SYSTEMATIC REVIEW OF THE RELATIONSHIP BETWEEN BODY MASS INDEX AND HEALTH AND OCCUPATIONAL PERFORMANCE AMONG LAW ENFORCEMENT OFFICERS, FIREFIGHTERS, AND MILITARY PERSONNEL

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Abstract: **Background**: The prevalence of overweight and obesity can reach 70-75% among tactical populations, which could negatively impact health and performance. The relationship between BMI and health and performance is well established among the general population, however literature on such relationships among tactical populations has yet to be collectively reviewed, summarized, and evaluated. Thus, the purpose of this systematic review was to review available literature on the relationship between BMI and health and performance among law enforcement, firefighters, and military personnel. **Methods**: Literature searches were conducted in PubMed and SCOPUS using combinations of search terms: body mass index, health*, cardiovascular disease, heart disease, heart attack, myocardial infarction, heart failure, stroke, hypertension, cancer, diabetes, performance, physical fitness test*, physical training, fitness test*, injury*, law enforcement, police, trooper, firefighter, military, soldier, airmen, and sailor. Included studies used BMI as adiposity assessment; involved cardiovascular disease (CVD), cancer, diabetes (T2DM), performance testing, and injuries among law enforcement, firefighters, or military personnel in the US; were peer-reviewed primary research between 2000-2020. Review studies; studies on other tactical populations, retirees, trainees; and studies using BMI as a covariate were excluded. Included articles were critically appraised using the Academy of Nutrition and Dietetics Quality Criteria Checklist. **Results**: After screening titles, abstracts, and full-text, 27 articles were included. Overall quality was neutral. Nine studies regarding CVD found that increasing BMI was associated with an increase in CVD risk factors. No cancer studies were included. One study on T2DM found that higher BMI was associated with increased risk of T2DM. Five studies on occupational/physical performance found that higher BMI was often indicative of decreased performance, but results were inconsistent. Twelve studies on injury were inconsistent. Increasing BMI often indicated increased risk of injury but may be protective against stress fractures. **Discussion & Conclusions**: Increased BMI was generally associated with negative health and performance outcomes among tactical populations. Public health practitioners should focus efforts on improving nutrition and physical activity to promote a healthy BMI among these individuals.

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CHAPTER I

INTRODUCTION

Research from 2014 indicates that 40.5% of American law enforcement officers were obese.[1] At that time, this statistic was higher than the national average of obesity, which was 35.5% and 35.8% for adult men and adult women in the United States (US), respectively.[1] This is concerning, as obesity is associated with illness, medically-related early retirement, and an increased risk of cardiovascular disease (CVD).[2,3] Cardiovascular disease is the leading cause of death in the United States, and previous studies suggest that CVD morbidity is more prevalent among law enforcement officers and law enforcement retirees than the general population.[4,5]

Similarly, research shows that the prevalence of overweight and obesity among firefighters is higher than the national average, with 53% being classified as overweight and 33% being classified as obese.[6] The leading cause of death among firefighters in the line of duty is CVD, specifically sudden cardiac death, which may have been prevented through changes in lifestyle and dietary habits.[7,8]

In addition, another group that may be affected by obesity and CVD is the military. Although they are required to meet specific weight, body fat, and fitness criteria upon entering the army, research shows that 27.2% of individuals entering the army were overweight and 23.1% were obese.[9] This increases their risk for CVD,[9,10] however, these risk factors may be mitigated through exercise protocols instilled during accession.[11]

Overweight and obesity are growing issues around the world, as the World Health Organization (WHO) has listed the two conditions collectively as the fifth leading risk factor for death in the world.[12] Research shows that being in the obesity class II category is strongly associated with CVD mortality.[12] Another study, conducted by Attard and colleagues,[13] found that body mass index (BMI) was significantly higher in those who were also experiencing diabetes, hypertension, and inflammation, showing that BMI is associated with other health risks as well.

