction
TC	Total Cholesterol
TG	Triglycerides
US	Ultrasonography

## CHAPTER I

### INTRODUCTION

Firefighters must endure many strenuous activities on duty, such as wearing heavy protective gear, dragging heavy equipment, climbing stairs and ladders, suppressing fires and performing life-saving techniques.<sup>26</sup> These occupational duties put tremendous stress on a firefighter's cardiovascular and muscular systems,<sup>20, 23, 28</sup> and have been documented as potential triggers for cardiovascular events.<sup>35</sup> For example, although fire suppression accounts for only 1-5% of on-duty time, it accounts for over 32.1% of on-duty cardiovascular deaths.<sup>19</sup> Cardiovascular disease (CVD) has been found to be the leading cause of on-duty deaths in career and volunteer firefighters.<sup>35</sup> It is suggested that despite having a physically demanding occupation, firefighters display lower levels of physical fitness and a higher prevalence of obesity and cardiovascular risk factors than the general population.<sup>28</sup> Several studies using body mass index (BMI) have shown that 73-88% of firefighters are overweight or obese.<sup>10, 18, 22, 34, 38</sup> In a study of 677 firefighters, Poston et al. (2011) reported: 1) a higher prevalence of overweight and obesity in firefighters than the general population using body fat percentage (BF%); 2) obese firefighters have substantially lower cardiovascular fitness levels (not meeting minimal exercise tolerance standard of 12.0 METs) than their non-obese counterparts; and 3) obese firefighters exhibit more adverse CVD risk factors.<sup>27</sup> This status not only diminishes overall health, but also increases the risk of on-duty cardiovascular events,<sup>11</sup> musculoskeletal injury,<sup>16</sup> and poor performance during firefighting ability tests.<sup>26</sup>

Many previous studies have indicated that higher levels of cardiorespiratory fitness have been associated with a healthier cardiovascular profile,<sup>30,32,36</sup> even in a firefighter population.<sup>28</sup> For example, a few studies have examined the relationship between certain risk factors (i.e. adiposity, resting blood pressure) and skeletal muscle characteristics.<sup>15,17,25</sup> Jackson et al. and Mason et al. found muscle strength to be inversely associated with prevalence and incidence of adiposity.<sup>15,25</sup> Strength was also found to be associated with reduced risk of incident hypertension in pre-hypertensive men.<sup>24</sup>

A classic study by Berenson et al.<sup>5</sup> revealed that the extent of atherosclerotic lesions in the aorta and coronary arteries increased with the number of these risk factors present. Thus, recent studies are now examining the relationship between clustered cardiovascular risk factors, often called a metabolic or cardiovascular risk profile, and muscular strength. These cardiovascular risk factors include blood pressure, blood lipids, blood triglyceride, and adiposity. In a cohort of 8,570 men aged 20-75 years, Jurca et al.<sup>17</sup> found an inverse relationship between muscular strength and the prevalence of metabolic syndrome in groups with low to moderate cardiorespiratory fitness (CRF), as can be found in the general firefighter population. Other studies show similar results when looking at clustered cardiovascular risk factors specifically; however, the influence of CRF is inconsistent.<sup>3,39</sup> For example, Vaara et al.<sup>39</sup> found muscular endurance, and not strength, to be inversely associated with clustered cardiovascular risk factors when accounting for CRF, while Artero et al.<sup>3</sup> found higher risk factor scores to be associated with lower muscular strength regardless of CRF status. However, we are aware of no previous studies that have examined the relationship between lower extremity strength and a cluster of cardiovascular risk factors in firefighters. Furthermore, isokinetic dynamometry provides the ability to examine torque-velocity relationships, where increasing contractile velocities are more dependent on primarily fast-twitch

muscle fibers which may be influenced by the associated inflammation seen with poor cardiovascular profiles.<sup>7,9,31,33,40</sup> The purpose of this study was to examine the relationship between muscular strength and clustered cardiovascular risk factors in overweight and obese firefighters when accounting for the influence of cardiorespiratory fitness.

### Research Question

1. Is there a relationship between isokinetic muscular strength at both fast and slow velocities and a cluster of cardiovascular disease risk factors in overweight and obese firefighters prior to and after accounting for cardiorespiratory fitness?

### Hypotheses

1. There will be a significant negative relationship between isokinetic muscular strength and a cluster of cardiovascular disease risk factors, however this relationship will be stronger at the fastest isokinetic velocity.
2. The relationship between isokinetic muscular strength and a cluster of cardiovascular disease risk factors will be attenuated but remain significant when accounting for cardiorespiratory fitness.

### Delimitations

1. Cardiovascular risk factors will be transformed to z-scores and summed to provide a continuous cardiovascular risk factor profile.

### Limitations

1. The participants are not truly random as they will be recruited from fire departments in the central North Carolina region.

2. Cardiorespiratory fitness will not be directly measured but estimated using a regression equation presented by Jackson, et al.<sup>14</sup>

#### Theoretical Assumptions

1. All participants will abstain from strenuous physical activity for 24 hours prior to testing.
2. All participants will fast for 8 hours prior to testing.
3. All participants will give a maximal effort when performing isokinetic contractions.

## CHAPTER II

### REVIEW OF LITERATURE

This review of literature will include previous research studies that are most related to current firefighter health and fitness, cardiovascular disease risk, as well as its relationship with muscular strength. Many of these studies are critical papers that will provide an important background for the proposed project. The results of each study will be provided along with suggested conclusions by the authors to facilitate an understanding of concepts related to this project.

#### *Sub-standard fitness and cardiovascular risk in firefighters*

#### Poston, Haddock, Jahnke, Jitarin, Tuley, and Kales (2011)

The primary purpose of this epidemiological study was to examine the prevalence of substandard fitness and overweight and obesity in career and volunteer firefighters using multiple body composition measurements. The secondary purpose was to examine any relationship between cardiovascular disease factors, muscular strength, flexibility, cardiorespiratory fitness and the prevalence of overweight and obesity in a firefighting cohort from the International Association of Fire Chief's (IAFC) in the Missouri Valley region. A combination of 478 male career (mean  $\pm$  SD, age =  $38.2 \pm 9.9$  yrs.) and 199 volunteer (age =  $39.7 \pm 12.0$  yrs.) firefighters were assessed for this study. Body fat percentage (BF%) measured by foot-to-foot bioelectrical impedance. The Jackson Strength Evaluation System was used to determine upper and lower body isometric strength, and the sit-and-reach test was used for flexibility. Resting heart rate (RHR), blood

pressure (BP), and blood lipids were assessed to examine cardiovascular disease risk factors, and a Self-Report of Physical Activity (SRPA) questionnaire was used to determine cardiorespiratory fitness.

Unstandardized prevalence rates were calculated for overweight and obesity using BMI and BF%. Firefighters were classified as overweight if their BMI was  $\geq 25$  kg/m<sup>2</sup> and the classification of obesity included a BMI of  $\geq 30$  kg/m<sup>2</sup> and BF% of  $\geq 25\%$ . The National Cholesterol Education Program (NCEP) criteria for metabolic syndrome was BP  $\geq 135/85$  mmHg, plasma triglycerides  $\geq 150$  mg/dL, plasma high density lipoprotein (HDL)  $\leq 40$  mg/dL, along with taking hypertension medication. To determine levels of substandard fitness, associations between body composition, strength, flexibility, blood lipids and aerobic capacity measurements were compared between normal-weight (BMI  $\leq 25$  kg/m<sup>2</sup>) firefighters and obese (BMI  $\geq 30$  kg/m<sup>2</sup>) firefighters.

