THESIS

ANTHROPOMETRIC INDICATORS OF OBESITY AND THEIR LINK TO LIFESTYLE AND CARDIOVASCULAR RISK IN COLORADO FIREFIGHTERS

Submitted by

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ABSTRACT

ANTHROPOMETRIC INDICATORS OF OBESITY AND THEIR LINK TO LIFESTYLE AND CARDIOVASCULAR RISK IN COLORADO FIREFIGHTERS

Cardiovascular disease (CVD) is the leading cause of death in firefighters as it is in the general population. Despite data promoting Colorado as the leanest state in the nation and the image of firefighters as healthy and physically fit, obesity is evident in Colorado firefighters and continues to be an important CVD risk factor. PURPOSE: To determine obesity prevalence, depending on measurement and classification, and its association with lifestyle factors and cardiovascular (CV) risk in a cohort of Colorado firefighters. METHODS: Analysis was conducted on data from 466 Colorado firefighters (41 females; 425 males). Using standard classification cut-points, prevalence of obesity was determined using body mass index (BMI), waist circumference (WC), waist to hip ratio (WHR), sagittal abdominal diameter (SAD), and percent body fat (%BF) from skin fold (SF) and hydrodensitometry (H) measurements. Lifestyle factors used in the analysis included diet, physical activity, sleep, tension and depression. Lipids, C-reactive protein (CRP) levels, predicted maximal oxygen consumption and fitness measures were also included. CV risk was assessed using the Cooper Risk Profile. Correlation statistics were run for each anthropometric measure with the above variables. RESULTS: Obesity prevalence varied by measurement: BMI=9.8% females, 19.1% males; WC=19.5% females, 18.9% males; WHR=19.5% females, 8.0% males; SAD=31.6% females, 43.5% males; %BF(SF)=17.1% females (7.3% for >35%BF), 15.1% males; %BF(H)=23.7% females (13.2% for >35%BF), 28.6% males. In both sexes, all anthropometric measures were positively correlated with triglycerides and CRP and inversely associated with high-density lipoprotein cholesterol (except BMI in females), the sit and reach test and estimated maximal oxygen consumption (except BMI in females) ($p \leq 0.05$). All anthropometric measures were significantly correlated with CV risk ($p \leq 0.05$) except WHR in females. The strongest link to CV risk was %BF(SF) in females and WHR in males. CONCLUSIONS: The prevalence of obesity in Colorado firefighters varies depending on the measure used. There are significant associations between obesity and lifestyle factors that should be further explored. Percent BF(SF) and WHR may be appropriate in assessing CV risk in populations of female and male firefighters, respectively, of similar demographics.

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CHAPTER I

INTRODUCTION

In a recent assessment of emergency responder recruits (n=160 ambulance and 210 firefighter candidates), 43.8% were overweight and 33.0% were obese. The recruits were between the ages of 18 and 35 years and expected to be in peak career shape, yet 7% of overweight and 42% of obese candidates were unable to meet the minimum cardiovascular exercise threshold of 12 metabolic equivalents (MET) (Tsismenakis et al., 2009). The prominent physical components of firefighting including dragging, lifting, and controlling active fire hoses, lifting and carrying heavy materials, running stairs and climbing ladders, which can result in peak heart rates of over 96% of maximum heart rate, and MET values above 16 (Del Sal et al., 2009).

In addition to negative impacts on performance, obesity is associated with higher rates of cardiometabolic conditions including cardiovascular disease and diabetes. The Jackson Heart Study showed that visceral and subcutaneous adipose tissue (VAT and SAT, respectively), which were highly correlated with BMI, were significantly associated with all tested cardiometabolic risk factors including systolic blood pressure, triglycerides, fasting plasma glucose, and inversely with high density lipoprotein cholesterol (HDL-C) and physical activity score. Additionally, significant correlations with VAT and SAT were observed for hypertension, diabetes, and metabolic syndrome in both sexes, even after adjusting for BMI, age, smoking and alcohol use (Liu et al., 2010).

Therefore, obese firefighters are at greater risk of cardiovascular events, which could affect not only the firefighter, but potential victims and fellow firefighters as well.

Researchers continue to try to pinpoint both causes and outcomes of obesity. Obese individuals tend to have higher total and low-density lipoprotein cholesterol (LDL-C), with decreased levels of HDL-C than individuals of normal weight, and increased triglyceride and blood glucose levels (Carroll et al., 2005; Tsismenakis, et al., 2009). While lipid profiles appear to be improving throughout the U.S., despite weight continuing to increase, it is important to consider the effect of increased lipid-lowering medication use (Ingelsson et al., 2009).

Clearly diet plays a major role in the development of obesity. In spite of dietary trends towards reduced cholesterol, total and saturated fat, persistent increases exist in total calories, sugar and more energy-dense foods. From 1971 to 2002, total calories consumed per day increased by approximately 300 kilocalories (kcals) in both men and women (Kant, Graubard, & Kumanyika, 2007). These changes are closely associated with a simultaneous and dramatic rise in obesity. Relatedly, energy expenditure, primarily in the form of physical activity, influences the presence of obesity (Hu, 2003). Sedentary behaviors, particularly in the form of TV watching and computer use, are independently associated with obesity (Ching et al., 1996). Sleep is another variable that appears to be associated with obesity, although a causal relationship has not been established in either direction (Ayas, White, Al-Delaimy, et al., 2003; Peppard, Young, Palta, Dempsey, & Skatrud, 2000). Tension, and/or the unhealthy coping mechanisms used to deal with tension, are related to increased obesity, particularly abdominal adiposity (Bjorntorp, 2001; Mainous et al., 2010). Depression can also lead to obesity, especially excess abdominal adiposity, which may create a cyclical pattern of increased depression (Seidell, 1998; Vogelzangs et al.).

A current objective of Healthy People 2020, which was retained from 2010, is to reduce the proportion of adults who are obese (HHS, 2009). This has resulted in an exorbitant amount of funds dedicated to research and education in an effort to prevent and decrease the economic and social burdens of obesity (Must et al., 1999; Thompson, Edelsberg, Colditz, Bird, & Oster, 1999). However, the fundamental question of how to measure and classify obesity remains. The most common definition of obesity in the U.S. is a body mass index (BMI) of ≥ 30 kg/m^2. While it has been repeatedly demonstrated that BMI is an accurate predictor of cardiometabolic risk, controversy exists regarding its application on an individual level due to its inability to distinguish between fat and fat-ree mass. Furthermore, evidence suggests that BMI tends to underestimate obesity (Kelly, Wilson, & Heymsfield, 2009).

Another common obesity assessment method is waist circumference (WC). Although still highly correlated to BMI, WC is more adept to identify ‘central’ or ‘abdominal’ obesity, which is an independent indicator of increased cardiovascular risk (de Koning, Merchant, Pogue, & Anand, 2007). Similarly, waist to hip ratio (WHR) uses a comparison of the two circumferences to establish a measure of abdominal adiposity against the frame of the hips. However, there is much discord in current research regarding the use of WHR for assessing obesity versus other measurement methods (Pouliot et al., 1994; Welborn & Dhaliwal, 2007).

Sagittal abdominal diameter (SAD) is a more recently developed measure for evaluating abdominal fat depots. It measures the length between the front and back of the abdomen, intending to lessen the influence of body frame inevitably accounted for in WC. SAD is almost always significantly correlated to WC measures (Pouliot, et al., 1994). Research suggests that SAD is another simple anthropometric measure that can be used to assess abdominal obesity and its known link with cardiovascular disease.

An alternative way to assess obesity is to measure overall fat. This can be done using various equipment and techniques, including skin fold measurements and hydrodensitometry (also known as hydrostatic or water weighing). Body fat measures, while still highly associated with measures such as BMI, WC and SAD, tend to produce the highest rates of obesity (McAuley et al., 2009). Even though body fat measures correspond to abdominal fat, they also account for subcutaneous fat which is generally less indicative of cardiometabolic risk (Davidson et al., 1999; Fox et al., 2007; S. R. Smith et al., 2001). Moreover, there is a lack of consensus as to whether ≥30% or ≥35% should be used to classify women as obese (WHO, 1995).

There is apparent need for further clarification regarding measuring and classifying obesity. In order to better understand this condition, it is also necessary to examine the characteristics that accompany it. The abundant sample of firefighters used in this study, and extensive information available on each subject, provides a unique data set from which we can enhance current knowledge of obesity and its effects on workers providing crucial public services.

Statement of the Problem

The purpose of this study is to examine obesity prevalence in firefighters and its association to lifestyle variables and cardiovascular risk, with consideration of the measurement method, in a population whose cardiovascular health and job performance may be particularly affected by obesity.

Hypotheses

1. The prevalence of obesity in firefighters will be highest when determined by percent body fat (%BF), followed by waist circumference (WC), waist to hip ratio (WHR), sagittal abdominal diameter (SAD) and body mass index (BMI).

2. The prevalence of obesity as measured by BMI, WC, WHR, SAD and %BF in firefighters will be similar to the prevalence in the general population of similar demographics.

3. Obesity by all measures (e.g. BMI, WC, WHR, SAD and %BF) will be positively associated with total cholesterol, LDL-C, triglycerides, blood glucose, total calorie intake, total sugar intake, saturated fat intake, tension and depression, and negatively correlated with HDL-C, total fiber intake, physical activity and sleep habits.

4. The level of CV risk in firefighters will be positively associated with all indicators of obesity.

5. WC will have the strongest association with CV risk in firefighters, followed by WHR, SAD, %BF and BMI, respectively.

Definitions

1RM: 1 repetition maximum is the maximum amount of weight an individual can lift in one repetition.

Adipocyte: A fat cell that specializes in the storage of energy as fat and is the primary component of adipose tissue.

ALA: Alpha-linolenic acid is an essential fatty acid found in many common vegetable oils.

Android: Increased upper body mass respective to lower body where fat is deposited primarily in the abdominal region; 'apple shaped' body.

Anthropometric: Relating to the measurement of human individuals to examine physical characteristics and variation.

Atherogenic: Atherosclerosis-causing.

Atherosclerosis: A condition in which arterial walls thicken due to plaque build up and the associated inflammation.

Biomarker: A substance used to indicate a biological state, such as measuring components of the blood to determine cholesterol levels.

BMR: Basal metabolic rate is the amount of energy required to conduct only the essential processes of living while at rest such as breathing and circulation.

Cardiometabolic Risk: A combination of risk factors such as high blood pressure, high blood glucose, elevated triglycerides, low HDL cholesterol, abdominal obesity, smoking and physical inactivity.

Catecholamines: Sympathetic nervous system hormones released by the adrenal glands in response to stress.

Cortisol: A steroid hormone produced by the adrenal glands.

C-PAT: Candidate Physical Ability Test is a timed pass/fail test that candidates must pass to become a firefighter. The C-PAT consists of eight separate events: stair climb, hose drag, equipment carry, ladder raise and extension, forcible entry, search, rescue, ceiling breach and pull; all while wearing a 50 lb vest to simulate firefighting gear.

DHA: Docosahexaenoic acid is an omega-3 fatty acid that can be internally manufactured from ALA or obtained from dietary sources.

Dyslipidemia: Abnormal amounts of lipids in the blood. In the context of this writing it refers to abnormally high levels of blood lipids (fat and/or cholesterol).

EPA: Eicosapentaenoic acid is an omega-3 fatty acid that is a precursor to DHA.

Epinephrine: A catecholamine that increases heart rate, constricts blood vessels and dilates airways.

Gynoid: Increased lower body mass respective to upper body where fat is deposited primarily in the hips and buttocks; 'pear shaped' body.

Hypertrophy: An increase in size, generally referring to bodily tissues or organs due to cell enlargement.

Hypothalamic-Pituitary-Adrenal Axis: The complex system and interactions of the hypothalamus, pituitary gland, and adrenal glands.

Lipolytic: Relating to lipolysis, a metabolic process of breaking down fat.

METs: A MET, or metabolic equivalent, is the metabolic rate while resting. One MET equals approximately 3.5 ml/kg/min of oxygen consumption.

Metabolic Disease: A disease that disrupts normal metabolism, such as diabetes.

MRI: Magnetic Resonance Imaging is a medical imaging technique used to view internal structures such as bones, organs or fat.

Norepinephrine: A catecholamine that acts both locally and generally in response to various stressors.

Postprandial: After a meal.

Relative VO_2peak: In this context, VO_2peak is interchangeable with VO_2max.

Sex-Steroid Hormones: Hormones that interact with androgen and estrogen receptors.

Subcutaneous Adipose Tissue: Fat located underneath the skin.

Triacylglycerides: Interchangeable with triglycerides.

Visceral Adipose Tissue: Fat located between the organs or ‘intra-abdominal’ fat.

Viscous Fiber: Soluble fiber.

VO_2max: The maximum rate at which an individual can consume oxygen. It is usually reported in ml/kg/min to account for body weight.

Delimitations, Limitations, and Assumptions

This study includes data from 466 Colorado firefighters who had previously participated in the Heart Disease Prevention Program (HDPP) at the Human Performance Clinical Research Laboratory (HPCRL) at Colorado State University. Not all subjects had data available on all variables included in this analysis. Therefore, population numbers (n) are noted where appropriate. Although many of the firefighters have participated in the HDPP multiple times, only the first visit of each subject was included in the analysis for consistency.

To calculate body fat via hydrodensitometry, residual volume must be accounted for in the equation. In this study, residual volume was measured by a SensorMedics Vmax 22 starting from HDPP inception until early 2010. At this point, a new pulmonary assessment machine, Medgraphics Ultima Series PX, was installed and used to determine residual volume. This change in equipment could have limited the precision of %BF measured by hydrodensiometry (H). Furthermore, occasionally residual volume results were not physiologically possible, in which case estimated residual volume was used to calculate percent body fat (%BF). Another limitation is the use of self-reported medical and lifestyle questionnaires from which many of the variables were collected. Additionally, for generalizability purposes, minority composition should be considered since Black and Asian individuals are underrepresented in Colorado compared to the national average, and are even less represented in this study population (Bureau, 2010). However, this proposition cannot be validated in reference to firefighter populations because there is an absence of published data on race in firefighters. Moreover, causal relationships cannot be suggested between variables due to the cross-sectional nature of the study.

Finally, it was assumed that laboratory personnel measured and recorded data accurately and consistently and that subjects provided truthful and complete self-reported data.

CHAPTER II

LITERATURE REVIEW

OBESITY

According to data from the 2007-2008 National Health and Nutrition Examination Survey (NHANES), the age adjusted prevalence of obesity in the U.S. is 33.8% (95% confidence interval [CI], 31.6%-36.0%). The prevalence varies depending on race, age and gender (Flegal, Carroll, Ogden, & Curtin, 2010). In Colorado, the prevalence of adult obesity was 19.1% in 2008. While significantly less than the national prevalence, obesity is still present in almost 1 out of every 5 Coloradoans, placing a heavy burden on the state's health and financial resources (CDPHE, 2009).

Obesity increases the likelihood of many diseases including diabetes mellitus, cancer, cardiovascular disease and stroke, and elevates mortality risk (Jaggers et al., 2009; Kalyani, Saudek, Brancati, & Selvin, 2010; Kivimaki et al., 2008; Towfighi & Ovbiagele, 2009; Y. Winter et al., 2008). Hence, obesity's attribution to approximately 280,000 to 325,000 deaths annually in the United States (Allison, Fontaine, Manson, Stevens, & VanItallie, 1999). The Cancer Prevention Study, conducted between 1997 and 2006, showed that obesity is associated with double the risk of all-cause mortality in older adults. The researchers used waist circumference (WC) measures of 48,500 men and 56,343 women, 50 years or older, to determine the following relative risks of all cause mortality: RR = 2.02 (95% CI) for men with WC $\geq$ 120 cm compared to WC $<$ 90 cm; RR = 2.36 (95% CI) for women with WC ≥ 110 compared to WC < 75 cm (Jacobs et al., 2010). While characteristics such as race, ethnicity, gender and age can complicate the effect of obesity, it is clear that obesity is generally associated with an increased risk for disease and death.

In addition to increasing the risk of chronic disease, obesity is expensive on both an individual and society level. Economists have shown that overweight and obese individuals' healthcare costs 37% more compared to people of normal weight, adding an extra $732 to every American's health care bill (Finkelstein, Fiebelkorn, & Wang, 2003; Loureiro, 2004). James and colleagues reported that 60% of the increased incidence in diabetes is the direct result of weight gain (James et al., 2003). In 2007, the estimated total cost of diabetes in the U.S. was $174 billion, including $116 billion in medical expenditures and $58 billion in reduced national productivity (ADA, 2008). Data from 2000 to 2002 showed that, on average, individuals with cardiometabolic risk factor clusters (defined as a BMI ≥ 25 kg/m^2, in addition to two of the following three: diabetes, hyperlipidemia and/or hypertension) missed 179% more work days and spent 149% more days in bed than those without. The resulting loss in productivity had a price tag of approximately $17.3 billion (Sullivan, Ghushchyan, Wyatt, Wu, & Hill, 2007).