Although being underweight and overweight may come with negative health effects, it is possible that it can also affect an individual's occupational and/or physical performance.[14] In a population of older adults in Brazil, being underweight was associated with poorer performance on strength and endurance tests, while there were no significant differences in performance between overweight and normal weight individuals.[14] Another study showed that the lowest levels of mobility were displayed in those in the severely obese BMI category.[15] In contrast, individuals undergoing the Physical-Fitness-Test (PFT) in Germany showed that BMI and performance were not as strongly correlated as other studies have shown. Females, who had relatively stable BMI's overtime, had more PFT failures than males, even though males displayed increasing BMI's over time.[16]

Previous research shows that BMI has been used to assess health status and performance in the general population, however, it is not as well known whether similar relationships exist in tactical groups, including law enforcement officers, firefighters, and the military. The validity of BMI to determine overweight and obesity is of question because it is not solely a measure of body composition, and therefore may be inaccurate in populations with higher percentages of muscle mass.[17] Research conducted on BMI accuracy among law enforcement officers and firefighters leans toward under classifying individuals as obese (i.e., misclassified as non-obese, when they are considered to be obese based on body fat percentage (BF%)[18,19] and waist circumference (WC) measurements).[19,20] Research conducted in military personnel has found that there is a strong correlation between BMI and BF% measurements.[21] Within all three tactical populations, BMI has misclassified individuals as obese and non-obese when compared to BF% and WC, however, it is still a commonly used measure of health and physical fitness due to it being a cost effective and convenient measurement.

Tactical populations have significant health concerns, similar to that of the general population. These health concerns are due in part to occupational factors; however, lifestyle plays a major role. As public health practitioners, we must find ways to modify this risk. Weight status is one modifiable risk factor for both health and poor performance. Since research shows that BMI is influential in both health and performance, more deeply investigating and understanding the connection specifically in tactical populations could be beneficial.

Research Question

- How is BMI associated with health and occupational performance in tactical populations, including law enforcement officers, firefighters, and military personnel?

Purpose

- To review available literature on the relationship between BMI and health and occupational performance in tactical populations, including law enforcement officers, firefighters, and military personnel.

CHAPTER II

REVIEW OF LITERATURE

Overweight/Obesity

Body mass index (BMI) is a screening tool used to assess for overweight and obesity at the individual level.[22] It is calculated by dividing an individual's weight, in kilograms, by their height, in meters squared. According to the Centers for Disease Control and Prevention (CDC), a BMI of <18.5kg/m^2 is considered underweight, between 18.5-24.9kg/m2 is normal, between 25-29.9kg/m^2 is overweight, and ≥30kg/m2 is obese.[22]

Research shows that the obesity rate among American law enforcement officers in 2014 was higher than the national average, at 40.5%, compared to 35.5% for adult men and 35.8% for adult women.[1] Some risk factors associated with the increased obesity rates among law enforcement officers include working night shifts, where convenience foods, including fast food and gas station products, are often the most available meal; lack of physical activity due to the sedentary nature of their job; and exposure to increased levels of stress and poor health choices both at work and when off duty.[5,23-27]

Similar to law enforcement officers, research shows that the prevalence of overweight and obesity among firefighters is higher than the national average.[6,7] More specifically, research from 2015 found that 33% of firefighters were obese, 53% were overweight, and 13% were of normal weight.[6] Factors that may contribute to the prevalence of overweight and obesity among firefighters include being exposed to strenuous work followed by periods of inactivity while on the job and poor dietary habits due to their 24-hour or rotating shifts.[8]

With military personnel, we see a similar trend. According to Hruby et al.,[10] 27.15% of individuals entering the army were overweight and 23.07% were obese. Data collected in 2014 from the Health Related Behaviors Survey (HRBS) of Active Duty Personnel, indicated that 31.6% of active-duty service members over 20 years old were a healthy weight, whereas 13.9% were considered obese.[28] One year later, 2015 HRBS data indicated that the percentage of active-duty service members over 20 years old in the normal weight category increased to 32.5%, along with the percentage of obese increasing to 14.7%.[29] In addition, 65.7% of active-duty service members were overweight or obese.[29]