Overweight and obesity combined using BMI were found in 33.5% and 43.2% of the career and volunteer firefighters, respectively, making 76.7% of the combined career and volunteer firefighter sample overweight or obese. This is compared to the 68% overweight and obesity prevalence in the age-standardized U.S. population. It has been thought that, like athletes, increased muscle mass and lower body fat cause elevations in BMI and subsequent overweight misclassification in firefighters. However, this study revealed that BMI may be more likely to underestimate overweight and obesity when compared to BF%. For example, 32.7% of career firefighters in this sample were BMI-classified overweight but were BF%-classified as obese. Surprisingly, the prevalence of obesity in career and volunteer samples combined was 51% using BF% estimates. The authors reported BMI-classified obese firefighters were 94% to 99% less likely to meet the National Fire Protection Association (NFPA) minimum standard of 12 METs



for aerobic capacity, upper and lower body strength, and flexibility were also more likely to meet criteria for metabolic syndrome. In conclusion, the authors highlight the substandard fitness values for this sample of firefighters and suggest future studies should examine interventions aimed at improving fitness and help to reduce the high rate of obesity and the obesity-related co-morbidities. Soteriades, Hauser, Kawachi, Christiani and Kales (2008)

The purpose of this prospective epidemiological study was to evaluate the association between being overweight and the risk of job disability during a Massachusetts statewide medical surveillance program and 6-year follow up of a cohort of male hazardous-materials firefighters. At baseline and at each follow-up assessment, BMI, age, job type (technician, support member), smoking history, cardiovascular risk factors (blood pressure, blood glucose, total cholesterol and triglycerides) were measured. Time to development of a short-term or permanent job disability (placement on 'injured on-duty' status, termination of duty, resignation, premature retirement or death) was measured as the number of years from baseline to follow-up until a firefighter was found medically unfit for duty or until the end of the study. Parametric and nonparametric statistical analyses were used to determine variable differences between different BMI categories. A multivariable-adjusted (age, job type, smoking history, and cardiovascular risk factors) regression model was then developed to evaluate any associations between various categorical measurements of BMI and the time to development of job disabilities.

All firefighters (n = 358) were followed for an average of 5.3 years. At baseline, 12% were categorized as normal weight ( $BMI < 25 \text{ kg/m}^2$ ), 53% were overweight ( $25 \leq BMI < 30$ ), and 35% were obese ( $BMI \geq 30$ ). Seventy six firefighters experienced a job disability event during the 6-year follow. The cumulative 6-year incidence rates were greater in obese firefighters (32%), than in normal and overweight firefighters (26 and 21%, respectively). Obese firefighters were also

more likely to suffer from hypertension than normal or overweight firefighters ( $P < 0.01$ ); however, no other cardiovascular disease risk factor differences were found.

According to the multivariable-adjusted regression model, there was a non-significant ( $P < 0.10$ ) 5% increased risk of job disability with every single unit increase in continuous BMI, signifying a potential increased risk of an adverse employment event with increased weight. The study also found that firefighters in highest tertile of BMI ( $BMI \geq 30.2 \text{ kg/m}^2$ ) for this study were 98% more likely to suffer an adverse employment event than firefighters in the lowest tertile ( $BMI < 27.2$ ).

Some limitations that reduce the generalizability of the study are the small epidemiological sample size along with a broad definition of a job disability event which may include health issues not related to weight. However, this study's data supports the need to improve the health status of firefighters and reduce job disability in the fire services. The authors suggested this be achieved by appropriate diet and exercise programs within the worksite.

Michaelides, Parpa, Henry, Thompson and Brown (2011)

The purpose of this study was to determine relationships between various fitness parameters and performance on a firefighting ability test. Ninety career firefighters (age =  $33 \pm 7$  yrs.; BM =  $97.04 \pm 15.51 \text{ kg}$ ) were recruited for this study. The simulated firefighting ability test consisted of six individual tasks to be performed in sequence which included a stair climb, rolled hose lift and move, Keiser sled, hose pull and hydrant hookup, mannequin (82 kg) drag, and charged hose advance tasks. Performance on firefighting tasks were measured as time to complete each task as well as total time to complete all six tasks. On a separate occasion, several fitness parameters were measured which included body composition, resting vitals and muscular characteristics. These fitness components included BF%, BMI, resting heart rate, sit-and-reach

flexibility, muscular endurance as push-up and sit-up tests, upper and lower body strength, grip and abdominal isometric strength, and anaerobic power as measured by a step test and a vertical jump test. A step-wise multiple regression was run to determine the proportion of variation in ability test times explained by variation in fitness parameters.

The average time to completion for overall ability test was  $7.07 \pm 1.76$  minutes. There was a significant negative association ( $P < 0.05$ ) between the overall time on the ability test and abdominal strength, muscular endurance, and step test anaerobic power. Significant positive associations existed between overall time and age, resting heart rate, BMI, BF%, and waist size, indicating heavier firefighters perform firefighting tasks more slowly than their lighter counterparts. After adjusting for multicollinearity, abdominal strength, step test anaerobic power, push-ups, resting heart rate and BF% determined a significant proportion ( $R^2 = 0.60$ ) of the variation in overall ability test times.

The data presented in this study confirms the notion that firefighters need to be physical fit to be able to perform common firefighting tasks. Some symptoms associated with excess adiposity, such as high resting heart rate, high BMI, high BF% have been proven to negatively impact firefighting performance. This study is practical for developing training programs to improve firefighting performance, but it is also useful for targeting specific health-related fitness components to modify. An intervention that increases muscularity and decreases adiposity in firefighters may result in improved firefighting performance.

Yang, Teehan, Farioli, Baur, Smith, Kales (2013)

The authors of this study used data from the National Institute for Occupational Safety and Health (NIOSH) to investigate the leading cause of death, sudden cardiac death (SCD), in firefighters under 45 years of age. The main cause of on-duty deaths in firefighters over 45 years

of age is SCD due to coronary heart disease; however, not much is known about the cause of SCD in younger firefighters. The aim of this retrospective case-controlled study was to examine the association between certain CVD risk factors and pathologic-anatomic specific features, as well as to compare the prevalence CVD risk factors in SCD with healthy controls. The study also compared autopsy findings between SCD cases and non-cardiac death cases.

All data about SCD cases in firefighters under 45 years of age between 1996 and 2012 were collected from public NIOSH investigated cases. An age-matched firefighter control group and age-matched non-cardiac death autopsy reports were also collected. Cardiovascular disease risk factors used in the multivariate logistic regression models were obesity, smoking status, diabetes (blood glucose  $\geq 150$  mg/dl or previous diagnosis), hypertension (resting BP  $\geq 140/90$  mmHg or previous diagnosis), and hyperlipidemia (TC  $\geq 200$  mg/dl, LDL  $\geq 160$  mg/dl, or previous diagnosis). History of coronary heart disease (CHD) for all firefighters was also recorded from NIOSH medical records. Odds ratios (OR) and 95% confidence intervals were used to determine any association with CVD risk factors in the SCD cases (n = 87) compared to the control group (n = 915).

When adjusting for all other co-variables, the biggest increase in risk for SCD came from having a history of CHD (OR = 6.89, P < 0.001). The prevalence of obesity, smoking status, as well as hypertension, were also significantly associated with increased risk for SCD (P < 0.005). Of all SCD cases, 63% of the firefighters presented a BMI  $\geq 30$  kg/m<sup>2</sup>, compared to the 36% of firefighters in the control group (OR = 2.2, P = 0.005). The author discusses obesity's well known link to various CVD risk factors (hypertension, hyperlipidemia, etc.) as a possible cause of SCD.

The primary finding of the study is that active firefighters with a history of CHD are 7 times more likely to suffer SCD. This study presents evidence that suggests managing these particular identified risk factors can decrease the likelihood of on-duty SCDs.