Obese individuals also tend to earn less in the workplace. An analysis by Crawley demonstrated that black, white, and Hispanic females, and Hispanic males, earn less wages with increasing weight. White females in particular earn about 9% less wages with each additional 64 lbs., which is equivalent to the wage effect of 1.5 years of education or 3 years of experience (Cawley, 2004). An increased body size may also result in increased expenses for larger clothes, furniture and transportation. Furthermore, obese individuals often pay more for life-insurance premiums and may have increased costs for weight management or control (Seidell, 1998). In addition to calculable costs, obesity can impose personal burdens that reduce overall quality of life including diminished social interaction and physical functioning.

OBESITY IN RESCUE WORKERS

In a 5-year prospective cohort study, the percent of obesity in 332 Massachusetts firefighters increased from 34.9% to 39.7%. On average, firefighters gained 1.15 pounds per year, while those with a BMI $\geq$ 35 gained an average of 1.92 pounds per year. Surprisingly, firefighters less than 45 years of age gained twice as much as firefighters over 45 years of age. Another alarming observation was that weight gain was increasing more each year (Soteriades et al., 2005).

A separate investigation of 370 emergency responder recruits, ages 18-34, showed that 43.8% were overweight and 33.0% obese based on BMI. This is of particular concern because young recruits are expected to be at or near peak career fitness. The mean BMI of the young cohort surpassed that of older veteran responders of the 1980s/1990s. Additionally, higher BMI categories were significantly associated with higher blood pressure, worse metabolic profiles, and lower exercise tolerance (Tsismenakis, et al., 2009).

Effect of obesity on cardiovascular disease

Obesity is a significant independent predictor of cardiovascular disease (CVD) (Hubert, Feinleib, McNamara, & Castelli, 1983). According to a 26-year follow-up of the original Framingham cohort (n=5,209 men and women), the percent desirable weight in men predicted 26-year incidence of coronary disease, coronary death, and congestive heart failure. In women, relative weight based on height was significantly and independently associated with coronary disease, stroke, congestive failure, and coronary and CVD death. Moreover, the data demonstrated that weight gain after the young adult years increased the risk of CVD in both sexes regardless of initial weight or the levels of risk factors which may have resulted from weight gain. This link between obesity and CVD is of particular concern in firefighters due to the alarming occurrence of CVD in this population.

Approximately 44% of all firefighter fatalities that occur on duty are the result of heart disease (not including deaths from strokes or aneurysms). This percentage is derived from the 440 cardiovascular disease-caused deaths out of 1,006 total on duty firefighter deaths that occurred during the ten-year period of 1995 to 2004. Autopsy data showed that 43.5% of the cardiovascular disease victims whose medical history was available (n= 308 out of 440 total) had prior history of one or more heart conditions such as previous heart attacks, bypass surgery or angioplasty/stent placement. Approximately 32.5% of the cardiovascular disease-caused deaths occurred during ground operations, another 25.2% occurred while responding to or returning from alarms and 11.4% occurred during training. The rest of the fatalities occurred while responding to non-fire emergencies, general administrative duties, and other on-duty activities including fire prevention, inspection and maintenance (Fahy, 2005).

According to the Public Safety Officers' Benefits Act of 1976, firefighters who die or are disabled due to the 'direct and proximate result of a personal injury sustained in the line of duty’ are eligible to receive $250,000 from the Bureau of Justice Assistance. Cases are reviewed individually and may cover cardiovascular events that occur on duty if medical evidence does not show that a cardiac emergency was imminent or that the firefighter aggravated the condition with his or her intentional and risky behavior ("The Public Safety Officers' Benefits Act of 1976,"). With nearly 700 claims submitted each year, CVD in firefighters suggests significant socioeconomic consequences.

Percent body fat, regardless of BMI, appears to play a significant role in cardiovascular disease markers. An investigation of 32 men with equal BMIs (30 ±1 kg/m^2) but varying amounts of body fat showed that cardiovascular risks varied in association with percent body fat. Compared to men with less than 15% body fat, men of the same BMI with greater than 15% body fat (determined by hydrostatic weighing) had significantly higher diastolic blood pressure, LDL cholesterol, fasting insulin, glucose and insulin area under the curve (AUC; a method used to assess prolonged status of glucose and insulin), and significantly lower testosterone, estradiol/testosterone ratio and total cholesterol/HDL cholesterol ratio. The men who were overweight, but had less than 15% body fat, had no significant differences from normal weight men with similar body fat percentages. This evidence suggests that excess adiposity, but not elevated body weight, is independently associated with cardiovascular disease risks (Segal et al., 1987).

Being fit or unfit is also an important indicator of cardiovascular disease risk. In a prospective cohort study of 21,925 men, aged 30-83 years, researchers determined that being fit may be a better risk reducer for all cause and cardiovascular disease (CVD) mortality than being lean. Lee et al. separated subjects according to cardiorespiratory fitness by VO_2max in mL*kg fat free mass $(FFM)^{-1}$*min^{-1}. The lowest quartile in each age group was classified as 'unfit' and the highest 3 quartiles were classified as 'fit'. The groups were further divided into 'lean', 'normal' or 'obese' based on body fat percentages (<16.7%, 16.7 to <25.0%, and ≥25%, respectively) to determine relative risks (RR) of all-cause and CVD mortality. The lean, fit category served as the control, resulting in the following RRs of death: lean, unfit = 2.06; obese, fit = 0.93; obese, unfit = 1.92. These data show that obese, fit individuals surprisingly had a slightly reduced risk of death compared to lean, fit individuals and both obese and lean, unfit subjects had an increased RR. In a separate analysis, the fit and unfit subjects were divided into low, moderate, or high waist circumference (WC) (<87 cm, 87 to <99 cm, and ≥99 cm, respectively) to determine all-cause mortality. Here, fit, low WC individuals were the control group. Therefore, unfit, high WC subjects had a RR of 4.71, the fit, high WC category had a RR of 0.98, and unfit, high WC individuals had a RR of 2.47. Such data stresses the importance of cardiovascular fitness in addition to a healthy body composition (Lee, Blair, & Jackson, 1999).

Effect of obesity on job performance

Obesity not only increases the risk of cardiovascular disease and places a significant financial burden on tax-payers, it may also jeopardize emergency victims. While it is difficult to quantify the direct result of obesity on a firefighter's ability to assist victims, a few studies have attempted to examine the effects of obesity on the job performance of firefighters.

One study tested fitness parameters in thirty-eight firefighters to determine how well the results could predict the time required to complete an ability test consisting of six simulated firefighting tasks. Percent body fat had a significant correlation with total ability test score ($r = -0.59$; $p < 0.01$), which shows that as percent body fat increases it tends to take longer for firefighters to finish the ability test (Michaelides, Parpa, Thompson, & Brown, 2007). These results reflect the findings of two similar studies that showed a positive relationship ($r=0.30$) between percent body fat and total test time, supporting the conclusion that high percentages of body fat are associated with poor performance (Rhea, Alvar, & Gray, 2004; Williford, Duey, Olson, Howard, & Wang, 1999).

Antonios J. Tsismenakis and colleagues assessed the effect of increased BMI on exercise tolerance and determined that all normal weight candidates met the minimum exercise requirement of 12 metabolic equivalents, while 7% of overweight and 42% of obese recruits failed to reach the threshold ($P<0.001$). The topic of excess weight clearly warrants attention when nearly half of emergency responder recruits cannot complete the minimum exercise requirement (Tsismenakis, et al., 2009).

In a study conducted on 115 rookie firefighters in Indiana, researchers were surprised to find that prior to a 16-week training program the firefighters had an average BMI of 26.8 ± 4.4 kg/m^2, categorizing their mean BMI as overweight. Moreover, the authors' hypothesis that the pretrained rookies would demonstrate a mean VO_2max of a minimum of 43 ml/kg/min, the level shown to be adequate for duties involved in firefighting, was not supported. The firefighters only had an average of 35 ml/kg/min, which was $88 \pm 20\%$ of that predicted for age- and gender-matched sedentary controls, and approximately 20% below the VO_2max deemed necessary for safe and effective firefighting (Roberts, O'Dea, Boyce, & Mannix, 2002).

In a study that compared 922 firefighters to 1408 police officers of the same region, researchers found that male firefighters weighed less, had a lower body-fat percentage (based on three-site skinfold test), lower prevalence of obesity, and lower muscular strength (assessed with 1RM bench press) than police officer counterparts, whereas the female firefighters weighed more than female police officers and had greater muscular strength, with no major difference between body composition or percent obese. The lower muscular strength data for males were unexpected due to the more vigorous pre-employment physical ability test requirement of firefighters in comparison to police officers. Moreover, firefighters were provided with weight training equipment and on-duty exercise time, while police officers were not. Even when bench press was expressed as a ratio to lean body mass, male firefighters still had significantly lower muscular strength. However, most firefighter tasks require lower body strength, which was not assessed. Additionally, the authors fail to address cardiovascular fitness differences between the two professional groups, which may play a prominent role in both job performance and cardiovascular health. Furthermore, muscular strength could be better assessed by several tests of muscular strength using all major muscle groups, instead of concentrating on the bench press exercise which primarily activates the pectoralis major and minor and the triceps brachii. Female firefighters exhibited greater muscular strength on the bench press test compared to female police officers. The reason for this difference was unknown, although there were far fewer female firefighters (n=37) compared to male firefighters (n=885) and the authors welcomed more research on female rescue workers (Boyce et al., 2008).

IMPLICATIONS OF OBESITY

Obesity is often related to a host of additional conditions, biomarkers, and lifestyle habits. Known associations include increased low-density lipoprotein cholesterol (LDL-C), increased triglycerides, altered dietary and physical activity and sleep habits, and increased depression. Whether these variables are the result of obesity, or the reverse is true, is still unclear. Rationale may indicate a cumulative effect in circumstances such as depression, which can cause decreased physical activity and increased eating, leading to obesity, which could further increase depression (Smits et al., 2010). Each variable is inspected for its relationship to obesity and potential role in the prevalence of obesity in firefighters.

Lipid Profile

According to an examination of NHANES data from 1960-1962 to 1999-2002, total cholesterol levels of adults ages 20 to 74 years has decreased from 222 mg/dL to 203 mg/dL ($p < 0.001$). More specifically, the age-adjusted mean LDL-C decreased from 129 mg/dL to 123 mg/dL in all adults 20 years or older from 1988-1994 to 1999-2002. As for high-density lipoprotein cholesterol (HDL-C), there were no significant differences in men from 1976 to 2002, whereas HDL-C in women increased from 53.8 mg/dL in 1976-1980 to 55.9 mg/dL in 1999-2002 ($p < 0.003$). These changes in serum cholesterol levels are strongly associated with an increase in the use of lipid-lowering medications, which rose from 3.4% in 1988-1994 to 9.3% in 1999-2002 ($p < 0.001$). A more dramatic increase in the use of lipid-lowering medications was observed in adults age 60 years or older during this time (6.8% to 24.3% in men and 8.7% to 21.6% in women). Unlike cholesterol, which showed a trend towards improved levels, serum triglycerides increased significantly from 116 mg/dL in 1988-1994 to 122 mg/dL during 1999-2002 ($p = 0.04$). Increased triglyceride levels are likely associated with the simultaneous increase in obesity prevalence during this period from 22.9% to 30.4% (Carroll, et al., 2005). Contradictorily, a recent study on lipid profiles of the Framingham cohort showed a significant decrease in triglycerides over a 10-year period (144.5 to 134.1 mg/dL in men; 122.3 and 112.3 mg/dL in women; P value = 0.004 in men and < 0.001 in women) with an increase in HDL-C (44.4 and 46.6 mg/dL in men; 56.9 and 60.1 mg/dL in women; P value <0.001 in both sexes). These changes happened in spite of an increase in BMI (27.8 to 28.5 in men; 27.0 to 27.6 in women; P value ≤ 0.001 for both sexes) even after accounting for lipid-modifying drugs (Ingelsson, et al., 2009). In a group of 370 emergency responder recruits (n = 210 firefighters), who ranged in age from 18 to 35 years, both overweight and obese recruits (BMI ≥ 25 kg/m^2 or ≥ 30 kg/m^2, respectively), were significantly associated with higher total cholesterol, LDL-C, triglycerides, and lower HDL-C (Tsismenakis, et al., 2009).

In a separate analysis of NHANES data, 2,587 young adults (men aged 20-35 years and women aged 20-45 years) were examined for coronary heart disease (CHD) risk. Approximately 59% of the subjects either had CHD (self-reported history of angina or myocardial infarction), CHD equivalents (self-reported stroke, diabetes, or fasting blood glucose ≥ 126 mg/dL) or one or more of the following risk factors: family history of early CHD, smoking, hypertension, or obesity. Obesity prevalence alone was 23.6% for men and 31.3% for women ($p < 0.05$; obesity in this case defined as a BMI ≥ 30 kg/m^2). As the number of CHD risk factors increased so did the prevalence of high low-density lipoprotein cholesterol (LDL-C; defined as ≥ 100 mg/dL). Among individuals without CHD risk factors, 10.1% of men and 4.6% of women had high LDL-C. Subjects with two or more risk factors had a high LDL-C prevalence of 25.9% and those with CHD or CHD equivalent had the highest prevalence of high LDL-C at 65.1%. High LDL-C is a risk factor for CHD whose likelihood is clearly increased by obesity (Kuklina, Yoon, & Keenan, 2010).

In a study of 1,437 firefighters from the Dallas Fire-Rescue Department, 142 subjects (10%) were at risk for high cholesterol (≥ 240mg/dL) and 210 subjects (15%) were at risk for high triglycerides (≥ 200mg/dL) (F. D. Winter, Seals, Martin, & Russell, 2010). Another examination of 321 Massachusetts firefighters, who were followed from 1996 to 2000, showed a decrease in total cholesterol from 224 (±39) mg/dL to 214 (±36) mg/dL ($p<0.0001$). Relatedly, the percent of firefighters with high total cholesterol (≥240 mg/dL) decreased from 33.3 to 21.4 ($p<0.0001$). The authors attribute the decrease in total cholesterol to the 9.5% increase in lipid-lowering medication use. This argument is further supported by the subject pool's increase in obesity (BMI ≥ 30 kg/m^2) from 34% to 40% and high triglycerides (≥200 mg/dL) from 27.4% to 35.1% over the study duration. Although only measured at follow-up, it is of interest to note that 17.8% of firefighters had high (160-189 mg/dL) to very high (≥190 mg/dL) LDL cholesterol and 25.6% had low (<40 mg/dL) HDL cholesterol, both of which are recognized risk factors for heart disease. The authors recommended greater medical oversight and preventive wellness initiatives for firefighters due to the large number of subjects with unmanaged, high-risk levels of cholesterol and triglycerides (Soteriades et al., 2002).

Glucose Levels

Obesity is also linked to impaired glucose tolerance, which is often a precursor for diabetes. In a group of healthy, older women, abdominal obesity (WC ≥ 95 cm) was associated with an increased number of abnormal oral glucose tolerance test after 30 minutes compared to women without abdominal obesity (162 ±19 vs. 132 ± 16 mg/dL; $P < 0.01$) (DiPietro, Dziura, & Yeckel, 2010). This evidence suggests that abdominal obesity may impair glucose tolerance, even in healthy individuals. The Framingham cohort showed that, despite significant increases in BMI in both sexes, only men had significant increases in fasting blood glucose levels over the course of 10 years (101.4 to 103.5 mg/dL; $P < 0.01$) (Ingelsson, et al., 2009). The authors did not attempt to explain these findings. The precise mechanisms contributing to the development of glucose intolerance and diabetes are still largely unknown (Tomlinson et al., 2008).