Cardiovascular Disease

Cardiovascular disease (CVD), the leading cause of death in the United States,[4] is influenced by obesity.[2,3] Similar trends exist for tactical populations. Cardiovascular disease accounts for 22% of on-duty law enforcement deaths,[1,5] and CVD morbidity is more prevalent among law enforcement retirees and officers when compared to the general population.[4,5]

Among firefighters, the leading cause of on-duty death is CVD, and research shows that sudden cardiac death, most of which could have been prevented through exercise, proper nutrition, and monitoring of overall health, accounts for 45% of on-duty deaths.[8,9] Soteriades and colleagues[9] found that even firefighters at a normal weight have 1.5 times the CVD risk compared to the general population. With that being said, obese firefighters have been found to have 1.8 times the CVD risk and extreme obese firefighters have been found to have 2.1 times the CVD risk compared to the general population.[9] Another study found that CVD risk factors, including age, smoking, hypertension, high cholesterol, and family history of CVD, were not significantly different between firefighters with a BMI of <30kg/m^2 compared to a BMI of >30kg/m^2, thus showing that higher BMI and heavier weight status alone may lead to the further increased risk.[8]

As for the military, data from 2015 indicate that 17.7% were diagnosed with high blood pressure and 13.3% were diagnosed with high cholesterol.[29] To compare, the CDC indicates that the prevalence of hypertension and high cholesterol among the US population between 2015 and 2016 was 29.0% and 12.4%, respectively.[30,31] Furthermore, when looking into the association between exposure to combat and risk of coronary heart disease (CHD) and ischemic stroke (IS) among men who served in World War II, the Korean War, and the Vietnam Conflict, data showed that 13.2% experienced CHD and 5.7% experienced IS.[11] In addition, combat veterans displayed the highest total cholesterol and lowest HDL cholesterol compared to non-combat veterans and non-veterans.[11]

Cancer

Wirth and colleagues,[32] conducted a review study looking into cancer risks among police officers. Researchers found that there was a significant increase in mortality due to all cancer, digestive organ malignancies, esophageal cancer, colon cancer, kidney cancer, and bladder cancer, among several others. Some risk factors of these cancers include radar emissions, ultraviolet (UV) light, obesity, physical activity, tobacco use, and alcohol consumption.[32]

In firefighters, cancer risk is increased among those who do not regularly wear or clean their personal protective equipment (PPE). Among these cancers is lung cancer.[33] Lee et al.[34] conducted a study investigating the cancer risk among male and female career firefighters compared to non-firefighters in Florida. Results showed that male firefighters were at increased risk of melanoma, prostate, and testicular cancers, but were at decreased risk of oral, pharynx, larynx, liver, lung, leukemia, and myeloid cancers. In contrast, female firefighters were at increased risk of brain and thyroid cancers.[34] A case-control study using California Cancer Registry data between 1988 and 2007 found that, among the 32 cancers examined, melanoma, prostate, and brain cancer risk were elevated among California firefighters.[35]

For military personnel, Zhu et al.[36] found significant differences in cancer incidence between those in the military and the general population. Specifically, military personnel displayed a lower incidence of colorectal cancer in white men; a lower incidence of lung cancer in white men, white women, and black men; and a lower incidence of cervical cancer in black women compared to the general population.[36] However, results indicate that military personnel of all races and sexes displayed a higher incidence of prostate and breast cancers compared to the general population.[36]

Diabetes

Diabetes prevalence among tactical populations is much less studied, and the few studies that do exist include non-US populations. In order to examine the relationship between workplace stressors and type 2 diabetes (T2DM), a cohort study was conducted in law enforcement officers, aged 20-60 years, in Tianjin, China.[37] Data indicate that 3.1% of the participants developed T2DM between 2008 and 2011.[37] Those diagnosed with T2DM were significantly older, had higher systolic and diastolic blood pressure, total cholesterol, triglycerides, larger waist and hip circumferences, and higher BMI compared to those who were not diagnosed with diabetes.[37] Nagaya et al.[38] conducted a cohort study to determine the incidence of T2DM among male clerical workers, manual/production, and transport/communication workers and law enforcement officers and firefighters in Japan. After adjusting for age, data showed that policemen and firefighters were at ~60% increased risk of diabetes compared to clerical workers.[38] Researchers suggest that the increased risk of diabetes was due to BMI, as the mean BMI among policemen/firefighters was 24.2kg/m^2, compared to 22.9kg/m^2 among clerical workers, and after adjusting for BMI, the increased risk diminished.[38]