*Cardiovascular risk factors and muscular strength*

Cesari, Penninx, Newman, Kritchevsky, et al. (2003)

This study was taken from a larger study called “The Health, Aging and Body Composition Study (The Health ABC Study)” investigating a cohort of aging men and women. The link between cardiovascular disease and inflammation is clinically relevant but still uncertain. Cytokines are important inflammatory markers that are measurable in the blood and hold potential influence on cardiovascular risk factors. The purpose of this study was to determine the association between the inflammatory markers interleukin (IL)-6, C-reactive protein (CRP), tumor necrosis factor (TNF)- $\alpha$  and clinically-diagnosed CVD. A total of 3,045 “well-functioning” older adults (age =  $74.2 \pm 2.9$  years) were divided into three categories. Those with “Clinical CVD” (802 participants) displayed clinically diagnosed cardiovascular pathologies (congestive heart failure, coronary heart disease, stroke, etc.). Those with “Subclinical CVD” (1,195 participants) were not clinically diagnosed but presented symptoms presented by the Rose Questionnaire for Angina or electrocardiographic abnormalities. A total of 1,030 participants showed no symptoms of CVD so were classified at “No CVD”. Serum IL-6, CRP and TNF- $\alpha$  were collected for analysis. Socioeconomic demographics and co-morbidities were also recorded as covariates. An ANOVA was run to determine differences in covariates between the three CVD groups. Any association between the continuous values or tertiles of inflammatory markers and the three CVD groups were determined using a multi-nominal logistic regression analysis. Odd ratios (OR) for each group were calculated.

Participants in the Clinical and Subclinical CVD groups were significantly older ( $P < 0.001$ ), heavier ( $P < 0.001$ ), more likely to smoke ( $P < 0.003$ ), have diabetes ( $P < 0.001$ ), or hypertension ( $P < 0.001$ ) than the No CVD group. They were also more likely to exhibit adverse lipid profiles with higher TC ( $P < 0.001$ ), and lower HDL ( $P < 0.001$ ). Unadjusted for covariates, all inflammatory markers levels were significantly higher in the Clinical and Subclinical CVD groups. According to the regression analysis, participants in the highest tertiles for IL-6, CRP and TNF- $\alpha$  were one and a half to two times more likely to be classified as Clinical or Subclinical CVD when compared to the No CVD group, independent of age, gender, race, and all other covariates. There also showed to be significantly increasing ORs for Clinical and Subclinical CVD for increasing continuous IL-6 and TNF- $\alpha$  levels, however not with CRP.

In conclusion, the regression analysis cannot state causation; however, this study provides physiologic evidence for the increased risk of CVD with increasing levels of inflammation based on multiple measureable inflammatory markers, independent of age, gender, race, mass, and smoking status. An important limitation of the Health ABC Study as it pertains to the current study is the use of an older cohort. Cardiovascular disease is an important risk factor for mortality in the elderly; however, the influence of inflammation on CVD risk factors is seldom studied in middle-aged adults.

Toth, Ades, Tischler, Tracy, LeWinter

Elevated levels of cytokine, specifically IL-6 and TNF- $\alpha$ , have previously been shown to be linked to CVD risk; however, the relationship of this elevation with physical functioning has not been investigated in depth. The destructive effect of these cytokine on muscle fibers have also been documented *in vitro*; however, the effect on overall muscle strength *in vivo* has not. The three aims of this study were to measure differences in aerobic capacity, muscle strength and

inflammatory marker levels between controls and participants with heart failure, to determine the association between inflammatory marker levels and muscle mass, and finally to examine the association between inflammatory marker levels and aerobic capacity and muscle strength.

Ten older adult males (age =  $63 \pm 3$  years, BM =  $80 \pm 4$  kg) with chronic heart failure (HF group), defined by a reduction in ejection fraction, were recruited for this study. Eleven age-matched control males (age =  $70 \pm 3$  years, mass =  $80 \pm 5$  kg) with no history of heart disease were also recruited. To control for caloric intake, a standardized diet (60% carbohydrate, 15% protein, and 25% fat) was provided to all participants for three days before blood, body composition, aerobic capacity, and strength tests. The inflammatory markers IL-6, TNF- $\alpha$ , and CRP were measured by enzyme-linked immunosorbent assay (ELISA) from blood serum. Dual energy X-ray absorptiometry was used to calculate fat mass and fat free mass (FFM). A graded treadmill VO<sub>2</sub> peak test was used to determine aerobic capacity. Muscle strength was measured as maximal isometric and isokinetic contractions of the knee extensors and an isometric forearm grip test. Isometric knee extensor contractions were performed on a dynamometer with leg fixed at 55° below horizontal. For isokinetic strength, participants maximally extended the right leg from 90° to 0° at an angular velocity of 90°/sec. The average of the peak torque recorded from three separate contractions was recorded for both isometric and isokinetic tests. In order to measure differences in outcome measures Student *t*-tests and ANCOVAs were performed. Pearson's product coefficients were calculated to examine relationships between specified variables.

Statistically, there were no significant differences in physical characteristics or body composition measurements between controls and heart failure participants. Even when VO<sub>2</sub> peak was adjusted for relative BM, as well as FFM, HF participants had significantly lower aerobic capacities than control participants, with controls consuming approximately  $2.55 \pm 0.19$  L/min and

HF's consuming only  $1.62 \pm 0.22$  L/min ( $P < 0.01$ ) absolutely. There was no statistical difference in isometric forearm grip strength between groups; however, both isometric and isokinetic knee extensor strengths were significantly higher in the control group than the HF group ( $P < 0.05$ ), even when adjusted for age and leg muscle mass ( $P < 0.01$ ). All serum inflammatory markers levels, except TNF- $\alpha$ , were significantly greater in HF participants ( $P < 0.05$ ). In a pooled analysis of all participants, there appeared to be a relationship between muscle mass and specific markers. TNF- $\alpha$  was negatively associated with arm, leg and appendicular muscle mass ( $r = -0.436, -0.545, -0.528$ , respectively,  $P < 0.05$ ). IL-6 was also found to be inversely related to leg and appendicular muscle mass ( $r = -0.438, -0.443$ , respectively,  $P < 0.05$ ). For the influence of these markers on aerobic capacity, it appears greater levels of cytokines are strongly related to lower levels reached for relative (FFM)  $\text{VO}_2$  peak, with Pearson correlation coefficients at  $r = -0.65$  ( $P < 0.01$ ) for CRP,  $r = -0.72$  ( $P < 0.01$ ) for IL-6, and  $r = -0.58$  ( $P < 0.01$ ) for TNF- $\alpha$ . The primary findings from the relationship to muscular strength are the strong negative associations between IL-6 and TNF- $\alpha$  with both isokinetic and isometric knee extension strength. There was a trend for those participants with higher levels of IL-6 and TNF- $\alpha$  to have less peak torque during all muscular contractions ( $P < 0.05$ ), except for TNF- $\alpha$  on isometric forearm grip.

While it is known that cytokine levels increase with age, the use of an age and body mass-matched control group in this study allows the authors to conclude that heart failure may be linked to increased inflammatory marker levels and subsequently, less strength. The catabolic effect of these inflammatory markers on muscle size cannot be assumed in this particular study because muscle mass of the leg and arm were identical between groups and statistical relationships remained after adjusting for these muscle masses. Other physiological mechanisms for disrupting muscular contraction by these cytokines must be at fault. This study provides evidence that chronic



inflammation, much like that seen with obesity and CVD, may result in weaker muscles independent of muscle mass.

Berenson, Srinivasan, Bao, Newman III, Tracy, Wattigney (1998)

This study was performed as a part of the Bogalusa Heart Study, a long-term epidemiologic study of cardiovascular risk factors from birth to 38 years old. The purpose of the study was to examine the influence of multiple CVD risk factors on the extent of atherosclerosis in the heart of young people. Cross-sectional surveys in which risk factors were assessed were performed on all age-eligible volunteer participants. Risk factors measured during these surveys included BMI, BP, TG, TC, HDL, LDL and smoking status, measured as the number of cigarettes smoked per week. Measurements were transformed into z-scores. Criteria for having an individual risk factor was defined as having a value above the 75<sup>th</sup> percentile (specific for study period, race, age, and sex) for the group as a whole.