The Dallas Fire-Rescue Department had mean glucose levels of 91 mg/dL in firefighters ≤ 29 years old, 89 mg/dL for 30-39 year olds, 92 mg/dL for 40-49 year olds, and 97 mg/dL in those ≥ 50 years old. This classified 42 firefighters, or three percent, as having high glucose (≥ 126mg/dL) (F. D. Winter, et al., 2010). The longitudinal study of Massachusetts firefighters showed no significant difference in mean blood glucose levels when subjects were divided into two groups of total cholesterol <240 mg/dL and ≥240 mg/dL (96.7±28.2 vs.96.6±12.6 mg/dL, respectively; n=146) (Soteriades, et al., 2002). In an examination of 806 Cincinnati firefighters, the mean fasting glucose was 97±13.9 mg/dL. However, when separated into firefighters who sustained CHD and those without CHD, fasting glucose means were 101±10.1 and 97±14.0 mg/dL, respectively (Glueck et al., 1996). While a majority of firefighters in these studies appear to have normal glucose levels, it is important to continue to explore the relationship between blood glucose levels and obesity in firefighters due to previous findings suggesting an association between the two variables.

Dietary Intake

Dietary intake has a tremendous impact on obesity, which is exemplified in an interesting model created by Dall and colleagues to predict the implications of a 100 kcal/day reduction daily intake in overweight and obese individuals. The researchers deduced that this hypothetical change would eliminate approximately 71.2 million cases of overweight/obesity, and increase national productivity by $45.7 billion in the long term (Dall et al., 2009). However, the opposite trend is occurring. From 1971 to 2002, the average caloric intake increased from 2391 to 2722 kcals in white males and 2220 to 2525 kcals in black males ($p<0.001$), which aligned with the steady increase of obesity from 12% to 29% and 19% to 26% in whites and blacks, respectively. A similar effect occurred in females with an increase in calories from 1530 to 1857 kcals in white women and 1387 kcals to 1843 kcals in black women with an increase in obesity from 16% to 36% and 24% to 47% in white and black females, respectively. In addition to total calories, energy density and percent energy from carbohydrates increased significantly, while percent energy from both protein and fat decreased with saturated fat and cholesterol intake (Kant, et al., 2007).

Fat is a calorically dense macronutrient that can contribute to obesity when consumed in excess. An examination of trends in NHANES data showed that fat consumption, including saturated and monounsaturated, have decreased over the past several decades [2.3% (3.6 g); 1.5% (0.4 g); and 1.3% (0.7 g) respectively). Cholesterol consumption also decreased an average of 64 g. These changes in dietary composition corresponded to the following improved serum cholesterol levels: 8 mg/dL decrease in total cholesterol, 8 mg/dL decrease in LDL-C, and a 1 mg/dL increase in HDL-C (Ernst, Sempos, Briefel, & Clark, 1997). Reports show that a reduction in saturated fat intake, combined with a low-carbohydrate diet and slight increase in physical activity, can significantly improve postprandial triacylglycerides and insulin sensitivity, regardless of persistent obesity (Maraki et al., 2010).

While the effects of fiber in the diet are less evident than other dietary components, there is evidence of benefits with increased fiber intake. One study used a dietary intervention that involved the consumption of two portions per day of whole-grain, ready-to-eat oat cereal containing viscous fiber. In the 77 intervention group participants, dietary fiber consumption increased from 15.8 g/d at baseline to 21.7 g/d at week 12, which corresponded to a significant decrease in total and non-high-density-lipoprotein cholesterol and waist circumference (Maki et al., 2010). Unexpectedly, individuals with diabetes have been shown to consume significantly more energy-adjusted dietary fiber than those with normal blood glucose levels ($p<0.001$) (Scott, McDougle, Schwirian, & Taylor, 2010).

Americans consume an average of 21.4 tsp. of added sugar per day (359 kcal), which translates to 15.8% of total caloric intake (Welsh et al., 2010). This is a sizeable increase from the average 10.6% of calories consumed in the form of added sugar during 1977-78 (Glinsmann, Irausquin, & Park, 1986). The Institute of Medicine recommends a maximal intake of ≤ 25% of energy from added sugars (Institute of Medicine, 2002). Yet a recent examination of NHANES data showed that 13% of the U.S. population's diet is composed of > 25% added sugars. At intakes above 5-10%, each 5% increase in added sugar resulted in less nutrient intake, indicating that consumers of high added sugar diets are at increased risk for nutrient inadequacy (Marriott, Olsho, Hadden, & Connor, 2010). Diets high in added sugars are also associated with atherogenic dyslipidemia and increased risk of cardiovascular disease (Frayn & Kingman, 1995; Parks & Hellerstein, 2000). In order to reduce the incidence of obesity, the 2010 Dietary Guidelines Advisory Committee recommends the avoidance of sugar-sweetened beverages, which are associated with higher body weight (US Departments of Health and Human Services and Agriculture; Vartanian, Schwartz, & Brownell, 2007).

When evaluating self-reported dietary intake, it is important to consider the underreporting of dietary intake, particularly in obese individuals. In nationally representative sample of 7,521 adults, increased odds for underreporting were observed for obese men (OR=2.01, 95% CI 1.46-2.77) and obese women (OR=1.68, 95% CI 1.23, 2.30) compared to participants with a normal BMI (Lutomski, van den Broeck, Harrington, Shiely, & Perry, 2010).

In a study of 33 Portland firefighters, subjects self-reported eating 6.1 to 6.9 servings of fruits and vegetables per day on average. After a wellness intervention to increase the amount of fruits and vegetables consumed and improve other health behaviors, servings went up to 7.2 to 7.4 per day on average in the experimental group, although the increase was not statistically significant (Elliot et al., 2004). In a separate examination of 28 wildland firefighters (2 females; 26 males), the amount of calories, carbohydrates and protein consumed over two days varied depending on the type of meals given to the subjects while fighting wildfires. When given a first strike ration pack, consisting of pocket sandwiches and on-the-go snacks, firefighters ate an average of 22.0±2.4MJ (~5,255 kcals) over the two days with 698 g from carbohydrates, 196 g from protein, and 347 g of caffeine. When given a ready-to-eat ration pack, which consisted of a main entrée and complimentary side items, firefighters consumed a significantly less amount of 18.4±2.5MJ (~4,395 kcals) with 546 g from carbohydrates and 134 g of protein, along with 55 g of caffeine (Montain et al., 2008). Barceló-Coblijn and colleagues studied the effects of fish oil versus flax oil in 62 Winnipeg firefighters. The researchers chose this population due to the traditionally high level of CHD risk factors found in firefighters. After the six groups completed their 12 weeks of varying levels of supplements, it was found that both levels of fish oil supplements (0.6 and 1.2 g/d) and the two highest levels of flax oil (2.4 and 3.6 g/d) significantly increased n-3 concentrations, primarily as a result of elevated ALA, EPA and DHA concentrations. The control group and the group taking 1.2 g/d of flax oil did not have significant increases in n-3 levels. This study suggests that firefighters could benefit from including foods or supplements rich in ALA, EPA and DHA into their diets due to their cardiovascular disease-reducing properties. The scientific literature on the diets of firefighters is minimal; hence, the motivation to explore the link between various dietary factors and obesity prevalence in this analysis.

Physical Activity

Current American College of Sports Medicine (ACSM) physical activity guidelines recommend moderately intense aerobic exercise for 30 minutes a day, five days a week, or vigorously intense cardio exercise 20 minutes a day, three days a week, combined with moderate strength training twice a week for healthy adults under age 65 to maintain health and reduce chronic disease risk. The guidelines note that in order to lose weight or maintain weight loss, exercise may need to be increased to 60 or 90 minutes, five days a week (ACSM, 2007).

Lack of physical activity has been linked to obesity. Two sedentary behaviors common in U.S. society are watching television and using the computer, both of which have demonstrated positive associations with elevated concentrations of insulin, obesity, metabolic syndrome, and diabetes (Ford, Kohl, Mokdad, & Ajani, 2005; Ford et al., 2010; Hu, 2003). In an assessment of a cohort of male health professionals (n=51,529), less physical activity was shown to be a major determinant of overweight in 2 years of follow up. Compared to men in the lowest quartile of physical activity, men in the highest quartile had a 50% lower odds ratio of becoming overweight (95% CI, 45%-55%). Both higher levels of non-sedentary activity and lower levels of TV viewing were independently correlated with reduced relative risk of becoming overweight (Ching, et al., 1996).

A major barrier in the reversal of obesity is pain associated with physical activity due to excess strain on muscles and joints. In a comparison of rates of arthritis and ‘arthritis-attributable activity limitations’ (AAL) between the US and Canada, US rates were noticeably higher (18.7% and 9.3% vs. 16.9% and 7.4% for arthritis and AAL in US and Canada, respectively). Researchers pointed to higher obesity rates and reduced physical activity in the US, especially in women, as potential explanations for the increased rates (Badley & Ansari, 2010). Another obstacle to increased physical activity in overweight and obese individuals is access to safe environments for recreation (CCD, 1999). Additionally, being obese can lead to feelings of embarrassment and/or reduced self-efficacy regarding working out a gym or public recreation center (Burton, Turrell, & Oldenburg, 2003).

Despite such barriers, the importance of physical activity cannot be overstressed. In attempt to clarify the ‘fitness vs. fatness debate,’ Larson-Meyer and colleagues took 36 adults and assigned them to one of three groups: control (CO: weight-maintenance diet), caloric restriction (CR: 25% reduction in energy intake), or caloric restriction plus aerobic exercise (CR+EX: 12.5% reduction in energy intake plus 12.5% increase in energy expenditure). After 24 weeks, both CR and CR+EX experienced significant losses in body weight ($p < 0.001$) of ~10%. Additionally, both groups reduced total body fat mass and visceral abdominal fat by ~25% ($p < 0.005$). Relative VO_{2peak} significantly improved by 22±5% in the CR+EX group ($p < 0.0001$) with a slight, yet non-significant improvement in the CR group by 7±5% ($p=0.06$). While HDL-C was significantly increased ($p < 0.02$) compared to baseline in all treatment groups, only CR+EX experienced significant improvements in diastolic blood pressure, total cholesterol, LDL-C and insulin sensitivity (Larson-Meyer, Redman, Heilbronn, Martin, & Ravussin). Improving aerobic fitness clearly has additional benefits than caloric restriction alone.

Researchers have examined the physical components of firefighting in many ways including studying training regimens, simulated firefighting tasks, and actual firefighting. In a study of the physiological demands of the firefighter Candidate Physical Ability Test (C-PAT), researchers tracked VO_2 and heart rate responses using a portable system in 57 subjects (23 females; 34 males). The subjects were not firefighters, but healthy adults who were familiarized with the C-PAT for two to three weeks before the testing took place. The 32 males who completed the C-PAT had an average VO_2max of 53.0 ± 7.4 mL/kg/min and a max heart rate of 188 ± 8 beats/min compared to 39.3 ± 5.2 mL/kg/min and 200 ± 12 beats/min in the two males who did not complete the C-PAT, although the difference was not significant. For the females, the 14 who finished had an average VO_2max of 51.9 ± 6.3 mL/kg/min and a max heart rate of 188 ± 6 beats/min compared to 45.9 ± 4.4 mL/kg/min and 196 ± 5 beats/min in the 9 females who did not finish the C-PAT, both of which were significant differences ($p < 0.05$). Using backward stepwise regression, the authors determined that absolute VO_2max alone or relative VO_2max, body mass and handgrip strength accounted for more than 67% of the variance in circuit completion time. However, when using such variables alone to predict completion time, the authors received large errors of estimation exceeding 75 s, showing that no single fitness test could accurately predict C-PAT completion time (Williams-Bell, Villar, Sharratt, & Hughson, 2009).

Researchers examined the physiologic effects on 20 Italian firefighters of a simulated firefighting activity that included the following consecutive tasks: child rescue, 250 m run, find an exit, and 250 m run. The tasks were designed to evoke a VO_2 equivalent of 406.26 ± 73.91 mL/kg. After 30 minutes of passive rest, VO_2 was still at an elevated 8.86 ± 2.6 mL/kg/min compared to the basal value of 4.57 ± 1.07 mL/kg/min ($p < 0.0001$) and recovery heart rate was 108 ± 15 beats/min compared to the basal rate of 66 ± 8 beats/min ($p < 0.0001$). The authors also analyzed the relationship between the time of job completion and the fitness level of the firefighters, but found no significant correlation. They attributed this to the considerable influence of psychological stressors in such a simulation. This experiment highlights the unique challenge facing firefighters of undertaking simultaneous, often intense, physical and mental demands (Perroni et al., 2010).

Another study on 13 Italian military firefighters examined which anthropometric variables had the most influence on physiologic effects of firefighting such as heart rate and energy expenditure. Multivariate linear step-wise regression showed that BMI was strongly correlated with mean and maximal heart rate values during firefighting (beta 1.08, $p = 0.05$; beta 1.17, $p = 0.04$). Weight was highly correlated with maximal energy expenditure (beta 0.51, $p = 0.03$), which was measured in METs using a multisensory body monitor in the form of an armband. Such evidence shows that physical fitness and anthropometric characteristics of firefighters influence their performance of firefighting tasks. In particular, BMI was the most influential variable on the physiologic responses of firefighters during live-fire work (Del Sal, et al., 2009).

In a study on the effects of fighting wildfires, researchers intricately measured energy expenditure using doubly-labeled water. They followed 17 firefighters (8 men; 9 women) for 5 days of wildfire suppression in various U.S. states. Tasks used to fight the wildfires included extensive hiking with a load (15-20 kg), fire-line construction with a Pulaski (modified axe for ground scraping), chainsaw work, and brush removal. During the typical 12 to 18 hour work shift, male firefighters expended an average of 20.4 ± 3.0 MJ/d (4,878 ± 716 kcals/d) and female firefighters had an average energy expenditure of 14.8 ± 3.0 MJ/d (3,541 ± 718 kcals/d). When energy expenditure was calculated relative to estimated basal metabolic rate (BMR), there was no significant difference between males and females (2.8 ± .5 xBMR; 2.5 ± .5 xBMR, respectively). The authors observed the variance in energy expenditure to be mostly affected by work assignment, self-selected work intensity, and location of the fire (Ruby et al., 2002). This is one of the few published articles on energy expenditure of firefighters on the job which is why it is included in this review. However, these results apply to the minority of firefighters who partake in fighting wildfires and should not be generalized to all individuals of the profession.

Sleep Habits

Sleeping less than 6 hours or more than 8 hours a night have been identified as risk factors for increased mortality. An assessment of over 1.1 million men and women showed that increased risk exceeded 15% when individuals reported sleeping ≥8.5 hours, <3.5 hours for women, or <4.5 hours for men (Kripke, Garfinkel, Wingard, Klauber, &

Marler, 2002). Studies with large populations (n>10,000) have demonstrated without exception that sleep ≥8 hours is associated with a significant mortality risk (Burazeri, Gofin, & Kark, 2003; Kripke, Simons, Garfinkel, & Hammond, 1979; Patel et al., 2004; Tamakoshi & Ohno, 2004). Researchers speculate that excess sleep could be related to depression, sleep apnea (in which individuals try to compensate for fragmented sleep), the 'process of dying' or disease, poor health related to sleep fragmentation, impaired resistance to stress and disease, or decreased time in daylight (Youngstedt & Kripke, 2004). However, causal relationships have not yet been established.

In a group of 71,617 female health professionals (aged 45-65 years) without reported CHD, both short and long self-reported sleep duration were independently associated with a modestly increased risk for coronary events over a 10-year follow up. Compared to the reference group (8 hours of sleep), women reporting 5 or fewer hours, 6, and 7 hours of sleep had the following relative risks (95% CI) for all CHD events (fatal and non-fatal): 1.39 (1.05-1.84), 1.18 (0.98-1.43), and 1.10 (0.92-1.31), respectively, after adjusting for age, diabetes, hypertension, hypercholesterolemia, snoring, BMI, smoking, exercise level, alcohol consumption, depression, aspirin use, hormone use and family history. The relative risk (95% CI) for ≥9 hours of sleep was 1.37 (1.02-1.85). Thus, getting both below (≤5 hours) and above (≥9 hours) the standard duration of sleep (8 hours) increases CHD risk in women by 39% and 37%, respectively (Ayas, White, Manson, et al., 2003).

Conversely, sleep deprivation can result in short-term consequences. A study in healthy, middle-age males showed that after a single night of sleep deprivation (mean 3.6 hours) subjects demonstrated higher sympathetic nervous system activity (identified by increased norepinephrine in the urine), which led to significantly higher blood pressure and heart rate the day following sleep deprivation (Tochikubo, Ikeda, Miyajima, & Ishii, 1996). Another study imposed short-term sleep deprivation (4 hours per night for 6 nights) on a group of healthy, young men. The intervention resulted in lower glucose tolerance and increased levels of cortisol and sympathetic nervous system activity. The researchers interpreted this data as evidence of sleep deprivation's negative impacts on carbohydrate metabolism and endocrine function which could augment the severity of age-related chronic disorders (Spiegel, Leproult, & Van Cauter, 1999).