Summary of Tactical Population Health

Altogether, research indicates that law enforcement officers, firefighters, and military personnel have increased rates of overweight, obesity, and chronic disease relative to the general population. Research suggests that weight and BMI are likely risk factors leading to some of the increased chronic disease risk. Fortunately, both weight and BMI are modifiable risk factors, which can be improved with proper nutrition and physical activity.

BMI and Health Status

According to the World Health Organization (WHO) in 2008, more than 2.8 million adults die each year from being overweight or obese, making overweight and obesity the fifth leading cause of death globally.[14] Previous research suggests that the relationship between BMI and mortality is U- or J-shaped, meaning that the lowest risk of mortality is found in the healthy weight category, and that risk increases as BMI increases or decreases when the trend is U-shaped or as BMI increases when the trend is J-shaped.[39] Another study looking into BMI and all-cause mortality and CVD mortality in Malaysian adults found that being underweight was significantly associated with all-cause mortality compared to being normal weight.[13] In contrast, being overweight decreased risk of all-cause mortality compared to normal weight, indicating an inverse relationship between BMI and risk of all-cause mortality. Furthermore, obesity class II (BMI between 35-40kg/m^2) was strongly associated with CVD mortality. The strength of this association decreased, but persisted, once researchers controlled for diabetes, hypertension, and hypercholesterolemia.[13] Attard and colleagues[14] conducted a prospective study following a cohort of adolescents into adulthood. Results showed that BMI increased over time, and BMI was significantly higher in those with diabetes, hypertension, and inflammation.[14] More specifically, risk of diabetes was strongly related to an increase in BMI during the ages of 15 and 20 years, risk of hypertension was strongly related to an individual's current BMI, and risk of inflammation was strongly related to BMI gain over time.[14] Laxy and colleagues[39] studied the relationship between BMI and health-related quality of life (HRQL), including physical functioning, as well as psychological and social well-being. Results showed a U-shaped inverse relationship, where the highest HRQL was found within the normal weight category. With that being said, the available research displays that being in the normal weight BMI category, compared to the underweight, overweight, and obese BMI categories, is associated with better health outcomes.[13,14,39]

BMI and Physical Performance

Research suggests that being both underweight and overweight come with risks of decreased physical performance.[15] One study, conducted by Ferreira and colleagues,[15] found that being underweight impaired physical function more than being overweight in a population of older adults in Brazil. Specifically, strength and endurance performance tests took longer for the 28.9% that were in the underweight category compared to the normal weight category, while there were no significant differences in completion time between those in the overweight and normal weight BMI categories.[15] Another study, focused on a population of obese older adults, found that those in the severely obese category had the lowest levels of mobility, followed by the moderately obese, overweight, and normal weight categories.[16] This was true for both performance-based mobility testing and self-report.[16] Leyk et al.[17] investigated BMI changes from adolescence into adulthood in Germany and found that there were no significant changes in BMI among women over time, whereas there was a linear increase in BMI among men over time. They found that although females had stable BMIs over time, their Physical-Fitness-Test (PFT) failure rates increased past 20 years old. In contrast, although data showed an increase in BMI over time in males, there was not an increase in PFT failure rates, showing that an increase in BMI may not have a negative impact on performance.[17] In addition, there have been studies looking into BMI and performance among athletes. In a study of elite female gymnasts, researchers found that a lower BMI was associated with better performance, however, performance was hindered with very low BMI (exact BMIs not indicated).[40] Similar to the association between BMI and health, research on BMI and performance indicates that performance is best in the normal BMI category, as strength and endurance is negatively impacted by being underweight and mobility is negatively impacted by being obese.[15,16,39]