Ninety-three persons that had previously participated in the Heart Study surveys were autopsied for atherosclerotic evaluation of the aorta and coronary arteries upon death. First, the percentage of total intimal surface that displayed atherosclerotic lesions was determined visually. Second, total area of these atherosclerotic lesions was further broken down into percentage distribution of fatty streaks, fibrous plaques, complicated and calcified lesions. The prevalence of atherosclerosis in various age groups was determined using a chi-square test. Correlation analyses were used to examine the association between the extent of atherosclerosis and individual and multiple risk factor z-scores. The effects of multiple risk factors on the extent of atherosclerosis were evaluated with an analysis of covariance.

Not surprisingly, prevalence of atherosclerosis increased with age ( $P = 0.001$ ). Individually, all risk factor variables, with the exception of HDL, were positively and significantly

correlated ( $P < 0.05$ ) with atherosclerosis in either the aorta or coronary arteries or both. The risk factor variables as a group were strongly related ( $r = 0.70$ ,  $P < 0.001$ ) to the overall extent of atherosclerotic lesions in the aorta and coronary arteries. However, the most relevant finding of this study is the effect of multiple risk factors on the presence atherosclerosis. Participants with three or more risk factors displayed 8.5 times the extent of fatty streaks and 12 times the extent of fibrous plaque in the coronary arteries compared to participants with no risk factors ( $P = 0.03$  and  $P = 0.006$ , respectively). The authors suggest that multiple risk factors have a synergistic effect on mortality due to coronary heart disease. This is important because many of these high risk factors are often diagnosed together, not only in young adults but in the general population.

Magnussen, Schmidt, Dwyer, Venn (2012)

The aim of this study was to investigate the cross-sectional relationship between muscle strength, endurance and power with individual and clustered cardiovascular risk factors in Australian youth. Individual risk factors measured include non-HDL, HDL, TG, SBP, DBP, mean arterial pressure (MAP), waist circumference (WC), and BMI. Individual risk factor z-scores were summed to create a clustered CVD risk score. Isometric muscular strength was measured as maximal contraction of hand-grip, shoulder extension, shoulder flexion, and of the leg. All force measurements were summed to create a muscular strength index. Muscular power was measured as the distance of a standing long jump. Muscular endurance was measured as the number of push up repetitions in 30 seconds. Muscular fitness measurements were normalized to body mass. Cardiorespiratory fitness was measured by a 1.6 miles timed run. Participants aged 9-15 years volunteered for this study.

A total of 1,642 (53% males) were measured. No significant interactions between sex and muscular fitness indices, so all analyses were pooled for sex. To examine trends between CVD

factors and each muscular fitness indices' quintiles, a linear regression analysis was performed. The results indicate that there is a significant decrease in clustered CVD risk score across increasing quintiles for each muscular strength ( $P = 0.04$ ), endurance ( $P < 0.001$ ) and power ( $P < 0.001$ ); however, when controlling for BMI, this trend only remains significant in muscular endurance and power. Lastly, to investigate the influence of CRF on any associations, a logistic regression was run between muscular power quintiles and CRF tertiles and the prevalence of a clustered CVD risk score  $\geq$  80th sex- and age-specific percentile. Only muscular power was used in the logistic regression because it was the strongest predictor of clustered CVD score. Muscular power was inversely associated to the clustered CVD risk score prevalence in all CRF (high, moderate and low) categories, while CRF was only inversely associated to the prevalence in the lowest muscular power quintile.

These results indicate that muscular fitness (strength, endurance, and power) are important predictors of CVD risk in youth, with lower muscular power increasing CVD risk independently of CRF. These results also suggest that muscular fitness possibly provide small to moderate protective benefits; however, the mechanisms are still unknown. While the sample size of this study is quite large, there are some limitations of the study. Muscular fitness was assessed using various field tests (i.e. 1.6 mile run, standing long jump, push up test), that may not be truly indicative of muscle or cardiorespiratory function. A study with more controlled assessments may be necessary to find any other associations between muscular fitness and CVD risk.

Vaara, Fogelholm, Vasankari, Santtila, Häkkinen, Kyröläinen (2014)

The purpose of this cross-sectional study of Finnish young men (20-30 years old) was to investigate the association between maximal strength, muscular endurance and CRF with single and clustered CVD risk factors. The study hypothesis was that both strength and endurance would

be associated with clustered and individual CVD risk factors independent of CRF. Cardiovascular risk factors selected for investigation were systolic and diastolic BP, fasted blood glucose, TC, HDL, and TG. These values were transformed into z-scores and summed to produce a continuous clustered cardiovascular risk factor score. Maximal strength was measured during a leg extension and bench press isometric muscle action. Muscular endurance was measured as the maximum number of repetitions during a 60 second push up, sit up and body weight squat test. These values were transformed into z-scores and summed to produce individual muscular strength and endurance indices. Cardiovascular fitness was measured as a predicted  $\text{VO}_2$  max using a progressive graded cycle ergometer test. Waist circumference and Self-Reported Leisure-Time Physical Activity were also recorded. A multinomial logistic regression adjusted for age, smoking and CRF was performed.

The study sample consisted of 686 participants (mean  $\pm$  SD; age =  $25 \pm 4.6$  years, mass =  $80.6 \pm 6.3$  kg). For individual risk factors, a significant inverse association ( $P < 0.05$ ) was found between muscular strength and TG, LDL and BP; however only diastolic BP remained significant after adjusting for CRF. Muscular endurance produced a significant inverse association ( $P < 0.005$ ) with all individual risk factors that remained significant ( $P < 0.05$ ) after the CRF adjustment. For the clustered cardiovascular risk factor score, muscular strength, endurance and CRF were all inversely associated ( $\beta = -0.16, -0.37, -0.32, P < 0.001$ , respectively) when adjusting for age and smoking status. However, strength became non-significant when accounting for CRF and CRF remained independently significant when accounting for both strength and endurance. Leisure-time physical activity had no impact on any associations; however, when accounting for waist circumference in the regression models, all associations became non-significant ( $P > 0.05$ ). In addition, in a model with waist circumference and all fitness parameters included, the strongest

and only relationship with the cluster risk factor score was waist circumference ( $\beta = 0.41$ ,  $P < 0.001$ ).

The primary finding of this study was that muscular endurance and not muscular strength is inversely associated with clustered CVD risk factor scores, independent of CRF. However, there are many strengths and limitations of this study that must be addressed. The large sample size and extensive data set allow the findings to be more generalizable. Though, the cross-sectional design of the study does not allow any causality to be determined. Another limitation of the study would be the use of isometric contractions as a measure of maximal strength. Isometric contractions only allow strength to be assessed at one specific joint angle, whereas joint angles of maximal contraction may be more individualized. Also, as shown by the results including the waist circumference model, body composition may play a greater role in cardiovascular measures in this study than anticipated. A more accurate and detailed measure of body composition (BF% or % lean mass) may produce different results.

Artero, Ruiz, Ortega, Espana-Romero, Vicente-Rodríguez, Molnar, et al. (2011)

The purpose of this study was to investigate the association of muscular fitness and CRF with clustered metabolic risk factors in adolescents. The authors chose this younger population because the onset atherosclerosis has been suggested to begin during adolescence. This study recruited 709 school-aged children (12.5–17.5 years old). An isometric grip strength dynamometer was used to assess upper body strength. A standing long jump test was used to assess lower body explosive power. The z-scores of each value was computed and summed to create a composite muscular fitness score. A 20 meter shuttle run test to failure was used to assess CRF. A continuous metabolic risk factor profile was computed using waist circumference, systolic BP, insulin

resistance (as measured by the homeostasis model assessment), TG, and TC/HDL. Each variable was transformed into a z-score and summed.