Obstructive Sleep Apnea (OSA) is a condition that moderately affects approximately 9% of middle aged men and 4% of women (Young et al., 1993). It is characterized by recurrent upper airway obstruction during sleep (Al Lawati, Patel, & Ayas, 2009). OSA reduces quality of life and is associated with several adverse safety and health consequences including CVD and motor vehicle crashes (Sassani et al., 2004; Shahar et al., 2001). Obesity, particularly central obesity, is a major risk factor for OSA. The proposed mechanisms by which obesity predisposes to OSA include narrowing of the upper airway due to fat deposition, alterations in airway and ventilation, and reduction in lung volumes (Stanchina et al., 2003; Strobel & Rosen, 1996). A prospective study showed that a 10% increase in weight was associated with a 6-fold increase in risk for OSA development while a 10% weight loss was associated with a 26% reduction in sleep apnea severity (assessed by the apnea-hypopnea index) (Peppard, et al., 2000).

Firefighters often have unique working hours and may be on shift up to 48 consecutive hours. The second highest proportion of firefighter deaths while on duty occur while responding to or returning from an alarm (25.2%) (Fahy, 2005). Whether or not the firefighters were sleeping when alarms occurred is unreported. However, it is reasonable to assume that quickly transitioning from sleep (which is typical in longer shifts) to a state of emergency response could put tremendous stress on firefighters' physiologic condition, perhaps contributing to on-duty cardiovascular events. A study in ambulance paramedics showed that altering paramedics' shifts to accommodate for long naps ameliorated subjective fatigue and improved physiologic functions that tend to decline with fatigue, such as reaction time and parasympathetic nervous system activity (Takeyama et al., 2009).

Tension

It has long been speculated that tension or 'stress' may lead to fat accumulation, particularly in the abdominal region, due to alterations in hormone levels. Björntorp and colleagues hypothesized that chronic stress increases visceral adiposity through chronic dysregulation of the hypothalamic-pituitary-adrenal axis, which is detected via high levels of coritsol and low levels of sex-steroid hormones (Bjorntorp, 2001). Stress has also been shown to be the strongest predictor of hypertension, which is strongly associated with obesity (Perez, Gutierrez, Vioque, & Torres, 2001).

Other researchers suggest it is not stress itself that results in obesity, but the unhealthy coping mechanisms individuals use to deal with stress. In an analysis of 5,773 multi-ethnic, middle-aged individuals, no significant relationship was found between chronic life stress and atherosclerosis (OR 0.93, 95% CI 0.80-1.08). However, Mainous et al. discovered that when they calculated the odds ratios of the indirect pathways between stress and atherosclerosis via unhealthy habits, opposed to controlling for them, the following significant relationships were unveiled: smoking (OR 1.46, 95% CI 1.21-1.76), high caloric intake (OR 1.56, 95% CI 1.29-1.88), and sedentary lifestyle (OR 1.16, 95% CI 1.01-1.33). In addition, both high caloric intake and sedentary lifestyle were strongly associated with BMI (OR 1.94 and 1.48, respectively) which was linked to atherosclerosis (OR 1.39, 95% CI 1.22-1.58). Hence, the authors propose that the unhealthy behaviors occur in response to stress and contribute to atherosclerosis, although they emphasize the need for longitudinal studies to confirm these findings (Mainous, et al., 2010).

Tension can be the result of psychological, physiological, or a combination of both stressors. In a computer simulated fire strategies and tactics drill, firefighters were asked to complete computer tasks while running on a treadmill at 60% VO_2max. The results of this challenge were compared to those of a treadmill test alone. While the psychometric measure of the State Anxiety Inventory (SAI) did not vary significantly between tests, the combined mental and physical test did elicit significant condition by time interaction effects in heart rate ($F_{4,44} = 4.24$, $p < 0.05$), respiratory rate ($F_{4,44} = 8.57$, $p < 0.001$), minute ventilation ($F_{4,44} = 6.54$, $p < 0.01$), and ventilatory efficiency ($F_{4,44} = 5.70$, $p < 0.01$). The results suggest that, although the firefighters only perceived an insignificant increase in mental requirements, their cardiorespiratory system responses were significantly elevated when psychological stressors were added to physical demands (Webb et al., 2010).

In a unique prospective examination of post traumatic stress disorder (PTSD), 43 professional firefighters were assessed immediately after basic training for pretraumatic characteristics including symptoms of PTSD, depression, and anxiety in addition to related personality traits and neuroendocrine activity. The firefighters were re-examined after two years for posttraumatic stress symptoms. A high level of hostility and a low level of self-efficacy were both significant predictors of PTSD symptoms. The presence of both characteristics at baseline accounted for 42% of the variance in posttraumatic stress symptoms after two years of service in a fire department ($F = 13.37$, $df = 2, 32$, $p < 0.001$). These changes occurred in conjunction with a significant increase in body weight from 78.33 ± 9.76 kg to 80.49 ± 9.48 kg over the 2 years of follow-up. Firefighters with either low levels of hostility, high levels of self-efficacy, or both showed no increase in psychopathological symptoms, indicating a protective effect of these personality traits in the development or prevention of stress-related symptoms. The authors suggest screening firefighters early in their careers for PSTD predictors and potentially helping those who are particularly susceptible to PSTD (Heinrichs et al., 2005).

Depression

It is reasonable to hypothesize that obesity may lead to depression due to physical conditions and social stigmas associated with obesity (Seidell, 1998; Van Itallie, 1985). Conversely, depression could result in obesity due to potential causal variables such as hormone dysregulation (similar to the consequences of stress), lack of physical activity, and poor diet linked to depression (Bjorntorp, 2001; Piwonski, Piwonska, & Sygnowska). In order to determine which condition more likely causes the other, Pine and colleagues followed 90 adolescents with major depression for 10 to 15 years. After controlling for age, gender, ethnicity, social class, income, and a host of lifestyle variables, the researchers found that adolescents with major depression had an average BMI of 26.1 ± 5.2 in adulthood, while adolescents without depression had a mean BMI 24.2 ± 4.1 as adults (p=.007). Two other variables that predicted adult BMI were poverty and duration of adolescent depression. This research suggests that depression during adolescence can lead to a higher BMI as an adult. With obesity occurring at an increasingly younger age in the U.S., it may be relevant to address depression during childhood to prevent obesity later in life (Pine, Goldstein, Wolk, & Weissman, 2001).

Another concern related to depression is visceral adiposity accumulation. Similar to the effects of stress, depression may result in chronic hormone dysregulation which can lead to abdominal obesity. As mentioned previously, abdominal obesity is of particular concern due to its close association with mortality and metabolic risks (Meisinger, Doring, Thorand, Heier, & Lowel, 2006; Reis, Araneta, et al., 2009; Reis, Macera, et al., 2009). In attempt to track the potential progression of visceral fat accumulation in depressed persons, Vogelzangs et al. followed a cohort of 2088 older men and women for five years. Researchers classified clinical depression in subjects as those scoring 16 or higher on the Center for Epidemiologic Studies Depression scale (CES-D). Abdominal obesity was assessed using computerized tomography (CT) scans, sagittal diameter, and waist circumference. Subjects were divided into three categories of visceral fat change over the 5-year study period (≥30% loss, no change, ≥30% gain). The authors found that, after adjustment for sociodemographics, lifestyle, diseases, and overall obesity, baseline depression was associated with a 5-year increase in both sagittal diameter (β=.054; P=.01) and visceral fat (β=.080; P=.001). These results support the position that depression increases the probability of abdominal obesity (Vogelzangs et al., 2008).

Depression may also play a role in individuals' ability to lose weight. In a study done on 87 U.S. veterans with knee osteoarthritis, which is strongly associated with obesity (Gelber et al., 1999), subjects were more likely to lose weight if they were less depressed. Wolf et al. also used the CES-D to evaluate depressive symptoms in the veterans. The researchers found a strong association between the CES-D score and weight loss at both 16 weeks of follow-up (r=-0.41; $p<0.001$) and 32 weeks of follow-up (r=-0.31; $p=0.01$). The inverse correlation is due to a higher CES-D score indicating greater depression. The only other variable that was significantly predictive of weight loss was nutrition counseling, which was only observed at 16 weeks of follow-up ($p=0.05$). This study indirectly emphasizes the importance of addressing depression in the treatment of obesity (Wolf et al.).

Interestingly, when weight loss does occur there appears to be a significant reduction in depressive symptoms. This effect was observed in 50 morbidly obese patients (BMI 51.7 ± 7.5) who underwent a 'duodenal switch' procedure that reduces the size of the stomach, reducing caloric and some nutrient absorption. At the end of one year, average BMI was reduced to 32.7 and was 31.7 by the end of year two. The Hospital Anxiety and Depression Scale (HADS) used to assess pre-operative symptoms showed moderately greater effect sizes of both anxiety (0.77) and depression (0.72; where effect sizes $0.5>0.8$ = moderate) compared to the population norm. At one year post-surgery, effect sizes were reduced to 0.18 and -0.39 for anxiety and depression, respectively (where effect sizes <0.2 are considered trivial compared to the population norm, and negative scores are better than the population norm). The numbers from the second year of follow-up reflected maintenance of improved anxiety and depression (0.16 and -0.27 respectively). The authors suggest that the main mechanism responsible for the reduction in symptoms of anxiety and depression was likely weight loss induced improvements in self-reported physical health (Andersen et al.). It is apparent that depression and obesity are often interrelated and that depression should be evaluated when assessing physical health, including both causes and effects of obesity.

Firefighters and rescue workers may be particularly susceptible to suicide and the depression that tends to precede it. In the Journal of Emergency Medical Services, two experienced Colorado firefighters relayed their experiences of how depression and suicide affect both patients and providers. Due to a dearth of formal information on the topic, they encourage the collection of accurate data on work-related stress, suicide attempts and completions to help identify trends within the industry. To build upon the U.S. Department of Health and Human Services' 2001 National Strategy for Suicide Prevention, Goals and Objectives (NSSP), the authors support a comprehensive suicide prevention strategy targeted to emergency rescue workers that improves access to mental-health counseling and develops a responder support network (Zygowicz & Grill, 2011).

In a study of Indian firefighters, both self-reported neurobehavioral symptoms and objective plasma catecholamine concentrations were assessed to determine the prevalence of anxiety, depression and other neurobehavioral conditions. Anxiety was not statistically significant compared to the control (40.3%; n=62 firefighters vs. 38.4%; n=52 controls). However, self-reported neurobehavioral symptoms of depression were a significant 52.6% in firefighters ($p < 0.05$; n=62). After controlling for age and smoking as possible confounders, firefighting was still associated with an increased prevalence in depression (OR=1.23; 95% CI, 0.73-2.01). Correspondingly, epinephrine levels were 2.4 times greater and norepinephrine levels were 2.7 times greater than control levels, while dopamine levels remained relatively unchanged. Both physical and emotional stress can elevate plasma catecholamine levels, which may explain the high level of depressive symptoms in the Indian firefighters (Ray, Basu, Roychoudhury, Banik, & Lahiri, 2006).

CLASSIFICATION OF OBESITY

With the prevalence of obesity continuing to increase, the topic of how to best measure obesity is garnering attention. Controversy exists as to whether body mass index (BMI), waist circumference (WC), waist to hip ratio (WHR), sagittal abdominal diameter (SAD), percent body fat (%BF), or a combination of these measures serves best to assess obesity. The intention of the obesity measurement is an important consideration in determining the appropriate measuring method. The measure may be used to assess an individual or a population, to predict a particular outcome, or to classify risk. All of these variables will influence the measure of choice. Additionally, the practicality of budget and skill level of the measurer will come into play. The following examines the current literature on each body composition measure for strengths and disadvantages, particularly from the perspective of evaluating firefighters and the outcomes essential to their job performance and overall health.

Body Mass Index

Body Mass Index (BMI) is a statistical measure of body size based on an individual's weight and height. It is calculated by dividing weight by height squared and reported in units of kg/m^2. BMI, which was originally known as the Quetelet Index, was developed by Belgium scientist Adolphe Quetelet in a quest to create a measurement of healthy weight. He accomplished this through the measurement of 5,000 Scottish soldiers in 1844 (Eknoyan, 2008). In 1972, the Quetelet Index was renamed Body Mass Index in a popular paper by Ancel Keys that determined BMI to be the best indicator of body fat percentage among weight and height ratios (Keys, Fidanza, Karvonen, Kimura, & Taylor, 1972). In his paper, Keys emphasized the importance of using BMI in the appropriate capacity of population statistics, opposed to individual use. However, due to the minimal requirement of knowledge, skill and equipment, BMI has become a common measure of individual weight categorization.

It has been widely demonstrated in scientific literature that BMI, when applied to population statistics, is an excellent predictor of cardiovascular risk (Kivimaki, et al., 2008; Kushner & Blatner, 2005; Lew & Garfinkel, 1979). A major analysis conducted on NHANES data found that, relative to the normal weight category (BMI 18.5 to <25), obesity (BMI $\geq$ 30) was associated with 111,909 excess deaths and underweight (BMI <18.5) with 33,746 deaths. The overweight category (BMI 25 to < 30) was not associated with excess mortality. These findings are in agreement with others that demonstrate a U-shaped curve when relative risk of mortality is plotted against BMI, with the minimum mortality close to a BMI of 25. Interestingly, the impact of obesity on mortality appears to have decreased over time according to the three progressive data NHANES sets. This could be the result of improvements in medical care, particularly for cardiovascular disease, the leading cause of death among obese persons (Flegal, et al., 2010).

While BMI provides an easy and inexpensive way to estimate prevalence of obesity within a population, it has shortcomings when used to assess individuals. Specifically, BMI cannot account for the role of bone density, muscle mass or fat distribution in individuals. Two individuals with the same BMI can have very different body compositions and corresponding health risks. Often those with increased muscle mass are misclassified as 'overweight' or 'obese' based on BMI categories (Kelly, et al., 2009; W. S. C. Poston & Foreyt, 2002). This is because BMI is a measure of excess weight for height instead of the excess fat for height that is often implied when an individual is classified as obese according to his or her BMI.

According to recently developed body composition reference values from NHANES DEXA data, BMI may be overestimating some groups and underestimating others due to variations in body composition among different genders and ethnicities (Kelly, et al., 2009). Different ethnicities experience cardiovascular risk at varying BMIs. For instance, some Asian cultures, including Chinese and Japanese, define overweight or obesity with a lower BMI than used in the United States (Deurenberg, Deurenberg-Yap, & Guricci, 2002; Ko et al., 2001). The Japanese classify obesity with a BMI of 25 or more, whereas the U.S. uses a BMI of 30. The Chinese denote overweight with a BMI of 24 and obesity with 28, versus 25 and 30 in the U.S. (Weisell, 2002). There is also evidence for different thresholds to determine disease risk among blacks and whites ((Deurenberg & Deurenberg-Yap, 2003; Wagner & Heyward, 2000). Furthermore, research shows that age influences obesity prevalence and that increased age may result in underestimated obesity prevalence using BMI (Gallagher et al., 1996; Movsesyan, Tanko, Larsen, Christiansen, & Svendsen, 2003).

Considering firefighting is a very physically demanding job, it is reasonable to hypothesize that firefighters maintain greater muscle mass than the general population to meet strength requirements of their profession. Therefore, BMI may not be the most appropriate body composition assessment for firefighters since it could potentially overestimate obesity in individuals who possess more muscle mass. However, according to a study conducted in 451 military personnel, BMI measurements did not produce the greatest obesity prevalence. The participants (n=222 men; 229 women) were all currently serving in the military and ranged in age from 18 to 55 years. The following percentage of subjects were classified as obese depending on the measurement method: 81.8% of men, 98.3% of women (%BF, estimated using a field-based Tanita Body Composition Analyzer foot-to-foot scale, based on NIH standards of >25% for men and >30% for women); 51.4% of men, 31.9% of women (WC based on NIH standards of >102 cm (40 in) for men and >88 cm (35 in) for women); 55.0% of men, 21.4% of women (BMI based on NIH standards of $\geq$30 kg/m^2). Surprisingly, %BF resulted in the greatest prevalence of obesity, while WC produced the lowest rates in men and BMI produced the lowest prevalence in women. The authors proposed lower cut-off points than the national standards for identifying obese individuals (WC = 100 cm vs. 102 cm and BMI = 29 vs. 30 kg/m^2 for men; WC = 79 cm vs. 88 cm and BMI = 26 vs. 30 for women) (Heinrich et al., 2008). These results were consistent with similar studies (Deurenberg-Yap, Schmidt, van Staveren, & Deurenberg, 2000; Deurenberg, Deurenberg Yap, Wang, Lin, & Schmidt, 1999; Okosun, Tedders, Choi, & Dever, 2000).