BMI Accuracy in Tactical Groups

Since BMI does not distinguish between fat-free mass and fat-mass, it is important to understand its accuracy in determining normal weight, overweight, and obesity among these tactical groups. Although BMI is often used to determine overweight and obesity, it is made for the general population, and therefore it is possible that this measurement is not valid in law enforcement officers, firefighters, and military personnel due to differences in body composition, including possibly increased muscle mass.[8,19,20]

Alasageirin and colleagues[19] conducted a study on BMI misclassification among law enforcement officers and found that BMI misclassified obesity among 48.8% of the officers in their sample. Among those 48.8%, 70.1% were misclassified as normal or overweight by BMI when they were obese according to BF% and 29.9% were misclassified as obese by BMI when they were normal according to BF%.[19] In a study of Russian law enforcement officers, 3.4% of males and 7.7% of females were misclassified as obese using BMI compared to WC.[22] When compared to BF%, BMI misclassified 2.5% of men and 0% of women as obese. In addition, 0.6% of men and 0% of women were misclassified as non-obese by BMI when compared to WC, while

11.8% of men and 68.8% of women were misclassified as non-obese by BMI when compared to BF%, indicating that BMI is putting law enforcement officers at a healthier weight status than more direct measures of adiposity suggest. These data show that BMI is fairly accurate among both sexes when compared to WC or BF% as the more direct fat mass assessment method.[22] Overall, research regarding BMI accuracy among law enforcement officers suggests that BMI is fairly accurate when compared to WC, however, it does have a tendency to underestimate obesity when compared to BF%, contrary to what one would expect.

Jitnarin et al.[20] looked into BMI accuracy among firefighters and found that 33% of subjects who were obese based on BF% were misclassified as non-obese with BMI. In contrast, 8% of those considered non-obese using BF% were misclassified as obese with BMI.[20] Similarly, 15% of those classified as obese using waist circumference (WC) were misclassified as non-obese with BMI, and 9% of those classified as non-obese using WC were misclassified as obese with BMI.[19] Given these misclassifications, researchers noted that most of the false positives based on BMI were close to the obesity thresholds of BF% and WC and tended to have higher rates of obesity with BF% and WC than BMI, which is opposite of what would be expected.[20] In another study on BMI accuracy among firefighters, using a BMI of $\geq$30kg/m^2 as a cutoff value for being overfat was more accurate than using $\geq$25kg/m^2 as the cutoff.[38] However, 20% of the sample was still misclassified.[41] Research regarding BMI accuracy among firefighters suggests that BMI underestimates obesity, as there were higher proportions of individuals being classified as non-obese using BMI, when they were actually considered obese using BF% and WC measures.

Rona et al.[17] studied the agreement between BMI, WC, and skinfold thickness in the United Kingdom's Army. According to BMI, 49.9% were in the normal weight category, 39.9% were overweight, and 11.1% were obese. When assessing WC, 75.9% were in the normal category, 13.7% were at high risk, and 10.4% were obese.[17] Results showed that BMI and WC data are closely related, with higher agreement at higher levels of obesity.[17] Research regarding BMI accuracy among military personnel suggests that BMI becomes more accurate at higher levels of obesity, however, it underestimates the proportion of normal weight individuals and overestimates the proportion of overweight individuals when compared to WC. This phenomenon is more along the lines of what one would expect with tactical populations.

Within all three tactical populations, BMI misclassified individuals as obese and non-obese when compared to BF% and WC. In law enforcement officers and firefighters, we often saw BMI underestimating obesity, however, in military personnel, we saw the opposite. Instead, BMI was overestimating obesity in military personnel, but this overestimation diminished at higher levels of obesity. Although BMI is not as accurate as one would like, it is still a commonly used measure of health and physical fitness due to it being cost-effective, as well as being a simple measurement requiring only height and weight information.