Partial correlations of individual risk factors and individual fitness tests revealed that each risk factor correlated weakly but significantly with each fitness test, with the exception of systolic BP on standing long jump and the 20 meter shuttle run. An analysis of covariance was used to assess the difference in clustered metabolic risk factors between quartiles and tertiles of muscular strength and CRF. *Post hoc* analyses revealed that 1) participants in the lowest quartile for strength or CRF displayed significantly higher metabolic risk profile scores ( $P < 0.05$ ) than all other quartiles, and 2) participants in the lowest tertiles of both muscular fitness and CRF displayed significantly higher metabolic risk scores ( $P < 0.001$ ) than all other groups. Multiple regression models were used to determine the association between each categories of fitness and cluster metabolic risk scores. Model 1 only adjusted for age, sex, pubertal status and location. Then to test independent associations, Model 2 also accounted for the other fitness variable. The regression analysis revealed that each muscular fitness and CRF scores is negatively associated with the cluster metabolic risk score ( $\beta = -0.33$ ,  $P < 0.001$  and  $\beta = -0.38$ ,  $P < 0.001$ , respectively), even when accounting for the other fitness variable ( $\beta = -0.24$ ,  $P < 0.001$  and  $\beta = -0.26$   $P < 0.001$ , respectively).

The most relevant finding of this present study is the exponential relationship between levels of fitness and risk for adverse metabolic profiles. Although the results show that there is an independent relationship between muscular fitness and these profiles, there seems to be a compounded effect when accounting for CRF. Cardiorespiratory fitness may not work alone when protecting against CVD. The importance of muscular strength is highlighted in this study.

However, the use of a cross-sectional design in adolescents deters causality, leaving more information on the influence of muscular strength on CVD risk in adults to be researched.

### *Isokinetic Muscular Strength*

#### Ivy, Withers, Brose, Maxwell, Costill (1981)

Unlike isometric contraction measurements, isokinetic contractions are more sensitive to different contractile properties, and can therefore be used to investigate differences in fiber type composition. The purpose of this study was to investigate these contractile properties (torque, power, work) between fiber type compositions in the vastus lateralis at various angular velocities during an isokinetic leg extension muscle action. Fiber type composition based on myofibrillar ATPase was determined by histochemical analysis of a vastus lateralis biopsy. A total of 15 male subjects aged 19-39 years (mean  $\pm$  SD, height =  $181.7 \pm 6.6$  cm, mass =  $77.4 \pm 7.6$  kg) were classified based on percentage of fiber types, either fast-twitch (FT) with  $\geq 60\%$  FT fibers, slow-twitch (ST) with  $\geq 60\%$  ST fibers or INT for intermediate. All isokinetic contractions were performed in a seated position against a lever arm attached to the participant's lower leg and the axis of rotation set at the knee joint. Participants were encouraged to produce maximal isokinetic force as the leg was extended from  $90^\circ$  flexion to full extension at angular velocities of 300, 240, 180, 120, or  $60^\circ/s$ . Maximum isometric force was also measured at  $65^\circ$  below extension. Peak torque, total work, peak power and rate of power production were all calculated and compared between FT (n = 5), INT (n = 5) and ST (n = 5) groups by analysis of variances (ANOVA) or a t-test.

According to t-tests between FT and ST dominant participants, peak torque, peak power, total work and total power were significantly greater in FT dominant group at each angular velocity except  $60^\circ/s$ . An ANOVA revealed that rate of power production was significantly greater in FT

than ST for angular velocities of 180°/s and above with the difference increasing significantly as velocity increases. A torque-velocity curve of mean torque produced at each velocity revealed that for all participants' peak power occurred between 180 and 240°/s. Subsequently, correlation coefficients were calculated for work and peak power with percent of FT fibers present in the muscle biopsy. The highest correlations for both work and peak power with FT fibers were found at 180°/s ( $\rho = 0.69$  and  $\rho = 0.57$ , respectively).

The results of this study are not surprising, as it has been suggested that the faster shortening cycle of FT fibers could influence contractile properties that incorporate force development (i.e. power and rate of power production). This study presents evidence that when using isokinetic dynamometry to examine factors that may be influenced by fiber type, an appropriate angular velocity must be chosen to ensure sensitivity to change. For studies investigating knee extension strength and fiber composition, the author suggests an angular velocity of at least 180°/s.

*Brown, Whitehurst, Gilbert, Buchalter (1995)*

The term load range has been used to describe the portion of an isokinetic muscle action in which a dynamometer would provide constant velocity resistance to the lever arm, through a given range of motion. However, the portion of time before and after this period of contraction is characterized by acceleration and deceleration in which the dynamometer offers no resistance. The aim of the current study was to characterize the effect of angular velocity and gender on the acceleration phase, the load range, and the deceleration phase during isokinetic leg extension. A total of nine males and nine females participated in this study. Participant set up and dynamometer procedures was identical to previous studies<sup>13</sup>. After a dynamic warm up, participants completed two maximal leg extension and then flexion concentric muscle actions at a preset order of 60, 120,



180, 240, 360, and 450°/sec with a rest between velocities. A repeated measures multivariate ANOVA (MANOVA) was run on range of motion (ROM) during the acceleration phase, the load range, and the deceleration phase of contraction between angular velocities. A secondary ANOVA was run to determine gender differences.

The primary results indicate that load range decreases, and the associated acceleration and deceleration phase increase with increasing angular velocities in both leg extension and flexion in both men and women ( $P < 0.05$ ). The authors suggest this is due to the increased time required to reach higher velocities. The secondary results indicated that women have a significantly larger part of their ROM coming from acceleration (e.g. slower rate of velocity development) and smaller load range than men in speeds above 240°/sec. It is speculated that this is due to differences in muscle mass as well as muscle fiber type composition. This study indicates that when choosing isokinetic measurements, it is important to select an appropriate angular velocity that will allow a great enough load range for torque to be assessed while also allowing individual differences to be assessed.

## CHAPTER III

### METHODOLOGY

#### Participants

Fifty-one overweight or obese ( $BMI \geq 25\text{kg/m}^2$ ) career firefighters aged 18-50 years were recruited for this study. Career firefighters were solicited from fire departments in the Chapel Hill and Raleigh-Durham area. A participant was excluded if they: 1) had a neuromuscular or metabolic disease or condition; 2) if they were pregnant or may become pregnant; 3) had a current or recent (within the past 3 months) joint or muscle problem of the lower body that would not allow them to complete the testing; 4) had performed heavy resistance training (at least three days a week) within the past three months; 5) had supplemented with sport nutrition products (creatine, whey protein, beta-alanine, etc.) in the last three months; or 6) had lost or gained 15 pounds within the last month. Participants were not excluded if they were on any metabolic, hypertension or lipid lowering medications. However, medication information was recorded on the health history questionnaire.

#### Study Design

Participants reported to the Exercise and Sport Science Department at UNC-CH on two separate occasions, totaling approximately two hours. The first visit was a 30 minute screening and testing familiarization session; which included practice for the strength assessments. The second visit lasted approximately 90 minutes. During the first visit, participants were asked to read

and sign an informed consent document and fill out a health history and exercise status questionnaire. Participants were then familiarized with all assessments to be performed.

Visit two occurred approximately three to 10 days after visit one where the following measurements were taken: 1) height and body mass, 2) resting vitals, 3) blood lipids, 4) body composition, 5) visceral fat thickness, and 6) isokinetic leg extension strength. For the blood lipid analyses and body composition measurements, participants were instructed to visit the lab following an eight hour fast (except water) and refrain from exercise for 24 hours.