Waist Circumference

Waist circumference (or 'abdominal girth') is a simple anthropometric measure of the circumference of the waist, generally measured at the level of the umbilicus using a spring-loaded tape measure. This measurement is particularly useful in indicating visceral fat depots, which are associated with increased risk for cardiovascular disease (de Koning, et al., 2007). According to the American College of Sports Medicine (ACSM), cardiovascular risk is increased in females with a waist circumference >88 cm and in males with a waist circumference > 102 cm (ACSM, 2005).

As early as 1953, scientific articles were published warning of the cardiovascular risks more closely associated with android compared to gynoid obesity (Vague, 1953). Since then, numerous studies have examined the link between fat distribution and cardiovascular risks. In one study, regional adipose tissue distribution was measured in 330 obese individuals, 215 women and 115 men, in addition to a random sample of 52-year-old women (n=38) and men (n=39) living in the same area. For both the obese and random sample of men, adipose tissue thickness was greatest in the abdominal region, whereas women had a greater proportion in the gluteal and femoral regions. Moreover, women had the largest body circumference measure around the hips while men had it around the abdomen. Women also had more relative body fat which is illustrated by their tendency to weigh less (-12.0 kg) and be shorter (-13.3 cm) than the males, yet have a greater amount of fat (+7.5 kg). Despite this apparent disadvantage, women had significantly lower fasting insulin, glucose, and triglyceride levels, with significantly lower blood pressure compared men. The authors were able to further clarify that abdominal obesity associated with abdominal adipocyte hypertrophy is most closely associated with metabolic complications. They speculated that this might be due to sex hormones or to the proximity of the liver to the lipolytic products of visceral adipose tissue (Krotkiewski, Bjorntorp, Sjostrom, & Smith, 1983).

Despite the apparent link between WC and cardiometabolic disease risk with the advantage of it being a simple and inexpensive assessment method, a lack of standards for measuring and classifying exists. Scientific organizations have drawn attention to the necessity of ethnic specific criteria for waist circumference risk categories (Federation; Services, 1998). Additionally, there are various protocols for measuring WC. Often the waist is measured at the most narrow circumference between the lower ribs and iliac crests. This is sensible for proportional individuals. However, when the goal is to determine abdominal obesity, and an individual has visceral accumulation, the narrowest circumference may not be the best representation.

Waist to Hip Ratio

Waist to hip ratio (WHR) is another anthropometric measurement that utilizes circumference dimensions. It is a progression from waist circumference that attempts to eliminate variation in waist size due to height and gender. Theoretically, the greater the WHR, the more fat accumulation around the waist compared to the hips. However, recent research has called this measurement into question claiming that it is less effective than both WC and sagittal diameter for determining health risks associated with abdominal obesity.

In an article by Welborn and Dhaliwal, BMI, waist circumference, waist to stature ratio and WHR were used to determine the measure that best predicts all cause mortality and cardiovascular disease mortality. The researchers gathered anthropometric measurements of 9309 urban adults for an 11-year mortality follow-up. The results showed that WHR was the best predictor for both all-cause and cardiovascular disease mortality. The cut-point for WHR in all-cause mortality was 0.93 in males and 0.79 in females. For cardiovascular disease mortality, the WHR cut-point was 0.93 in males and 0.80 in females. The authors concluded that WHR was by far the best predictor of all-cause and cardiovascular disease mortality, with equivalent and highly significant hazard ratios in both sexes (Welborn & Dhaliwal, 2007).

Similarly, in a study conducted on 1,669 older adults with chronic kidney disease (CKD), WHR was significantly associated with cardiac events (classified as MI, fatal CHD, stroke, or a combination of the three) (p-value < 0.001), while BMI was not (p-value 0.15). In continuous terms, WHR was linked to cardiac events by a hazard ratio of 1.53 (1.33-1.76, $p<0.001$) with each 0.1 unit increase. BMI did not have a significant association with cardiac events, which was demonstrated by a hazard ratio of 0.99 (0.97-1.01, $p=0.30$) for each 1 kg/m^2 increase. When evaluated by categories, the highest WHR levels (1.02-1.28 for men; 0.96-1.20 for women) were associated with a 36% increase in the risk of cardiac events compared to the lowest group (0.78-0.95 for men; 0.65-0.87 for women). Neither overweight (BMI 25-29.9 kg/m^2) or obese (BMI ≥ 30 kg/m^2) categories as defined by BMI was independently associated with cardiac events (Elsayed, Tighiouart, et al., 2008). Interestingly, these data may underestimate the association between WHR and cardiovascular risk due to the study method of measuring WC at the smallest circumference between the lower ribs and iliac crest. If an individual has android obesity, it is reasonable to assume that the smallest circumference would not accurately assess the extent of his or her visceral fat.

Another study suggests that both WC and WHR are similarly effective for assessing cardiovascular risk. Fifteen articles (n = 258,114; 4,355 CVD events) using both categorical and continuous measures of WC and WHR were included in a meta-analysis by de Koning and colleagues. Results for both men and women showed that for each 1 cm increase in WC, the relative risk (RR) of a CVD event increased by 2% (95% CI, 1-3%). For each 0.01 increase in WHR, the RR increased by 5% (95% CI, 4-7%). When comparing the extreme quantiles, WHR was more strongly associated with CVD than was WC, although the difference was not significant (WHR: RR = 1.95, 95% CI, 1.55-2.44; WC: RR = 1.63, 95% CI, 1.31-2.04). Although WHR may have advantages, it is a less reliable measure than WC when self-reported and may be inappropriate for measuring obesity or weight loss (de Koning, et al., 2007).

Sagittal Abdominal Diameter

Sagittal abdominal diameter (SAD), which is also known as ‘abdominal height’, is the measure of the distance between the front and back side of the body at waist level. It is commonly measured between the top of the iliac crest and the minimal waist, although there is not yet consensus on optimal landmarks or methodology. Generally, either a sagittometer (a sliding beam caliper with a ruler) or ruler and water level are used to measure SAD.

SAD is strongly associated with intra-abdominal or visceral fat (Despres, Prud'homme, Pouliot, Tremblay, & Bouchard, 1991; Han, McNeill, Seidell, & Lean, 1997; Pouliot, et al., 1994). As noted previously, visceral fat is positively linked to both cardiovascular and metabolic disease risk (Amato et al., 2010; Onat et al., 2004; Sandeep, Gokulakrishnan, Velmurugan, Deepa, & Mohan, 2010). Therefore, SAD may be another simple, economical way to estimate cardiovascular disease risk in both individuals and populations.

Studies have suggested that SAD is a better indicator of health risk than both WHR (Pouliot, et al., 1994) and WC (Petersson, Daryani, & Riserus, 2007; Riserus et al., 2004; D. A. Smith et al., 2005). This is plausible considering SAD solely focuses on the projection of the abdomen, better eliminating the variation in body build that may be present with WC and WHR. However, published findings are conflicting (Afghani et al., 2004; Mukuddem-Petersen et al., 2006; Turcato et al., 2000).

In a study conducted on 1,420 white and black adults ages 20-38 from Bogalusa, Louisiana, SAD was closely associated with other obesity measures, particularly waist circumference (0.937-0.944, $p<0.001$). It was also an independent predictor of levels of total cholesterol, triglycerides, very low density lipoprotein cholesterol, low density lipoprotein cholesterol, high density lipoprotein cholesterol, glucose, and insulin ($p<0.05$ to $p<0.001$ with r values ranging from 0.13 to 0.52). Furthermore, SAD was correlated more strongly with serum lipoprotein levels, plasma glucose, and blood pressure than other obesity measures, making it a slightly better predictor of coronary heart disease. Consequently, the authors advise using SAD to assess a component of visceral fat that may be lacking in other measures (Gustat, Elkasabany, Srinivasan, & Berenson, 2000).

In another study that compared SAD, visceral fat area (VFA; measured using MR imaging) and WC, SAD was the only measurement closely associated with metabolic syndrome using forward binary logistic regression ($p<0.01$). The study consisted of 43 high vascular risk patients who were included for having either coronary artery disease (CAD), ischemic stroke or CAD equivalents. A threshold of >22.7 cm SAD identified metabolic syndrome with 91% sensitivity and 80% specificity. This data demonstrates there may be no advantage in using more expensive and skill-requiring MR imaging to measure visceral fat, when SAD can accurately identify cardiometabolic risk (Hoenig, 2010).

Despite these findings of SAD advantages, other studies have found little difference between WC and SAD for determining visceral adipose tissue and corresponding cardiovascular risk. For instance, research by Pouliot and colleagues conducted on middle aged men (n=81) and women (n=70) showed that WC and SAD were strongly associated with abdominal visceral fat ($r=0.87$ for women and 0.77 for men; $r=0.87$ for women 0.80 for men, respectively), both of which had stronger correlations than WHR ($r=0.67$ for women and 0.71 for men). The authors make the argument that WC and SAD are more appropriate for measuring visceral fat accumulation than the commonly used WHR. They also suggest that WC values >100 cm and SAD values >25 cm are most likely to be linked to cardiometabolic disturbances (Pouliot, et al., 1994).

Percent Body Fat

While some measures of body composition focus on the location of adiposity, others attempt to measure the overall amount of fat in the body. Two body composition assessment methods that measure total body fat are skinfold assessments and hydrodensitometry, both of which are reported in percent body fat (%BF). Reports vary regarding the accuracy of these measurements (Aristizabal, Restrepo, & Amalia, 2008; Demura et al., 1999; Wagner & Heyward, 1999). Slight errors in measuring technique, differences in environmental conditions, and the equation used to determine %BF can all influence results. For instance, hydrostatic weighing measurements are dependent on gas volume in the lungs after maximal exhalation, and a minor error of 100 ml of air is correlated to 0.7% error in %BF (Going, Roche, Heymsfield, & Lohman, 1996). Therefore, technique of body fat assessment and corresponding accuracy should be considered in evaluating reports of %BF.

Percent BF has been identified as an important component in gauging CVD risk. Individuals identified as obese by bioelectric impedance analysis (BIA) according to %BF standards (≥25% for men; ≥35% for women) have increased CVD risk. This is particularly relevant for African American populations in which both prevalence of and mortality from CVD is higher compared to Caucasians (Zeno, Deuster, et al., 2010). Percent BF has also been shown to be an indicator of prognostic factors for mortality associated with chronic heart failure (CHF). Higher lean body mass and/or lower fat mass was independently linked to factors that are prognostically advantageous in CHF such as hand-grip strength. Conversely, increased body fat was associated with undesirable prognostic factors including lower exercise capacity and greater C-reactive protein levels (an inflammatory biomarker) (Oreopoulos et al., 2010).

In a study by McAuley and colleagues, 13,155 men (mean age 47.7; SD ± 9.9 years) with hypertension (defined by systolic blood pressure of ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg) were examined for a relationship between %BF (assessed using hydrostatic weighing, the sum of seven skinfold measures, or both methods) and fitness with various disease and mortality outcomes. In the low fitness group (n=2,026; defined as the lowest 20% of cardiorespiratory fitness (CRF) determined by a maximal treadmill exercise test) 72.8% of men had a %BF of ≥25, while the moderate fitness group (n=5,290; defined as the middle 40% of CRF) had 49% and the high fitness group (n=5,839; defined as the top 40% of CRF) had 18.2% ($p<0.0001$). The hazard ratio (HR) for all-cause mortality for men whose %BF ≥25 was 1.23 (1.07-1.41; $p=0.004$) and the HR for CVD mortality was 1.25 (1.01-1.56; $p=0.04$). By having a %BF ≥25, subjects had 2% greater chances of mortality compared to 6% increased risk for a WC >102 cm and 27% greater risk for a BMI ≥ 30 kg/m^2. When fitness level is incorporated, the men with %BF ≥25 with low fitness have a HR of 2.41 (1.93-3.02) compared to 1.19 (0.90-1.56) for men of the same %BF level with high fitness. Moreover, men with ≥25% BF and low fitness had a HR of 3.43 (2.44-4.78) while highly fit men with the same %BF had a HR of 0.86 (0.52-1.43). This research demonstrates that while %BF alone can influence mortality risk, CRF has a major impact on mortality outcome (McAuley, et al., 2009).

Several studies have examined %BF in firefighter populations and its effects on job-related tasks. A study conducted on Charlotte-Mecklenburg firefighters (n=922) showed that average %BF (measured using skinfold calipers) was 28.8% (SD ± 8.1) in females (n=37) and 17.8% (SD ± 5.7) in males (n=885). Ten percent of male firefighters were classified as obese (≥ 25% body fat) and 38% of females were classified as obese (≥ 30% body fat) (Boyce, et al., 2008). A group of firefighters from central California had a mean %BF (measurement method not specified) of 17.1 ± 6.0 (n=51 municipal firefighters) and 15.6 ± 4.1 (n=17 industrial firefighters). The industrial firefighters were required to maintain a %BF ≤ 20% for employment, which means obesity was not present in this population. Although the municipal firefighters were not required to meet a particular standard of %BF, an environment was established in which physical fitness was valued and encouraged (Garver et al., 2005). In an analysis of 16 years of data from firefighters in Chicago, Illinois, %BF (assessed using the sum of three skinfold measures) was negatively correlated with the following physical tests: standing broad jump, 46-metre dash, flexed-arm hang, hose couple, body lift and carry, body drag, stair climb, and obstacle run ($p < 0.05$). Contrarily, fat-free weight was positively associated with almost all of the physical tests, especially the ones focusing on strength (Misner, Boileau, & Plowman, 1989).

CHAPTER III

METHODS AND PROCEDURES

This study employs a secondary data analysis to evaluate previously collected information on career and voluntary firefighters who participated in the Heart Disease Prevention Program (HDPP) through the Human Performance/Clinical Research Laboratory (HPCRL) at Colorado State University. At the time of participation, each firefighter provided his/her consent to permit the use of his/her data for research purposes. The Human Research Committee at Colorado State University approved this study.

RESEARCH METHODS

The HDPP at Colorado State University is a comprehensive physical evaluation program with three main objectives:

1. Assessment of known risk factors for cardiovascular disease
2. Reduction of the likelihood of developing heart and vascular disease
3. Use of cardiovascular risk factor status in the development of individualized strategies for lifestyle change

Intended for the use of Colorado citizens and beyond, this program helps fund research, student fellowships and program operations in the Department of Health and Exercise

Science. Additionally, the HDPP aligns with the Department's mission to promote healthy lifestyles. All information collected through HDPP is included and maintained in a computerized database. This study uses the HDPP database to investigate the research hypotheses.

SUBJECT SELECTION

Since January 2002, the HDPP has been used by several fire departments throughout Colorado as a means to conduct annual and semi-annual health and fitness evaluations for on-duty firefighters. The fire departments included in this study are Poudre Fire Authority (Fort Collins, CO), Parker Fire Protection District (Parker, CO; currently part of South Metro Fire Rescue Authority), Red White and Blue Fire District (Breckenridge, CO), Durango Fire and Rescue Authority (Durango, CO), Loveland Fire and Rescue (Loveland, CO), Salida Fire Department (Salida, CO), Castle Rock Fire and Rescue Department (Castle Rock, CO), Livermore (Livermore, CO), Indian Hills (Indian Hills, CO) and Vail Fire Department (Vail, CO). These fire departments self-selected to provide evaluations to their employees. This service is available to all fire departments in Colorado. From January 2, 2002 to August 15, 2010 a total of 466 career firefighters participated in the HDPP. All participants were free of diagnosed heart disease and had no contraindications to exercise testing at the time of their evaluation. Although many subjects were evaluated more than once over the decade, only the first visit of each firefighter was included in this analysis to maintain consistency.

PROCEDURES

Each firefighter completed a medical history questionnaire; an emotions questionnaire including depression, anxiety, anger, hope, hostility, cynicism, forgiveness, social support and orientation to life; and a four day nutrition log prior to physical evaluation. On their assigned day, each firefighter arrived at the HPCRL to submit their forms, receive a preliminary evaluation and complete a maximal graded exercise test. In addition, each subject had a blood sample drawn by venipuncture of an antecubital vein for analysis by an off-site contract laboratory. Subjects were advised to fast for a minimum of twelve hours prior to the blood draw, but encouraged to drink abundant water and take any medications as prescribed as long as they did not require the accompaniment of food. All evaluations and tests at the HPCRL were conducted by trained laboratory technicians in compliance with established protocols. The self-reported data included in the questionnaires and nutrition log were used to determine demographic information, personal and family history of chronic disease, medication use, and alcohol and tobacco history.