Another aspect of BMI accuracy is weight perception. Although there were no studies found regarding weight perception among law enforcement officers, research among firefighters and military personnel suggest that these populations tend to underestimate their weight. Research conducted in male firefighters indicated that a high proportion underestimate their weight, especially when they are actually classified as overweight or obese.[42] Specifically, 89% accurately perceived themselves as a normal weight, whereas only 32.4% accurately perceived themselves as overweight and only 8.2% accurately perceived themselves as obese.[42] Among military personnel, a study conducted in overweight and obese adults found that those reporting military service were 44% more likely to underestimate their weight compared to non-military service participants.[43] Another study found that among overweight males in the military, 57% accurately perceived themselves as overweight, whereas 42% believed they were of normal weight, and 1% believed they were underweight.[44] On the other hand, females in the military seemed to perceive their weight more accurately, as 91% of overweight females accurately perceived themselves as overweight, with only 6% believing they were of normal weight and 3% believing they were underweight.[44] This common underestimation of weight status in tactical populations may be important in determining the individual, and even population, readiness to change dietary and lifestyle habits.

Need for Connecting BMI with Health and Performance in Tactical Populations

Since BMI is a commonly used tool to measure health and physical fitness, it is important to study the association between BMI and health and performance in tactical populations. Not only are overweight and obesity associated with health concerns, but it can also impact overall performance on the job. It is known that there are occupational factors that may increase the risk of these health concerns; however, it is important to note that lifestyle factors may also play a role in the development of these chronic diseases and that one modifiable risk factor is weight status. In summary, investigating the relationship between BMI and health and performance among law enforcement officers, firefighters, and military personnel could be beneficial in improving their long-term health outcomes, as well at their performance on the job.

CHAPTER III

METHODOLOGY

Search Strategy

The search strategy for this systematic review was developed *a priori* utilizing the PRISMA checklist.[45] Relevant studies were identified from literature searches in PubMed and SCOPUS electronic databases. Filters for searches included journal articles and published in the last 20 years. Search terms, used in various combinations, included body mass index, health*, cardiovascular disease, heart disease, heart attack, myocardial infarction, heart failure, stroke, hypertension, cancer, diabetes, performance, physical fitness test*, physical training, fitness test*, injury*, law enforcement, police, trooper, firefighter, military, soldier, airmen, and sailor.

Inclusion and exclusion criteria were established *a priori*. Studies were included if they used body mass index (BMI) as the primary weight/adiposity assessment method; involved the most common chronic diseases (cardiovascular disease (CVD), cancer, diabetes) or mortality from these chronic diseases; involved job-related or occupational performance testing or injuries on the job; involved current law enforcement officers, career and volunteer firefighters, or military personnel; involved a United States population; were peer-reviewed journal articles on primary research; and were published from 2000-2020. Relevance to the population was established if articles included BMI as the exposure and included health or performance outcomes. Articles were excluded if they were review studies; involved other first responders aside from law enforcement officers, firefighters, or military personnel; involved retirees; involved Reserve Officer Training Corps (ROTC) or military academy cadets; involved law enforcement or firefighter cadets or trainees in an academy; or used BMI only as a covariate. A flowchart of the article selection process can be found in Figure 1.

Prior to submission for peer-reviewed publication, the search strategy and quality assessment will be completed independently by two reviewers. After completing these processes independently, reviewers will compare results to identify discrepancies. Identified discrepancies will be discussed until agreement is reached. Reviewers will reach 100% agreement on all included/excluded studies and quality assessments.

Data Extraction and Critical Appraisal

Information was extracted from each included article and summarized. Extracted information included authors; year of publication; study design; tactical population, sample size, and characteristics; intervention, exposure and duration, and follow-up period; outcome measures; and results. Some studies reported more, however, only outcomes of interest were extracted. In addition, articles were assessed for quality using the Academy of Nutrition and Dietetics Evidence Analysis Library (AND EAL) Quality Criteria Checklists for Primary Research.[46] This checklist includes four questions on relevance and ten questions on validity of the article. Each question is rated as “yes,” “no,” “unclear,” or “N/A.” If most of the validity questions, including questions 2, 3, 6, and 7 are rated as “yes,” the article is rated as positive, meaning that the report has clearly addressed issues of inclusion/exclusion, bias, generalizability, and data collection and analysis. If the responses to questions 2, 3, 6, and 7 do not indicate that the report is positive, the article is rated as neutral, indicating the article is not exceptionally strong nor exceptionally weak. Lastly, if six or more of the validity questions are "no," the article is rated as negative, indicating that inclusion/exclusion, bias, generalizability, and data collection and analysis are not adequately addressed.