### Height and Body Mass

Height (HT) and body mass (BM) were measured to the nearest 0.5 cm and 0.01 kg, respectively, with a calibrated stadiometer (Detecto, Webb City, MO, USA) and scale (BOD POD®, Life Measurement, Inc., Concord, CA.). BMI was then calculated using the following equation  $BMI = BM/HT^2$  (kg/m<sup>2</sup>).

### Resting Vitals

Resting blood pressure (BP) was measured with an automatic blood pressure cuff (Omron Healthcare Co. Ltd., Kyoto, Japan) after participants rested in a supine position for approximately 10 minutes. Blood pressure cuff size was chosen for each participant according to manufacture guidelines. Blood pressure was measured twice with one minute in between and the average was recorded.

### Blood Lipids

A person trained in phlebotomy drew a five mL venous blood sample in the Neuromuscular Research Laboratory. The sample was placed into a K3-EDTA blood collection tube and

immediately put on ice. A fasting blood lipid panel was analyzed by Mclendon Laboratories of UNC-Chapel Hill Hospital, including high-density lipoproteins (HDL), low-density lipoproteins (LDL), and triglycerides (TG).

### Body Composition

A four-component (4-C) model for body composition was used to determine fat mass (FM), fat-free mass (FFM), and BF%, using air displacement plethysmography, dual-energy X-ray absorptiometry and bioimpedance spectroscopy as described by Wang et al. in 2002<sup>41</sup>:  $FM (kg) = 2.748(BV) - 0.699(TBW) + 1.129(Mo) - 2.051(BM)$ . The measurements for body volume (BV), total body water (TBW), bone mineral (Mo) are described below. Fat-free mass was calculated by subtracting FM from BM while BF% will be calculated using the following equation:  $BF\% = (FM/BM) \times 100$ .

Air displacement plethysmography was used to estimate BV with a calibrated BOD POD (Cosmed, Inc., Rome, Italy). Before testing, participant removed all metal, including jewelry, watches, necklaces, and glasses; then while wearing tight spandex shorts and a swim cap, they were sealed in an egg-shaped fiberglass chamber. Using a predicted thoracic gas volume, BV was calculated based on the inverse relationship between air volume and pressure under isothermal conditions and represented by Boyles Law ( $P_1/P_2 = V_2/V_1$ ). The participant was instructed to remain still and breathe normally during testing.

Dual-energy X-ray absorptiometry (DEXA, Hologic Discovery W, Apex v2.0, Bedford, MA, USA) was used to estimate BMC. For the DEXA scan, each participant rested supine centered on the DEXA table after removing all items from their person. Each participant was instructed to lay as still as possible while the DEXA arm scanned from head to toe. Bone mineral content (BMC) was converted to bone mineral (Mo) using the following equation<sup>41</sup>:  $Mo = BMC / 0.9582$ .

ImpediMed SFB7 (ImpediMed, Inc., Carlsbad, CA, USA) bioimpedance spectroscopy (BIS) was used to estimate TBW. BIS was used while each participant was lying supine on a padded table. Consideration was used to ensure participant had no contact with metal during their test. Electrodes were placed at the distal ends of the participants' right hand and foot. Prior to electrode placement, excess body hair was shaved, and the skin at each site was cleaned with alcohol. HT, BM, age and sex were entered into device and the average TBW calculated from the two trials was recorded.

### Visceral Fat

Visceral fat of the abdomen was assessed with a brightness mode (B-mode) portable ultrasound (US) imaging device (LOGIQe 5, General Electric Company, Milwaukee, WI, USA) and a multi-frequency linear-array probe (12L-RS; 5-13 MHz; 38.4 mm FOV) (General Electric Company, Milwaukee, WI, USA) at a site one cm above the umbilicus along the xypho-umbilical line, as previously done by Pontiroli et al. in 2002.<sup>29</sup> For the US assessment, participants rested on a padded table in a supine position for 10 minutes to allow for any fluid shifts.<sup>6</sup> Hypoallergenic water-soluble transmission gel (Aquasonic 100, Parker Laboratories, Inc., Fairfield, NJ, USA) was applied to the participant's skin to reduce field artifacts and enhance acoustic coupling. Depth was adjusted to each individual to include the epithelial line and the aorta. Adiposity was measured as the distance between the internal surface of the rectus abdominis and the rear wall of the aorta, using the measure function, as described by Armellini et al.<sup>2</sup>

### Cardiovascular Disease Risk Factors

A CVD risk factor profile was calculated from the following variables: systolic blood pressure (SBP), diastolic blood pressure (DBP), HDL, LDL, TG, BF%, and visceral fat. Each

variable was transformed to a z-score based on the sample mean and standard deviation. The z-scores for all risk factors of an individual were summed to create a continuous CVD risk factor score for that individual, as done in previous literature.<sup>1,3</sup> The negative z-score of HDL was used, as it is negatively associated with CVD risk. A lower overall score would indicate a better overall CVD risk factor profile.

### Isokinetic Muscular Strength

Isokinetic muscular strength was assessed during a maximal concentric isokinetic muscle action of the leg extensor muscles using a calibrated HUMAC Norm dynamometer (Computer Sports Medicine Inc., Stoughton, MA, USA). All participants were seated in the dynamometer with a restraint harness around both shoulders and around the waist with the right limb strapped down around the thigh using a Velcro restraining strap (90 mm width). The participant's right leg was secured to the lever arm using a padded Velcro strap (90 mm width) around the leg just proximal to the lateral malleolus. The participant's knee was aligned with the dynamometer's axis of rotation. Participant's range of motion (ROM) was set using a handheld goniometer. Before performing maximal contractions, each participant performed three to four submaximal trials as a warm-up. Participants then performed three maximal isokinetic contractions at randomly ordered velocities of 60°/sec and 240°/sec with two minutes recovery between velocities. Participants were instructed to extend the leg from 90° of flexion as hard and as fast as they can. Participants were given strong verbal encouragement during each contraction.

### Signal Processing

The torque (Nm) signals from the dynamometer were sampled at 2 KHz and recorded simultaneously with a Biopac MP150WSW data acquisition system and AcqKnowledge software

(Biopac Systems, Inc., Santa Barbara, CA, USA). All digitized signals were stored on a personal computer (Think Pad T420, Lenovo, Morrisville, NC, USA) and processed off-line with custom-written software (LabView 8.5, National Instruments, Austin, TX, USA). The torque signals were filtered using a fourth order, zero phase shift low pass Butterworth filter with a 10 Hz cutoff frequency. Peak torque (PT) was determined as the highest (100 data points) 50-ms epoch during constant angular velocity.<sup>12</sup> The repetition with the highest PT was selected and normalized to body mass for analysis.

### Cardiorespiratory Fitness

An estimated measure of cardiorespiratory fitness (CRF) was assessed using the following functional aerobic capacity prediction models ( $R = 0.812$ ,  $SE = 5.35 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ) developed by Jackson et al.<sup>14</sup>

$$\text{Female: } \text{VO}_{2\text{peak}} = 50.513 + 1.589(\text{PA-R}) - 0.289(\text{Age}) - 0.552(\text{BF}\%)$$

$$\text{Male: } \text{VO}_{2\text{peak}} = 56.376 + 1.589(\text{PA-R}) - 0.289(\text{Age}) - 0.552(\text{BF}\%)$$

Parameters include age, body fat percentage (BF%), and physical activity level (PA-R) as assessed by the exercise status questionnaire.

### Statistical Analysis

Descriptive statistics are reported as mean  $\pm$  standard deviation. Normality assumption was assessed using the Shapiro-Wilk test of normality. If any dependent variable was found to not be normally distributed, variable was transformed using natural log (ln) before running further analysis. Pearson's correlation coefficients were calculated to determine the relationship between isokinetic muscular strength and the clustered CVD risk factor profile for each isokinetic velocity.