Blood chemistry

All blood chemistry analyses were completed by an off-site contract laboratory. The contract laboratory measured hs-CRP, total cholesterol (TC), HDL cholesterol, and glucose from unfrozen plasma samples using a Beckman Coulter DxC 800 Synchron© Clinical System (Beckman Coulter, Inc., Fullerton, CA). LDL cholesterol was calculated using the Friedewald equation (Friedewald, Levy, & Fredrickson, 1972) for subjects with a serum triglyceride level below 400 mg/dL:

$$LDL = TC - (HDL + (TG / 5))$$

The results of all blood chemistry analyses were faxed to the HPCRL upon completion.

Anthropometric measurements

Height and weight were measured on a standard medical beam scale and standiometer as part of the preliminary evaluation. Body mass index (BMI) was then calculated as weight in kilograms divided by height in meters squared. Waist circumference (WC) was measured to the nearest quarter inch at the level of the umbilicus using a spring-loaded Gulick tape measure (Lafayette Instruments, Lafayette, IN). WC was taken twice and the mean of the two measurements was determined and recorded. The same procedure was used to measure hip circumference with the exception that the measurement was taken at the maximum circumference of the buttocks. Hip and waist circumference measurements were used to calculate waist to hip ratio (WHR).

Sagittal abdominal diameter (SAD) was measured vertically using a Campbell caliper (Rosscroft, British Columbia, Canada), a sliding-beam caliper, at the level of the umbilicus with the subject lying in a supine position on a firm examination table. SAD was measured twice to the nearest 0.05 inch after a normal expiration. The average of the two measurements was calculated and recorded.

Body composition

Body composition was measured via skinfold assessment and hydrostatic weighing. Skinfold assessment consisted of a seven-site skinfold measurement (chest, triceps, subscapular, midaxillary, suprailiac, abdominal, and thigh) using the ACSM standardized description of skinfold sites and procedures (*ACSM's Guidelines for Exercise Testing and Prescription*, 2000). Measurements were repeated a minimum of two times or until two trials were within 2 mm. For hydrodensitometry, body density was determined as outlined by Katch (Katch & Michael, 1969) and percent fat was calculated using the Siri equation (Siri, 1993). Residual lung volume was measured using the nitrogen dilution method (Saha, 1965) (SensorMedics Vmax 22, Conshohocken, PA, and Medgraphics Ultima Series PX, St. Paul, MN) and included in the calculation of percent body fat. Computer software (Body Comp 32) was used for all calculations of percent body fat and body density.

Blood pressure

Blood pressure measurements were obtained via standard protocol as described in the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (Chobanian et al., 2003), using a mercury sphygmomanometer (Trimline Medical, Branchburn, NJ) with a constant deflation valve. Cuffs were selected to appropriately fit each subject’s arm. After five minutes of rest, subjects had their blood pressure measured in the supine position, followed by seated and then standing positions. Measurements occurred before starting the graded exercise test. When multiple measurements were available, systolic and diastolic blood pressures were calculated as an average of these measures.

Graded exercise test

A graded exercise test (GXT) was administered to each firefighter to assess cardiorespiratory fitness. All GXT sessions were supervised by a cardiologist or internal medicine specialist. After a thorough evaluation by the supervising physician, each subject was given detailed instructions on the GXT procedure. Subjects followed a Bruce protocol (Bruce, Kusumi, & Hosmer, 1973) on a motor-driven treadmill to end points identified by ACSM Guidelines, including volitional fatigue or until the physician terminated the test (*ACSM's Guidelines for Exercise Testing and Prescription*, 2000). During each GXT, a 12-lead electrocardiogram (ECG) was used to monitor the subject's heart rhythm and rate. Each minute, heart rate was recorded. Every three minutes, blood pressure was measured by a trained technician and the subject assessed the rate of perceived exertion (RPE) using the Borg scale (Borg, 1982). After reaching his/her maximal exercise capacity, the firefighter cooled down with a five-minute-walk at a self-selected pace. During this time, heart rate and blood pressure were measured every minute. A final heart rate and blood pressure measurement was recorded after the subject rested in a chair for one minute. After the test was completed, the supervising physician reviewed each subject's resting, exercise, and maximal ECG printouts for any irregularities in heart rhythm or rate. Any firefighter with a positive or nondiagnostic GXT was referred to the Heart Center for the Rockies (Fort Collins, CO) or his/her primary care physician for additional testing and was taken off-duty until medically cleared.

In the current study, only subjects performing a Bruce protocol were included in the final analyses. Maximal oxygen consumption (VO_2max) was predicted based on total GXT time using a previously validated formula (Bruce, et al., 1973):

$$VO_2max\ (ml/kg/min) = 6.7 - 2.82 * (\text{weighing factor for gender}) + 0.056 * (\text{duration of treadmill test in seconds})$$

where the weighing factor is 1 for males and 2 for females. An extremely high correlation has been shown between predicted VO_2max using this formula and measured VO_2max (r=0.92) (Bruce, et al., 1973). Cardiovascular fitness was also expressed as maximal metabolic equivalents (METs; 1.0 MET = 3.5 ml/kg/min) achieved during the GXT.

Dietary intake

A four-day dietary record was completed by each firefighter as part of his/her pre-evaluation paperwork. The subjects were instructed to record everything they consumed, with the exception of water, for two on-shift days and two off-shift days, which they indicated at the bottom of each log. The firefighters were instructed to include details such as food item, portion size, brand name (if applicable), preparation method, and time consumed. Recorded dietary intake was analyzed with Nutritionist Pro™ Diet Analysis software (Stafford, TX).

Fitness levels

Fitness assessments consisted of the following six tests: flexibility, hand grip strength, leg strength, arm strength, push-ups and curl-ups. With the exceptions of the push-up and curl-up tests, firefighters performed each test three times and the best performance was noted. Flexibility was performed using a sit and reach box. The participant sat with his or her feet against the box without shoes, and was instructed to reach forward as far as possible without bending his or her knees. For hand grip strength, the combined strength of left and right hand grip was determined. Leg strength was determined by a force plate with a half squat simulating set-up. Arm strength was assessed with the same equipment but with a biceps curl set-up. All strength tests were isometric with 30 seconds rest between trials. For both push-ups and curl-ups, subjects performed the exercises at a standardized pace via metronome. When the firefighters could no longer complete the exercise correctly or in time with the metronome, the total number of respective push-ups or curl-ups was recorded.

In addition to the fitness tests, firefighters' activity levels were analyzed using results from a Health History Questionnaire (HHQ) developed by the HPCRL. One of the questions asked participants to record how many hours they spend, on a usual weekday and weekend day, doing vigorous activities (digging in the garden, strenuous sports, jogging, aerobic dance, sustained swimming, brisk walking, heavy carpentry, bicycling on hills, etc.), moderate activity (housework, light sports, regular walking, golf, yard work, lawn mowing, painting, repairing, light carpentry, ballroom dancing, bicycling on ground level, etc.), and light activity (office work, driving car, strolling, etc.).

Sleep habits

Sleep habits were assessed using data from two separate questionnaires. The first was the HHQ, which asked, "How many hours of sleep do you usually average per night?" The second questionnaire was the Stanford Usual Physical Activity Assessment Questionnaire (Sallis et al., 1985). Under the Seven-Day Physical Activity Recall Questionnaire section, the first question asked for the number of hours, on average, the subject slept during the last five weekday nights, Sunday through Thursday, recorded to the nearest half hour. The second question requested the same information for Friday and Saturday nights. The combination of questions was used to compare consistency between correlations of sleep habits and obesity measurements when sleep habit questions were asked either more or less generally.

Tension

Tension was assessed using the Spielberger State Anxiety Scale. This scale was part of the pre-evaluation emotions questionnaire completed by subjects. It contains 10 sentences which an individual may use to describe how he/she feels. The subject is instructed to indicate which answer best describes how he/she feels at that moment on a scale of 1 to 5 (1 indicating 'Strongly Agree' and 5 indicating 'Strongly Disagree'). When calculating the score, the negative feelings are reversed on the scale. The score can range from 10 to 50 with a higher score indicating greater symptoms of anxiety (Spielberger, 1970).

Depression

Depression was evaluated using the Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff, 1977). This scale was also part of the pre-evaluation emotions questionnaire completed by subjects. It contains a list of 20 ways a person may feel or behave. The subject is instructed to circle how often he/she has felt or behaved that particular way during the past week. Each item is assigned 0 to 3 points. When calculating the score, positive items are reversed. The cumulative score can range from zero to 60, with higher scores indicating symptoms of depression.

Cardiovascular risk

Cardiovascular risk was assessed using an adapted version of the Cooper Clinic Mortality Risk Index which predicts 15-year mortality risk in men aged 20 to 69 years (Janssen, Katzmarzyk, Church, & Blair, 2005). This profile assigns a coronary risk level of very low, low, moderate, high, or very high based on the subject's personal history of heart attack or bypass, family history of heart attack, smoking habits, tension-anxiety level, age, resting ECG, exercise ECG, total cholesterol/HDL cholesterol, TG, %BF and whether or not the subject has diabetes or known coronary heart disease without a heart attack or bypass.

DATA ANALYSIS

Descriptive characteristics were analyzed using standard descriptive statistics and presented as means with standard deviations. All analyses were performed using SPSS

19.0 statistical software (IBM, Armonk, NY). P-values were two-sided and considered statistically significant when $p < 0.05$.

Obesity prevalence measured by BMI, SAD, WC, WHR, and %BF was calculated using the following established cut-off points (Hypothesis 1):

- BMI $\geq$ 30 kg/m^2
- SAD > 22 cm for males; SAD > 20 cm for females
- WC > 102 cm for males; WC > 88 cm for females
- WHR > 1.0 for males; WHR > 0.85 for females
- %BF > 25% for males; %BF > 30% for females; %BF > 35% for females

The same cut-off points were used for both methods of measuring percent body fat. Percent body fat for female firefighters was calculated using both >30% and > 35% since both are commonly used as classifications for obesity in females (Okorodudu et al., 2010). Obesity prevalence of the study population was then compared to that of the general population (Hypothesis 2). Data reported by the Colorado Department of Public Health and Environment in *The Weight of the State: 2009 Report on Overweight and Obesity in Colorado* was used to facilitate this comparison (CDPHE, 2009). Nonparametric correlations were used to analyze the associations between obesity measures and both lifestyle variables and biomarkers (Hypothesis 3). Nonparametric correlations were also employed to assess the relationship between obesity and cardiovascular risk, comparing various measures of obesity (Hypotheses 4 and 5).

CHAPTER IV

RESULTS

A total of 466 Colorado firefighters were included in the final analyses. The characteristics of the study population are presented in Table 1. A majority of firefighters were male (91.2%), white (95.6%) and had a college degree (64.7%). Additionally, most of the participants were members of Poudre Fire Authority (41.1%), Parker Fire Department (18.0%) or Castle Rock Fire and Rescue Department (15.6%).

Table 1: Characteristics of the study population.

	N	% Total	Mean	SD	Min	Max
Sex						
Females	41	8.8%				
Males	425	91.2%				
Age (yrs.)	466		38.1	9.5	21	65
Weight (lbs.)	465		189.7	31.9	126.5	334.8
Height (in)	465		70.1	2.8	63.5	79.0
Race						
White	413	95.6%				
Black	2	0.5%				
Hispanic	16	3.7%				
Other	1	0.2%				
Education level						
Junior High	1	0.2%				
High School	124	28.1%				
College	286	64.7%				
Graduate	22	5.0%				
Postgraduate	9	2.0%				
Fire department						
CRFRD	71	15.6%				
DFRA	11	2.4%				
IHFR	6	1.3%				
Parker	82	18.0%				
PFA	187	41.1%				
RWBFD	62	13.6%				
Other	36	7.9%				

Note: Education level = highest level of education completed.
Abbreviations: SD, standard deviation, CRFRD, Castle Rock Fire and Rescue Department; DFRA, Durango Fire and Rescue Authority; IHFR, Indian Hills Fire Rescue; Parker, Parker Fire Department at time of data collection, currently part of South Metro Fire Rescue Authority; PFA, Poudre Fire Authority; RWBFD, Red White & Blue Fire District; Other, firefighters from Loveland Fire and Rescue Department, Salida Fire Department, Vail Fire Department, and unspecified departments.

The minimum and maximum values of each obesity-measuring method are presented in Table 2, along with average values. It is of interest to note that the mean value for SAD is just below the 20 cm obesity cut-off for females (19.6 cm) and slightly above for 22 cm cut-off for males (22.1 cm). The remainder of the measurements for both men and women had averages several units below the designated obesity thresholds.

Table 2: Anthropometric characteristics of female and male firefighters separated by measurement method.

	Females					Males				
Measurement	**N**	**Mean**	**SD**	**Min**	**Max**	**N**	**Mean**	**SD**	**Min**	**Max**
BMI (kg/m^2)	41	24.4	4.3	20.1	38.5	424	27.3	3.9	19.8	44.3
WC (cm)	41	81.4	12.6	67.3	97.8	423	92.6	10.7	73.7	135.9
WHR	41	0.81	0.07	0.70	1.05	423	0.91	0.06	0.73	1.08
SAD (cm)	38	19.6	5.9	13.7	46.0	395	22.1	4.2	10.8	37.0
%BF(SF)	41	21.5	7.4	12.1	42.8	424	18.4	6.3	4.8	36.9
%BF(H)	38	23.9	8.7	11.6	44.2	395	21.1	7.8	2.5	48.7

Abbreviations: BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; SAD, sagittal abdominal diameter; %BF(SF), percent body fat measured by skin folds; %BF(H), percent body fat measured by hydrodensitometry.

Figure 1 displays the percentage of obese firefighters based on each measurement method. The use of SAD resulted in a dramatically higher percent individuals classified as obese, particularly in males (43.5%). This was 14.9% higher than the second highest obesity classification in males which was derived by %BF(H) (28.6%). Similarly, in females SAD gave the highest prevalence of obesity (31.6%) and %BF(H) the second highest (23.7% for those >30%BF). BMI and WC produced a similar obesity prevalence in males (19.1% and 18.9%, respectively), while %BF(SF) had a lower prevalence of 15.1% and the lowest measure was 8.0% obese, produced by WHR. For females, WC and WHR produced the same obesity prevalence (19.5%) but there was almost a 10% decrease when BMI was used (9.8% for BMI vs. 19.5% for WC and WHR). For %BF, there was a clear difference between obesity measured by skin fold and by hydrodensitometry. The percentage of firefighters classified as obese was higher using hydrodensitometry than skin folds for both sexes (28.6% vs. 15.1% in male, 23.7% vs. 17.1% in females). Additionally, using >35% body fat to classify obesity in females resulted in approximately 10% fewer obese female firefighters than using >30% for both SF and H (7.3% vs. 17.1%; 13.2% vs. 23.7%, respectively). Finally, when compared to a representative sample of CO adults, obesity determined by BMI is less in this study sample of firefighters than the CO prevalence of 19.1% (CDPHE, 2009).

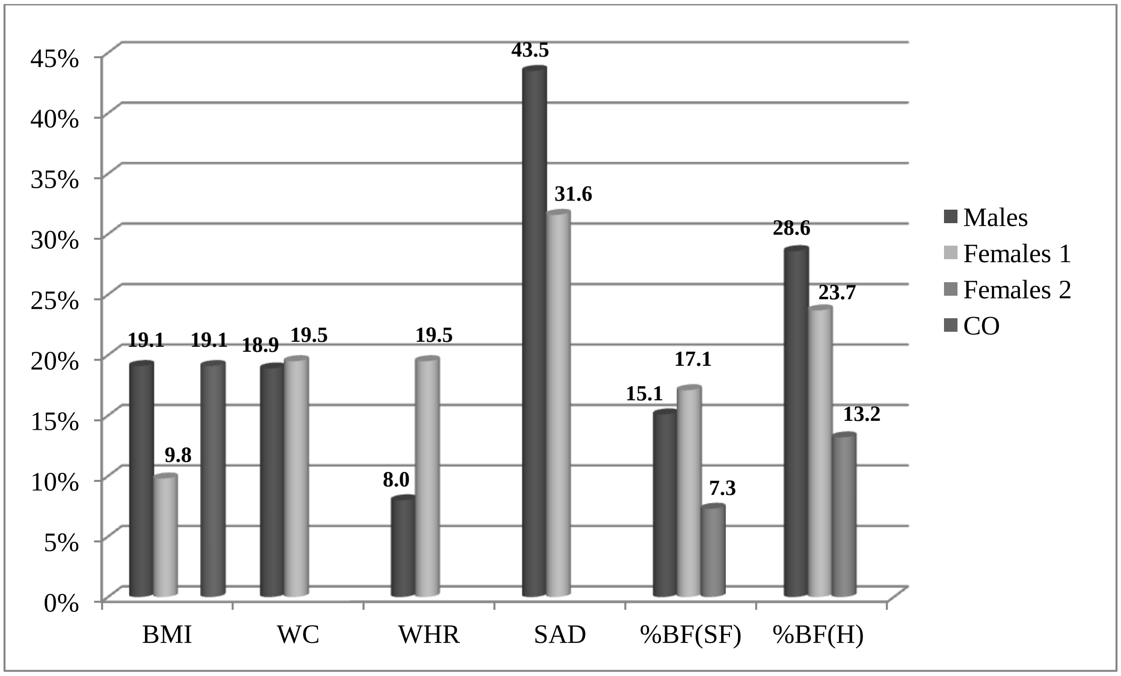

Figure 1: Percent obese according to method of measure. Obesity is classified by the following thresholds: BMI (≥30kg/m^2); WC (>102cm males; >88cm females 1); WHR (>1.0 males; >0.85 females 1); SAD (22cm males; >20cm females 1); %BF (SF&H) (>25% males; >30% females 1; >35% females 2). CO is the prevalence of adult obesity in CO measured in 2008 using BMI.