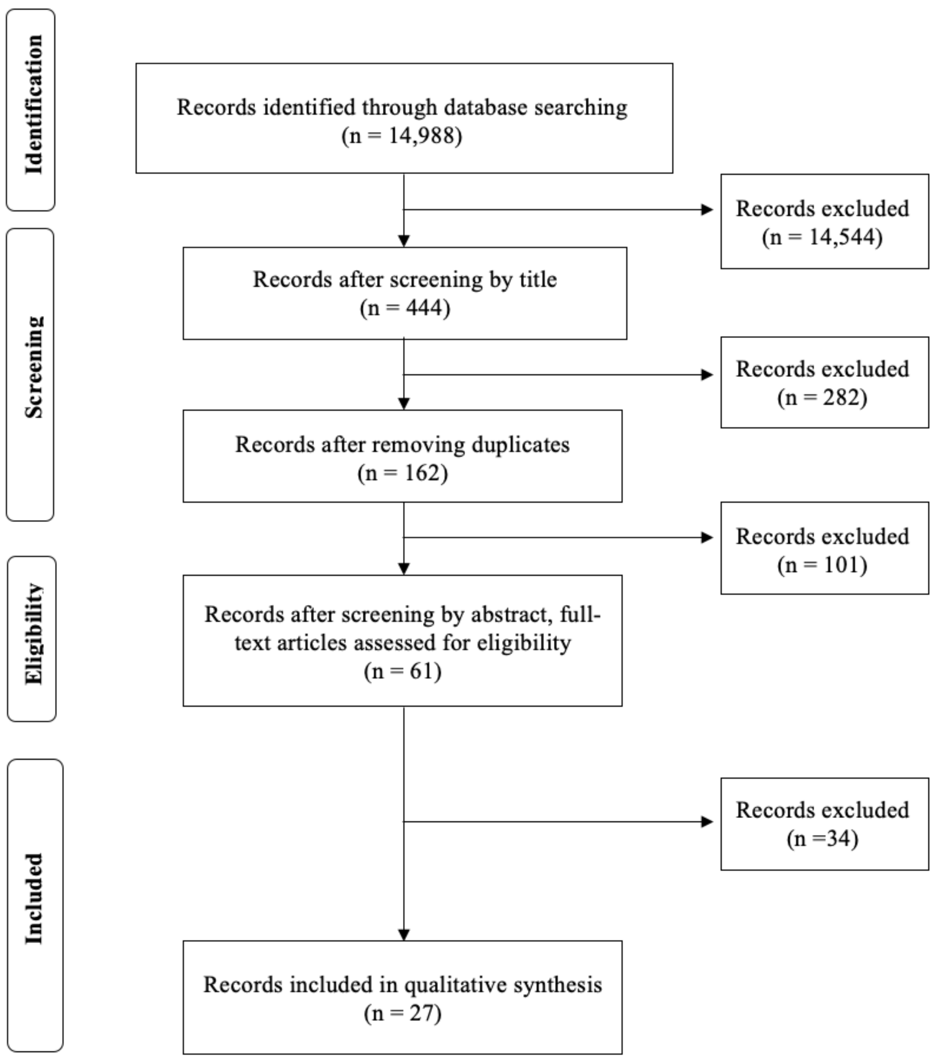

Figure 1: Flow diagram of the literature search and filtering process for the current systematic review on BMI and health and occupational performance outcomes among law enforcement officers, firefighters, and military personnel.

CHAPTER IV

FINDINGS

Study Selection and Characteristics

A total of 14,988 records were identified in the initial database search and 14,544 were excluded after screening titles. Four hundred forty-four titles were included from initial searches based on relevance as indicated by search terms, inclusion criteria, exclusion criteria, and relevance to research question. Two hundred eighty-two duplicate titles were removed. From the 162 remaining titles, abstracts were reviewed based on inclusion/exclusion criteria and relevance to research questions. One hundred one studies were removed at this stage. From the 61 included abstracts, full-text articles were assessed based on inclusion/exclusion criteria and relevance. Thirty-four full-text articles did not meet inclusion criteria and were removed. The 27 remaining full-text articles were read, summarized, and assessed for quality.