To account for differences in CRF, a partial correlation coefficient was used to examine the relationship between strength and the clustered CVD risk factor when controlling for CRF. All analyses were performed on SPSS version 20.0 (SPSS, Inc., Chicago, IL, USA) with an alpha level set *a priori* at  $P \leq 0.05$ .



## CHAPTER IV

### RESULTS

#### Participant Characteristics

Forty-nine firefighters were enrolled from central North Carolina fire departments, while forty-three (41 males, 2 females) had complete data on risk factors and strength measurements. According to BMI criteria, 29 firefighters were found to be obese ( $BMI \geq 30 \text{ kg/m}^2$ ), while 14 were overweight ( $25 \leq BMI \leq 30 \text{ kg/m}^2$ ). Both female participants were taking hormonal contraceptives for the duration of the study. Physical characteristics, CRF ( $VO_2$  peak), and strength descriptive statistics are listed in Table 1.

#### CVD Risk Factors

The Shapiro-Wilk test for normality indicated HDL, TG, and  $VO_2$  peak were not normally distributed ( $P = 0.008$ ;  $P < 0.001$ ; and  $P = 0.013$ , respectively). Therefore, the natural log for the variables were used for further Pearson's product correlation analyses; however, raw means and standard deviations are reported. Descriptive statistics for all CVD risk factors and CVD risk factor profile are listed in Table 2.

#### Relationship between CVD Risk Factor Profile and Strength

Relative PT for  $60^\circ/\text{sec}$  was found to not be normally distributed so the values were transformed using natural log for further analyses. According to the Pearson's product correlation, CVD risk factor profile was not significantly related to isokinetic PT at both  $60^\circ/\text{sec}$  ( $r = -0.10$ ,  $P = 0.51$ ) and  $240^\circ/\text{sec}$  ( $r = -0.14$ ,  $P = 0.37$ ). After controlling for CRF, these relationships remained

non-significant for 60°/sec and 240°/sec isokinetic PT ( $r = 0.04$  and  $r = -0.01$ ,  $P > 0.05$ , respectively). Figures 1.A and 1.B show the distribution of relative isokinetic PT across CVD risk factor profiles.

## CHAPTER V

### DISCUSSION

Firefighters are critical to public safety due to their role in emergency services and must be able to withstand cardiovascular and muscular exertion. However, approximately 80% are overweight or obese and display poorer than average fitness.<sup>10,18,22,34,38</sup> This is the first study to examine the relationship between CVD risk factor profiles and isokinetic strength in overweight and obese career firefighters. The primary findings of this study indicated there was no significant relationship between CVD risk factor profiles and isokinetic leg extension strength at either slow and fast angular velocities prior to and accounting for CRF.

Previous findings have demonstrated that there is an inverse relationship between muscular strength and CVD risk factor profiles.<sup>3,17,21,39,42</sup> These findings were reported in youth boys and girls<sup>21</sup> and adolescent boys.<sup>3</sup> In addition, Wijndalele et al.<sup>42</sup>, Jurca et al.<sup>17</sup>, and Vaara et al.<sup>39</sup> reported a similar relationship in adults. However, of these findings one study reported a similar relationship after accounting for CRF<sup>3</sup>, one study reported an attenuation of the relationship after adjusting for CRF,<sup>17</sup> and two studies reported no relationship in men following an adjustment for CRF.<sup>39, 42</sup> As discussed by Jurca et al.<sup>17</sup> it is possible that muscular strength and CVD risk profiles may "...merely [be] a surrogate index of the protective effect exerted by CRF." (pg.1305). These findings are in contrast to the results of the current study which indicated isokinetic muscular strength at both velocities was unrelated to a cluster of CV disease risk factors in overweight and obese firefighters. One of the strengths of the current study was the controlled isokinetic strength

testing at a slow and fast velocities. This was recently recommended by Artero et al.<sup>3</sup>, who indicated future studies should include the “... use of laboratory tests such as isokinetic strength” (pg.710). Despite these strengths, the present results do not support a protective effect of muscular strength on the CVD risk factor profiles. Future studies might consider investigating this relationship in individual risk factors in an overweight and obese firefighter population to determine any individual protective effect of muscular strength.

The differences between our findings and these previous studies may be due to an inadequate sample size, and the current CVD risk profile of our study sample. Previous studies that have reported an inverse relationship included sample sizes from 709 to 8570 participants,<sup>3, 17,21,39,42</sup> whereas the sample size from this study included 43 firefighters. Future studies should consider examining a larger firefighter population. An additional limitation of the current study may be that the present sample may represent a healthier group of adults despite their above average BF% values. For example, previous studies in similar aged, non-obese samples report mean blood ranges from 1.03-1.44 mmol/L for triglycerides, 2.43-3.59 mmol/L for LDL, and 1.18-1.49 mmol/L for HDL<sup>17,39</sup>, while the current blood lipid mean values fell within these ranges, with 1.31 mmol/L for triglycerides, 2.85 mmol/L for LDL, and 1.09 mmol/L for HDL. Because the CVD risk factor profile is composed of multiple different z-scores, it is dependent on measurements from within the sample. The sample selected for this study may be too homogenous to determine any relationship within itself. For example, Artero et, al.<sup>3</sup> found no difference in metabolic risk scores between the three highest quartiles of muscular strength, but found the lowest quartile to have a significantly greater score than the others. As indicated by Wijndaele et al.<sup>42</sup> “a more heterogeneous sample, including more unhealthy individuals and therefore, more extreme values.” (pg.239) may yield a stronger relationship. Recent literature has also started examining

the phenomenon known as the “obesity paradox”, which hypothesizes CRF and not obesity is a better predictor of CVD and all-cause mortality than BMI.<sup>4</sup> This could potentially explain why the healthier CVD risk profile was seen in the study sample. Additionally, total body lean mass may influence the ability to regulate these blood lipids and blood glucose, thereby improving observed cardiovascular risk factors. Higher levels of lean mass may exert a protective effect against greater cardiovascular and metabolic risk itself, with muscular strength as a consequence of greater lean mass. In future studies, controlling for lean mass may elicit significant relationships between strength and cardiovascular risk factors. Furthermore, future studies might consider examining inflammatory markers as indicators of CVD, as they have been shown to be sensitive to differences in muscular strength.<sup>8,9,31,33,40</sup>

In conclusion, our findings suggest that there was no inverse relationship between isokinetic muscular strength at both slow and fast velocities and CVD risk factor profiles in overweight and obese firefighters. These findings are in contrast to previous studies,<sup>3,17,21,39,42</sup> which may be due to the smaller sample of firefighters with healthy CVD risk profiles.

## APPENDIX A: TABLES

(Appendices are not to be copyrighted)

Table 1: Participant Characteristics

Measure	Mean $\pm$ SD
Age (years)	36.6 $\pm$ 7.4
Height (cm)	179.8 $\pm$ 7.1
Weight (kg)	106.6 $\pm$ 20.5
VO <sub>2</sub> peak (mL/kg·min)	36.3 $\pm$ 5.9*
Relative 60°/sec PT (N·m/kg)	1.9 $\pm$ 0.5*
Relative 240°/sec PT (N·m/kg)	1.1 $\pm$ 0.3

\*Not normally distributed

Table 2: Cardiovascular Risk Factors

Risk Factor	Mean $\pm$ SD
DBP (mmHg)	75.9 $\pm$ 8.6
SBP (mmHg)	127.6 $\pm$ 10.3
HDL (mg/dL)	42.3 $\pm$ 11.5*
LDL (mg/dL)	110.4 $\pm$ 19.6
TG (mg/dL)	116.7 $\pm$ 63.3*
BF%	30.4 $\pm$ 5.2
Visceral Fat (cm)	2.5 $\pm$ 0.7
CVD Risk Factor Profile	0.0 $\pm$ 3.5

\*Not normally distributed

APPENDIX B: FIGURES

(Appendices are not to be copyrighted)

Figure 1. A.