In Table 4, correlations between a host of variables and the obesity-measuring methods are shown for female firefighters. Significant positive associations existed between all the measurement methods with triglycerides and CRP ($p \leq 0.05$). Significant inverse relationships were detected among all obesity-measuring methods and HDL cholesterol (except BMI; $p \leq 0.05$), flexibility and estimated VO_2max (except BMI; $p \leq 0.05$). Interestingly, a strong inverse relationship was demonstrated for SAD and the number of hours slept/night in the last two weekend nights ($r=-.443$, $p \leq 0.01$) and the last five weekday nights ($r=-.475$, $p \leq 0.01$), showing the less female firefighters slept on average in the last week, the higher their measure for SAD. However, no significant relationship existed for hours slept/night and SAD or any of the other obesity measurements and sleep habit variables.

Table 3: Anthropometric measurement correlations with a variety of blood lipid profile, diet, physical activity, and other lifestyle variables in female firefighters (n=38).

Females

Variable	BMI	WC	WHR	SAD	%BF(SF)	%BF(H)
Total cholesterol	.110	.128	.256	.183	.238	.020
HDL cholesterol	-.303	-.476**	-.393*	-.609**	-.451**	-.537**
LDL cholesterol	.109	.188	.223	.310	.320	.197
Triglycerides	.362*	.401*	.506**	.469**	.445**	.362*
CRP	.519**	.614**	.574**	.381*	.626**	.606**
Blood glucose level	.121	.197	.273	.371*	.362*	.319
Average kcals/day	-.121	-.206	-.151	-.191	-.299	-.219
Avg. saturated fat/day	.112	-.140	-.245	.045	-.029	.097
Average total sugar/day	-.076	-.013	.058	-.021	-.175	-.180
Avg. dietary fiber/day	-.096	-.026	.144	-.223	-.070	-.216
Light activity/weekend	.304	.095	.278	.042	.158	.098
Light activity/weekday	-.017	.087	.206	.223	.272	.085
Moderate activity/wkend	.076	.162	0.56	.091	.187	.098
Moderate activity/wkday	-.205	-.091	-.161	-.226	-.241	-.192
Vigorous activity/wkend	.070	.037	-.196	-.282	-.185	-.066
Vigorous activity/wkday	-.305	-.216	-.294	-.320	-.309	-.329
Flexibility	-.530**	-.465**	-.436**	-.663**	-.704**	-.580**
Left Grip Strength	-.035	-.072	-.066	-.338*	-.247	-.382*
Right Grip Strength	-.009	-.111	-.068	-.208	-.263	-.308
Combined Grip Strength	-.176	-.196	-.124	-.257	-.509*	-.295
Leg Strength	-.118	-.210	-.206	-.522	-.724**	-.418
Arm Strength	.050	-.122	-.162	-.324	-.582*	-.176
Push-ups	-.112	-.262	-.327	-.327	-.640*	-.427
Curl-ups	-.038	-.283	-.177	-.165	-.608*	-.105
Estimated VO^2max	-.253	-.463**	-.358*	-.639**	-.614**	-.736**
Hrs sleep 2 wkend nights	-.051	-.163	-.212	-.443**	-.141	-.266
Hrs sleep 5 wkday nights	.121	-.125	-.212	-.475**	.000	-.087
Hours Sleep/Night	.185	.009	.059	-.221	-.106	-.107
Anxiety	.105	.188	.159	-.060	.001	-.053
Depression	.129	.326	.209	.270	.147	.196

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).
Abbreviations: CRP, C-reactive protein; Avg., Average; wkend, weekend; wkday, weekday; Hrs sleep 2 wkend nights, Number of hours of sleep/night during the last two weekend nights (Fri-Sat); Hrs sleep 5 wkday nights, Number of hours of sleep/night during the last five weekday nights (Sun-Thurs).

Associations between anthropometric measurements and blood lipid profile, fitness, and lifestyle variables in male firefighters are presented in Table 4. Significant positive relationships were found between all obesity-measuring methods and the following: total cholesterol, LDL cholesterol (except BMI), triglycerides, CRP, and blood glucose level ($p \leq 0.05$). Significant inverse relationships existed between all anthropometric measures and HDL cholesterol, average calories consumed per day, average total sugar consumed per day, average dietary fiber consumed per day, flexibility, push-ups, curl-ups and estimated VO_2max ($p \leq 0.05$). Significant relationships with sleep were limited and inconsistent. No significant relationships were detected for anxiety or depression with any of the measures of obesity.

Table 4: Anthropometric measurement correlations with a variety of blood lipid profile, diet, physical activity, and other lifestyle variables in male firefighters (n=402).

Males

Variable	BMI	WC	WHR	SAD	%BF(SF)	%BF(H)
Total cholesterol	.109*	.162**	.228**	.179**	.236**	.235**
HDL cholesterol	-.290**	-.295**	-.211**	-.273**	-.166**	-.195**
LDL cholesterol	.088	.135**	.184**	.164**	.197**	.207**
Triglycerides	.369**	.406**	.384**	.350**	.361**	.332**
CRP	.303**	.387**	.353**	.286**	.363**	.348**
Blood glucose level	.223**	.219**	.199**	.257**	.215**	.176**
Average kcals/day	-.118*	-.140**	-.204**	-.151**	-.156**	-.151**
Avg. saturated fat/day	-.054	-.045	-.072	-.084	-.055	-.096
Average total sugar/day	-.169**	-.173**	-.219**	-.200**	-.135*	-.159**
Avg. dietary fiber/day	-.131*	-.115*	-.126*	-.118*	-.110*	-.117*
Light activity/weekend	.005	.006	.042	-.046	.023	.000
Light activity/weekday	.001	.038	.026	-.050	.065	.055
Moderate activity/wkend	-.063	-.031	-.035	-.030	-.094	-.095
Moderate activity/wkday	-.060	-.063	-.046	.016	-.120*	-.077
Vigorous activity/wkend	-.124*	-.116*	-.086	-.061	-.116*	-.096
Vigorous activity/wkday	-.049	-.113*	-.130*	-.024	-.168**	-.134*
Flexibility	-.097*	-.170**	-.187**	-.164**	-.178**	-.107*
Left Grip Strength	.105*	.076	.011	-.010	-.076	-.064
Right Grip Strength	.113*	.092	.020	.011	-.054	-.051
Combined Grip Strength	.095	.113	.054	.050	-.038	-.028
Leg Strength	.035	-.015	-.070	-.145	-.153	-.209*
Arm Strength	.052	-.114	-210**	-.116	-.249**	-.352**
Push-ups	-.343**	-.604**	-.570**	-.410**	-.641**	-.569**
Curl-ups	-.350**	-.479**	-.472**	-.395**	-.490**	-.521**
Estimated VO^2max	-.501**	-.609**	-.539**	-.493**	-.620**	-.542**
Hrs sleep/wkend night	-.092	-.098	-.118*	-.044	-.063	-.065
Hrs sleep/wkday night	-.156**	-.105*	-.077	-.092	-.066	-.131**
Hours Sleep/Night	-.052	-.069	-.092	-.066	-.026	-.057
Anxiety	-.007	.011	-.015	.005	-.017	-.024
Depression	-.005	.037	.026	.089	.052	.033

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).
Abbreviations: CRP, C-reactive protein; Avg., Average; wkend, weekend; wkday, weekday; Hrs sleep 2 wkend nights, Number of hours of sleep/night during the last two weekend nights (Fri-Sat); Hrs sleep 5 wkday nights, Number of hours of sleep/night during the last five weekday nights (Sun-Thurs).

Table 5 lists the correlations between each measure of obesity and CV risk according to the Cooper Risk Profile. While these relationships do not indicate cause or direction, a significant relationship between a particular method of measuring obesity and CV risk demonstrates a close link between the two variables. This is the case for all of the obesity-measuring methods except WHR in females (r=.291). The rest were positively correlated ($p \leq 0.05$) with %BF(SF) having the closest link to CV risk in females (r=.538; $p \leq 0.01$) and WHR in males (r=.557; $p \leq 0.01$).

Table 5: Correlation between cardiovascular risk and anthropometric measurements.

	BMI	**WC**	**WHR**	**SAD**	**%BF(SF)**	**%BF(H)**
Cardiovascular Risk						
Females (n=37)	.384*	.364*	.291	.477**	.538**	.406*
Males (n=398)	.440**	.507**	.557**	.401**	.540**	.550**

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

CHAPTER V

DISCUSSION

The present study examined the prevalence of obesity in firefighters using several methods and classifications. The obesity measures were further inspected for associations with blood lipid profile, physical fitness and lifestyle variables with cardiovascular risk. A multitude of researchers have assessed anthropometric measures of obesity and their association with cardiovascular and other chronic disease (Elsayed, Sarnak, et al., 2008; Freiberg et al., 2008; Ho et al., 2001; Rexrode et al., 1998; Schafer et al., 2002). However, no published study to date has included the combination of measures used in this study (BMI, WC, WHR, SAD, %BF(SF) and %BF(H)). Furthermore, few other studies have analyzed data from as large a pool of firefighters and even fewer have included females (Demers, Heyer, & Rosenstock, 1992; Elliot et al., 2007; Glueck, et al., 1996; Hansen, 1990; Scanlon & Ablah, 2008; F. D. Winter, et al., 2010). Finally, the amount and breadth of variables analyzed, including blood lipid profile, diet, physical activity, fitness, sleep, anxiety and depression, were unique to published articles on firefighters. Therefore, the comprehensiveness of the data presented in this study is warranted and provides a better foundation upon which to develop ways to reduce obesity and its negative implications in firefighters.

PREVALENCE OF OBESITY

Obesity prevalence varied depending on measurement method. Using SAD to determine obesity prevalence resulted in an increased prevalence for both males and females (43.5% and 31.6%, respectively) compared to the rest of the measurements. These prevalence values are almost 15% and 8% greater than the second highest obesity measurements for males and females, respectively. A study by Snijder et al. showed that SAD had the strongest correlation to visceral fat values measured by computed tomography compared to BMI, WC, and dual-energy x-ray absorptiometry (DXA) in all populations except black males (Snijder et al., 2002). This shows that SAD could be an effective, yet simple indicator of visceral fat. However, it is important to evaluate the appropriateness of using SAD cutoff values of >22 cm for males and >20 cm for females to classify obesity. These thresholds were selected based on the findings of Riserus and colleagues who studied over 4,000 subjects to determine the optimal SAD cutoffs of 22 cm in men and 20 cm in women for elevated cardiometabolic risk (Riserus, de Faire, Berglund, & Hellenius, 2010). The researchers proposed the cutoffs could be used in both research and screenings to identify obesity. While this study uniquely provided thresholds for classifying obesity via SAD, it is important to consider that the conclusions were based on a specific population of Swedish 60-year-olds. Therefore, although these are one of the few scientifically supported cutoffs for SAD, they may not have been appropriate for this study population of firefighters.

A study conducted on Brazilian adults using SAD identified 23.1 cm and 20.1 cm as the best cut-off for predicting central obesity in men and women respectively (Pimentel, Portero-McLellan, Maesta, Corrente, & Burini, 2010). Another study suggested that SAD values of >25 cm in both men and women are likely to be associated with disturbances in lipoprotein metabolism and in plasma insulin-glucose homeostasis (Pouliot, et al., 1994). Riserus and colleagues confirmed the strong correlations between SAD and indicators of cardiovascular risk (insulin resistance and hyperproinsulinemia) and agreed that a measure of >25 cm would most likely be associated with metabolic disorders (Riserus, et al., 2004). However, this was before the same head researcher identified the SAD thresholds in 2010 used to determine obesity in this study. Additional research is needed to confirm appropriate SAD cutoffs for obesity and may need to include customized thresholds for various ethnicities, sexes and ages.

In men, BMI and WC had the most similar obesity prevalence (19.1% and 18.9%, respectively). These findings agree with research showing close correlations between BMI and WC (Freiberg, et al., 2008; Ho, et al., 2001; Pengelly & Morris, 2009). WHR produced the lowest prevalence of obesity in male firefighters (8.0%). Females had the exact same obesity prevalence according to WC and WHR measurements (19.5%). When compared to BMI, the obesity prevalence for females was almost 10% lower (9.8%). It is important to note that both WC and WHR measured the circumference of the waist at the height of the umbilicus. While some researchers have used umbilical waist in WC studies (Grinker, Tucker, Vokonas, & Rush, 2000; Rexrode, et al., 1998), others argue it underestimates true waist circumference or has a weaker association with CV risk than minimal waist measurements, particularly in females (Croft, Keenan, Sheridan, Wheeler, & Speers, 1995; Willis et al., 2007). If the latter assertions are applicable to the data presented in this study, the obesity prevalence values determined by both WC and WHR should be higher than reported. Umbilical waist was used for WC to maintain consistency with WHR, which was recorded using waist measurements at the height of the umbilicus.

Surprisingly, obesity detected by %BF(SF) was dissimilar from %BF(H) for both males and females (15.7% vs. 28.6% for males; 17.1% vs. 23.7% for females, respectively). Despite using distinctive methods, the two measures of body fat intend to calculate the same variable: overall body fat. However, %BF measured by skin folds clearly produced lower values of obesity prevalence than %BF measured by hydrodensitometry. In another comparison of body composition measures, %BF(SF) and %BF(H) had a fairly strong correlation of .809 (Isjwara, Lukito, & Schultink, 2007). Theoretical errors have been calculated at approximately 3-4% for predicting body fatness via densitometry and approximately 5% using skin calipers (Lohman, 1981). If the maximal percent error for both methods occurred in the present data, the incongruities in %BF numbers would be justified for females, but not for males. The discrepancies continued when the more liberal cut-off of >35% BF was used to classify obesity in females [7.3% for %BF(SF) and 13.2% for %BF(H)]. Additionally, using the >35% threshold reduced obesity prevalence in female firefighters by 9.8% for %BF(SF) and by 10.5% for %BF(H). DeLorenzo and colleagues calculated that a BMI of 30 kg/m^2 corresponds to approximately 25% BF in males and 35% in females (De Lorenzo A, 2003). In this study, 9.8% of females had a BMI of ≥ 30 kg/m^2 while the >35% BF(SF) and (H) prevalence were 7.3% and 13.2%, respectively, which aligns with DeLorenzo's position. While the range is wider for males, the 19.1% percent obese according to BMI falls between the two %BF values of 15.1% (SF) and 28.6% (H). Regardless of the how the %BF numbers are scrutinized, %BF(SF) in both males and females and %BF(H) in males had the strongest correlations to CV risk.

In order to compare the prevalence of obesity of subjects in this study to that of the general population, BMI data must be employed since it is the only published data available on general population obesity in both the U.S. and Colorado (CO). For the 465 firefighters on which BMI data was available, 18.3% met the classification for obesity ($\geq$30 kg/m^2). The prevalence of obesity in the general, adult population of Colorado was 19.1% in 2008. Therefore, the Colorado firefighters of this study had an obesity prevalence of almost 1% less (0.08%) than the general Colorado population. Moreover, their prevalence was 7.5% less than the national prevalence of 26.6%. When divided by sex, 9.8% of the female firefighters in this study were classified as obese by BMI, whereas CO women ranged from an average obesity prevalence of 17.4% to 21.6% based on adult age categories. This demonstrates a dramatically lower obesity prevalence in CO female firefighters compared to general population CO females. The male firefighters also had a lower prevalence of obesity, 19.1%, compared to the range of 19.8% to 23.9% in various adult age ranges of a representative sample of CO men (CDPHE, 2009). The lower obesity prevalence in CO firefighters compared to the general adult population of CO was unexpected. A study by Poston et al. of 478 professional firefighters from the Missouri Valley region (Colorado, Iowa, Kansas, Missouri, North Dakota, and Wyoming) reported an obesity prevalence of 33.5% defined by BMI, which is well above the national prevalence of 26.6% (W. S. Poston et al., 2011). Similarly, the cohort of Massachusetts firefighters (n=332) started with an obesity prevalence of 35% at baseline (1996). Five years later, obesity prevalence increased to 40% in the same population.