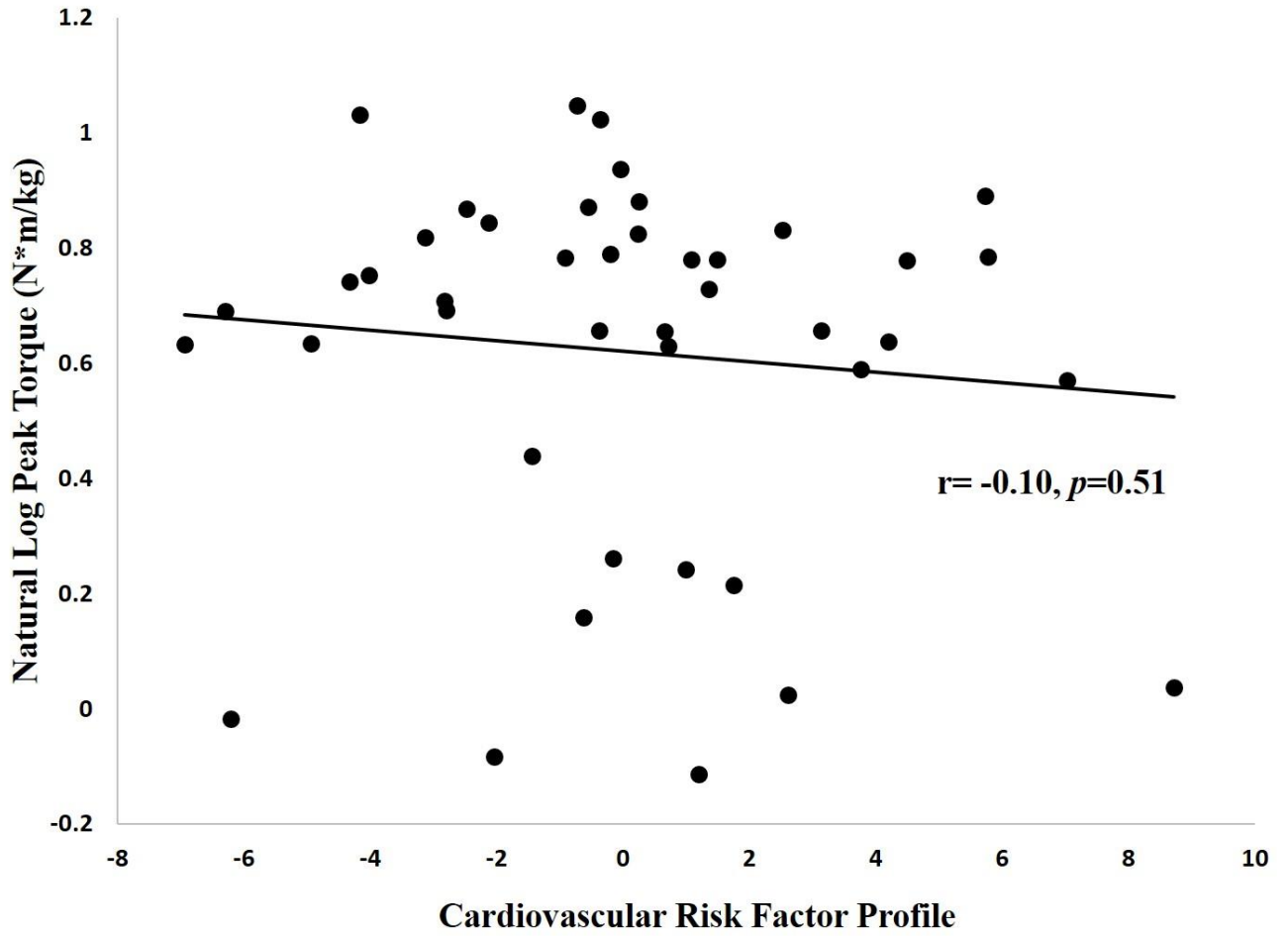
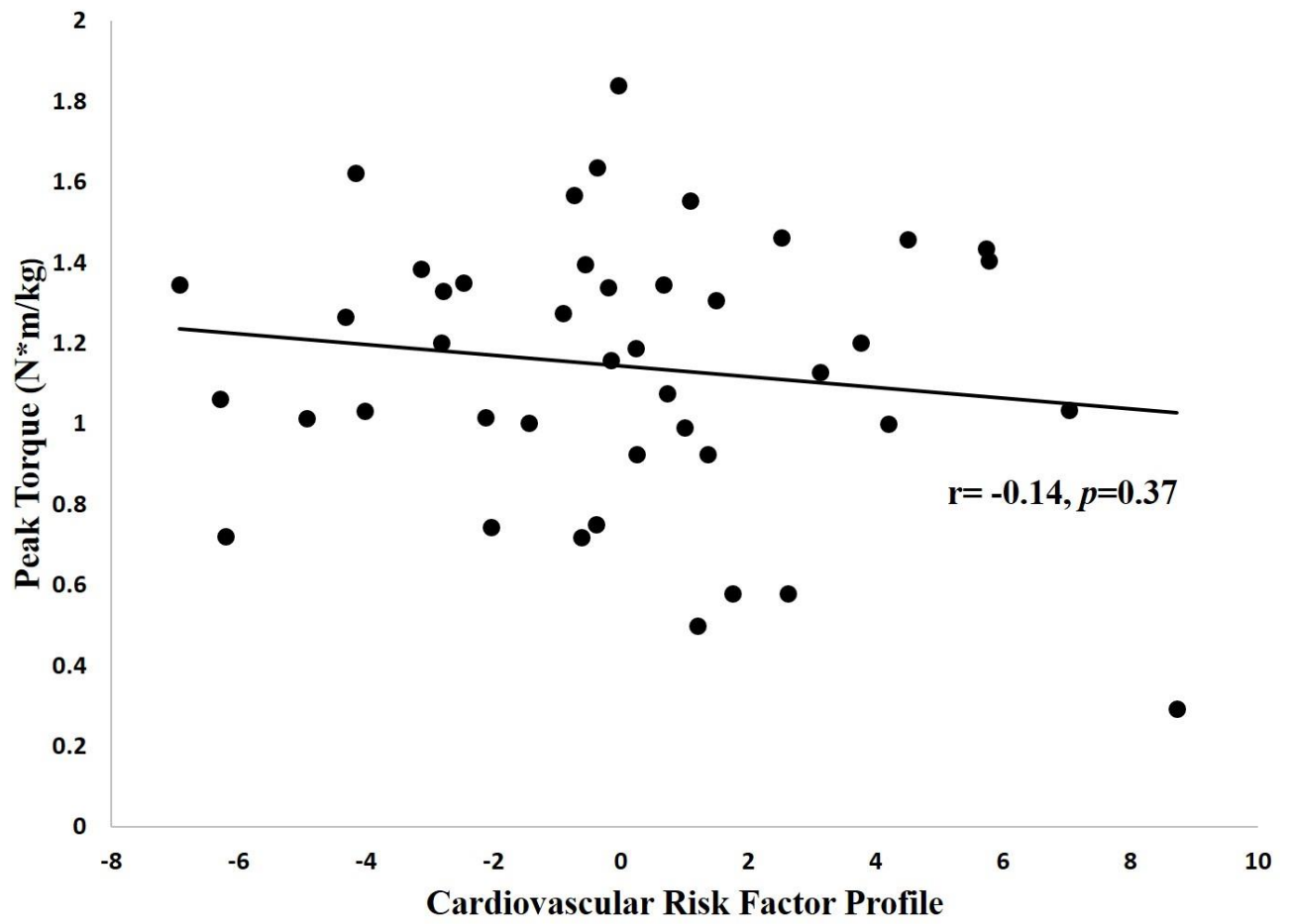




Figure 1.B.



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