While it is still concerning that 18.3% of CO firefighters in this study were classified as obese by BMI, it is clear that this population fairs better than other firefighter cohorts with obesity prevalence greater than the national value.

IMPLICATIONS OF OBESITY

The hypothesized associations between obesity measures and implications were not all supported by the data of the present study. Often significance varied by sex, which could be largely influenced by the disparity of power for the two populations (n=41 for females; n=425 for males).

The significant positive associations with obesity measures for females were primarily TG and CRP. SAD and %BF(SF) also showed a significant positive link to blood glucose level. For males, the variables that had significant positive associations with at least five of the obesity-measuring methods included total cholesterol, LDL cholesterol, TG, CRP, and blood glucose level. These significant positive relationships reflect previous findings regarding obesity's link to LDL-C, TG, and CRP (Devaraj, Valleggi, Siegel, & Jialal, 2010; Ho, et al., 2001). Unexpectedly, total calorie intake was inversely associated with all obesity measurements in males. This means as average calories consumed per day increased, obesity measurements decreased. This is counterintuitive to the majority of research showing increased caloric intake increases the probability of obesity (Das et al., 2007; Kant, et al., 2007). However, average calories consumed per day allows room for variability in influential details such as macronutrient composition, meal frequency, and time of day consumed (de Castro, 1998; Mattes &

Campbell, 2009). Still, average sugar consumed per day was inversely related to all measures in males, which is contradictory to research linking increased sugar intake to obesity (Vartanian, et al., 2007). No significant relationship existed for average calories consumed per day or average total sugar intake per day with any obesity measure in females. Average saturated fat intake per day, tension and depression had no significant links to any of the obesity measures in either sex. All three variables have previously been linked to obesity (Andersen, et al.; Ernst, et al., 1997). The reason for the lack of significant association between these variables and obesity in this population is unknown.

A negative correlation was hypothesized for HDL-C, which was supported by all measures of obesity for both sexes, except BMI in females. Published research supports the relationship of obesity decreasing as HDL-C increases and vice versa (Ho, et al., 2001). Average daily fiber intake was not significant for any female obesity measure, but it was linked to all measures in men. Since increased dietary fiber intake has been shown to reduce obesity, the lack of significant results in females may be due to the small population size (Maki, et al., 2010). Physical fitness was assessed using a variety of variables. In females, all specific fitness tests, except right grip strength, were significantly linked to at least one obesity measure, with flexibility and estimated VO_2max being most consistent. Male firefighters also displayed inverse relationships mostly with fitness tests, although some patterns, such as ‘vigorous activity per weekend’ or ‘weekday’ were also significant for several obesity measures. Flexibility, push-ups, curl-ups, and estimated VO_2max unanimously had significant inverse associations with all indicators of obesity. There is a lack of research inversely linking obesity to flexibility, push-ups or curl-ups, as most relevant research consists of intervention studies in which specific fitness tests are improved or obesity is reduced, but not both (Blake, Miller, & Brown, 2000). VO_2max has been shown to be inversely related to obesity, although often it is simply the weight loss that increases relative VO_2max (Larson-Meyer, et al.).

Sleep habit correlations were sporadic with males displaying significant, inverse relationships for BMI, WC, WHR, and %BF(H), and females showing a fairly strong inverse association between sleep and SAD. Existing research exploring the relationship between obesity and sleep habits is generally indirect and focuses more on sleep apnea or overall mortality, so it is difficult to directly compare sleep habit results found in this study to others (Al Lawati, et al., 2009; Kripke, et al., 2002; Strobel & Rosen, 1996).

As mentioned previously, correlations between obesity implications and measures of obesity do not imply causation in either direction. They do, however, provide further clarity regarding whether or not the examined variables have significant relationships, the relative strength of those relationships and whether they are positive or inverse relationships. All the implications included in this study have been either theoretically or scientifically linked to obesity and assist in the understanding of how such variables relate to obesity in this population of firefighters.

OBESITY AND CARDIOVASCULAR RISK

It was hypothesized that all measures of obesity would be significantly and positively linked to CV risk, which was validated for all obesity measures except WHR in females (r=-0.291). While the limited power of female subjects could influence significance, all other obesity measures were significant correlates with CV risk in females, making this implication less likely. Another possibility is that the WHR threshold of >0.85 used in this study was an underestimate of obesity, considering one article reported a WHR of 0.82 in women represented the amount of visceral adipose tissue below which subjects are generally free from metabolic disease (Lemieux, Prud'homme, Bouchard, Tremblay, & Despres, 1996). WHR in females has been linked to metabolic risks more closely than BMI or WC, so perhaps the correlation data would be different if there was more focus on metabolic and lipid profiles (Ho, et al., 2001). Yet the threshold of >0.85 is commonly used to measure obesity by WHR in females (Dalton et al., 2003). Therefore, it is unknown why WHR in females was the only non-significant correlate with CV risk in this population of firefighters, especially since most exploring the relationship between WHR and CV risk in female subjects is combined with male data (Wang & Hoy, 2004; Yusuf et al., 2005).

The strongest associations with CV risk in females were SAD and %BF(SF) (r=0.477 and r=0.538, respectively; p<0.005). Both of these measures require limited equipment and training to conduct. While both highly corresponded to CV risk, SAD classified 31.6% of female firefighters as obese and %BF(SF) classified only 17.1% as obese, which is almost a 15% difference. If the %BF cutoff recommendation of >35% is used, the difference is even more dramatic (24.3%). There are two factors that may explain these discrepancies in obesity prevalence. One is that the thresholds for both SAD and %BF in women require greater scrutiny. There is a lack of consistency for both measurements in classifying obesity, particularly in women (De Lorenzo A, 2003;

Okorodudu, et al., 2010; Pouliot, et al., 1994). Furthermore, if obesity thresholds are insufficiently supported by corresponding increases in cardiometabolic risks, they are inadequate for CV risk identification. The second factor is that the two measurements are evaluating separate variables. Percent body fat appraises total body fat, including both visceral and subcutaneous, while SAD focuses on assessing abdominal fat, which is strongly associated with visceral fat. Visceral fat is generally recognized as having a stronger association with cardiometabolic disease (Folsom et al., 1993; Liu, et al., 2010; Rexrode, et al., 1998). Yet the designated thresholds and evaluation capabilities of both SAD and %BF(SF) aligned to generate strong correlations with CV risk in female firefighters.

In males, WHR had the closest association with CV risk ($r=.557$; $p<.001$) with both measures of %BF close behind ($r=.550$ for %BF(H); $r=.540$ for BF(SF); $p<.001$). A study by Dalton and colleagues, which used the same WHR thresholds as the current study, found that before adjusting for age (which can be difficult in a clinical setting) WHR was the most useful measure of obesity in identifying individuals with CVD risk factors compared to BMI and WC (Dalton, et al., 2003). Additionally, a case-control study of over 12,000 cases of first myocardial infarction (MI) showed that WHR had a population attributable risk (PAR) of 33.7 (31.0 to 36.5; 95% CI) when using a cutoff of >0.9 for men, while obesity classified by BMI (>30 kg/m^2) had a PAR of 2.8 (2.0 to 4.0; 95% CI). WHR consistently predicted MI better than BMI, with risk of MI and WHR values progressively rising simultaneously without evidence of a threshold (Yusuf, et al., 2005). The strong link found between WHR and CV risk also aligns with evidence compiled to show the increased negative impacts of visceral fat compared to overall body fat (Lapidus et al., 1984; Liu, et al., 2010; Reis, Araneta, et al., 2009). However, %BF has also been shown to be an independent predictor of CV risk in men (Segal, et al., 1987). WC and SAD were still highly significant correlates of CV risk too ($r=.507$, .350 and .401, respectively; $p<0.001$).

STUDY STRENGTHS AND LIMITATIONS

This study possesses several strengths. First, the relatively large sample size reduced the likelihood of a type II statistical error ('false negative' or the failure to reject a false null hypothesis). Moreover, the study population included firefighters from eight separate fire departments throughout Colorado. These departments vary in geographic location, size and demographics, increasing the generalizability of the results. This is also one of limited analyses which included female firefighters. Another study strength is the qualified staff who guided the firefighters through the tests and collected the data. All measures of obesity were performed by trained students and laboratory employees. Furthermore, the cardiovascular risk level was assigned using a modified version of the Cooper Clinic Mortality Risk Index, a standardized and well-accepted assessment. Several of the variables were objective measures including LDL and HDL cholesterol, triglycerides and blood glucose, which reduced the likelihood of bias influencing associations among variables. Furthermore, the participating departments required all firefighters to attend the HPCRL for testing, eliminating volunteer bias.

This study also had limitations. In addition to the objective measures of obesity implications, self-reported variables were analyzed including diet components, physical activity, sleep habits, tension and depression. Self-reported measures can be subject to recall bias which can influence reported variables due to a subject's memory of a situation, and in this case, the potential desire to meet expectations of supervisors and/or co-workers (Elliot, et al., 2004; Taber et al., 2009; Winick, Rothacker, & Norman, 2002). Another consideration is that obesity prevalence is lower in Colorado than the national average (19.0% vs. 26.9%, respectively, as of 2009), so the obesity prevalence from this study may not be generalizable to all U.S. firefighters (Control, 2009). Moreover, for consistency, only the first visit of each firefighter was used for analysis. Since some participants started attending the HDPP in the year 2002, obesity prevalence may not be representative of the current obesity occurrence in firefighters. Due to the transient setting of the university laboratory and the extended data collection period, there were a large number of students and staff involved in the data collection and entry portion of this experiment, which could potentially reduce measurement precision. Finally, the descriptive nature of this study prohibits the suggestion of causal relationships between anthropometric measures and both obesity implications and CV risk. Cross-sectional studies such as this employ one time measures that cannot be projected beyond that point in time. Therefore, the temporality of this study prevents implications of one variable leading to another. Further clinical studies using interventions, retro- and prospective methods are required to determine if and how these variables influence one another.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND FUTURE RECOMMENDATIONS

SUMMARY

The present study sought to analyze data on a cohort of CO firefighters to enhance knowledge of obesity prevalence in this population, its associated implications and link to CV risk. Anthropometric and body composition measures of the subjects were compared to investigate if and how method of measure influenced obesity prevalence. The differences produced by the six separate methods were wide-ranging, particularly among sexes. The various methods were further analyzed for associations with variables commonly connected to obesity including blood lipid profile, diet, physical activity, sleep, anxiety and depression variables. Again, correlations varied widely between sexes. However, some variables including TG, CRP, HDL cholesterol, flexibility and estimated VO_2max remained fairly consistent across both sexes in their relationship to obesity. Finally, the various measures of obesity were examined for correlations with CV risk. All measures showed significant links to CV risk with the exception of WHR in females.

CONCLUSIONS

The percent of firefighters classified as obese in this study ranged from 7.3% to 31.6% in females and 8.0% to 43.5% in males. Obviously, both the measurement and threshold used to determine obesity impacts the resulting prevalence. There were also variations in both the strength and direction of associations among obesity implications and measures with many more significant relationships found in males, likely due to the larger subject pool. In general, positive associations were found between obesity measures and CRP and TG. Inverse relationships were displayed for obesity measures with HDL cholesterol and particular measures of fitness including estimated VO_2max and flexibility. For the purpose of choosing the body composition measure most closely associated with CV risk in firefighters, WHR should be used in males and %BF(SF) in females, assuming the other available choices are BMI, WC, WHR, and SAD. Out of all the options, hydrodensitometry requires the most expensive equipment, extensive training and can be challenging for subjects to complete. Therefore, %BF(SF) can serve as a close runner-up for determining obesity linked to CV risk in males. Using %BF(SF) for both sexes will maintain consistency and may simplify the overall data collection and reporting.

A general lesson from this study is that obesity statistics should be reviewed critically. It is important to determine not only the method used to measure obesity, but the guidelines exercised to classify it. Furthermore, the sex, age and ethnicity distribution of the population will influence the application of obesity data. Even BMI, with its well-established cut-off of 30 kg/m^2, is being re-evaluated to better assess varying populations. With increasing interest in the rising prevalence of obesity, it is essential to establish meaningful categories of obesity based on demographics to address particular objectives. For example, which measure of obesity best predicts CV risk in 30- to 40-year-old, Hispanic females? While research is increasingly being published to address such questions, the available data still does not reflect the gravity of the obesity epidemic. Therefore, the present study is merited and progresses the existing knowledge of obesity, its implications and association with CV risk in firefighters, a population especially susceptibility to CV disease.

FUTURE RECOMMENDATIONS

In order to reduce the incidence of obesity and its associated CV risk in firefighters, several preventive measures should be instituted by fire departments. An environment where appropriate equipment and space are available for regular physical activity should be available to the workers (IAFF, 2008). Exercise sessions should include specific interval training with a wide variety of tasks requiring different intensities and decision-making strategies (Perroni, et al., 2010). The incorporation of mental challenges in addition to physical ones will better emulate firefighting duties. It will also be helpful if such physical activity programs are supported by co-workers and management (IAFF, 2008).

It is critical to track the progress of such programs by regularly assessing body composition and aerobic capacity. Del Sal and colleagues purport encouraging firefighters to maintain a BMI of less than 25 kg/m^2 (Del Sal, et al., 2009). Fitness assessments in addition to body composition measurements will give providers a better indication of overall health (Zeno, Kim-Dorner, et al., 2010). The C-PAT is one fitness assessment tool already used by fire departments. While very physically demanding, the C-PAT is only required for initial employment. It has been shown to evaluate physical fitness at a specific time point and does not indicate the likelihood of maintaining long-term fitness. Moreover, there is no single fitness test that can predict aptitude on the C-PAT, emphasizing the importance of including a variety of fitness parameters in physical ability assessments (Williams-Bell, et al., 2009). Programs similar to the HDPP help meet assessment goals and are invaluable to the health and safety of firefighters, their co-workers and the people they serve.

Recent studies of anthropometric measures have employed less explored variables that may be useful in future assessments. A recent study of 111 Chinese men showed that waist to height ratio (WHtR) had the strongest correlation to intra-abdominal fat compared to BMI, WC and WHR (Wu, Xu, Chen, & Zhang, 2009). Although less reviewed, WHtR is easy to measure and may be a useful indicator of chronic disease in the future. Another anthropometric measure with potential is thigh circumference. Thigh circumference indicates increased muscle mass in the thigh region, which has been associated with decreased CV risks and mortality (Heitmann & Frederiksen, 2009). Similarly, waist to thigh ratio (WTR) has been used to help predict mortality risk with the reasoning that a lower WTR suggests a relative scarcity of visceral fat, increased subcutaneous fat or muscle or both (Reis, Macera, et al., 2009). Furthermore, greater hip circumference has been linked to decreased CV risk. Increased hip measurements may be an indicator of increased gluteal muscle and perhaps overall skeletal muscle (Yusuf, et al., 2005). In addition to specific measures of muscle mass, overall lean muscle can be applied to calculate VO_2max as a product of muscle mass (mL O_2/kg lean mass/min) to better assess cardiorespiratory fitness in populations of varying body composition, which may apply to firefighters. This methods eliminates the lowering effect of excess fat mass on relative VO_2max calculations, allowing investigators to focus on comparisons of estimated cellular oxygen turnover (Goran, Fields, Hunter, Herd, & Weinsier, 2000).

Another innovative body composition appraisal is the Fat Mass Index (FMI). An adaptation to BMI, FMI is a measure of body fat per height reported in kg/m^2 that can be compared to BMI to better understand body composition (Kelly, et al., 2009).

Finally, to successfully detect obesity in individuals and populations using a measurement method other than BMI, inconsistencies in the cutoffs and risk prediction abilities of other methods must be ameliorated. It will also be important to establish categories by sex, age, and ethnicity to more acutely determine the significance of anthropometric data and its relation to disease. This study examined data from a population of firefighters, who are at increased risk for CV disease, to help achieve the goal of accumulating valuable evidence on obesity prevalence and its associations with lifestyle variables and CV risk.

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