Of the 27 articles included for review, 9 articles focused on cardiovascular disease (CVD), none on cancer, one on diabetes, five on occupational/physical performance, and 12 on injury. Four studies were conducted with law enforcement officers, 10 with firefighters, and 13 with military personnel. The majority of study designs were cross-sectional (n=15). Other study designs include retrospective cohort (n=5), prospective cohort (n=5), case-control (n=1), and secondary analysis (n=1).

Cardiovascular Disease

Nine included studies were related to BMI and CVD. Of these nine studies, two were conducted in law enforcement officers, six in firefighters, and one in military personnel. All nine studies were cross-sectional in design. Cardiovascular disease was assessed in numerous ways, including modified metabolic syndrome (MMetS), heart rate variability (HRV), hemodynamic variables, microvascular and macrovascular function, left ventricular mass (LVM), and general CVD risk factors, including blood pressure (BP), cholesterol, and triglycerides (TG).

Anderson, Yoo, and Franke[47] conducted a cross-sectional study determining the association between BMI and MMetS among 448 sworn law enforcement officers of the Iowa Department of Public Safety. Researchers measured metabolic syndrome risk factors, including systolic BP, diastolic BP, serum TG, HDL cholesterol, and plasma glucose according to the American Heart Association and National Heart, Lung, and Blood Institute criteria. Height and weight data were collected, instead of WC, to assess the abdominal obesity criteria as having a BMI $\geq 30 kg/m^2$. To assess BMI as an independent variable, researchers used MMetS, which excluded BMI from the metabolic syndrome criteria. Modified metabolic syndrome was defined as having at least three of the four remaining risk factors. Results indicated that law enforcement officers with metabolic syndrome had a higher prevalence of overweight and obesity compared to those without metabolic syndrome (98.4% vs 73.5%, respectively, $p<0.0001$ for trend). After adjusting for age, race, sex, smoking history, and physical activity, law enforcement officers in the overweight BMI category had a 6.52-fold increased odds of developing MMetS compared to those in the normal BMI category (OR = 6.52, 95% CI = 1.49-28.57). Furthermore, law enforcement officers in the obese BMI category had 10.46-fold increased odds of developing MMetS compared to those in the normal BMI category (OR = 10.46, 95% CI = 2.38-46.05). These results indicate that an increasing BMI was associated with an increased risk of MMetS.

Andrew and colleagues[48] conducted a cross-sectional study on the associations of indices of adiposity, lean body mass, and physical activity, with HRV among 360 law enforcement officers from the Buffalo Police Department. Subjects were part of the Buffalo Cardio-Metabolic Occupation Police Stress cohort. Height, weight, BMI, and waist circumference (WC) were measured by certified staff. Heart rate variability was measured using electrocardiograms (ECG), and measured HRV was reported as long transformation of low-frequency (LnLF) and high-frequency (LnHF) HRV. Results indicated a weak positive association between BMI and heart rate (HR) ($r=0.120$), and a weak negative association between BMI and LnHF and LnLF HRV ($r=-0.098$ and -0.096, respectively). In addition, 10% of LnHF HRV was due to BMI after controlling for age, sex, and anthropometrics ($r^2 = 0.1012$). These results show that as BMI increased, there was a small increase in HR and a small decrease in HRV. A decrease in HRV is indicative of increased CVD risk.

Looking now at firefighters, Choi et al.,[49] conducted a cross-sectional study on the relationship between three adiposity measures (BMI, WC, and body fat percentage (BF%)) and CVD risk factors among 355 firefighters (347 men and 8 women) in Southern California. Subjects participated in the Firefighter Obesity Research: Workplace Assessment to Reduce Disease (FORWARD) study. Data on medication use for heart problems, hypertension, hyperlipemia, and DM and on tobacco use were collected via questionnaire. Researchers measured height, weight, BMI, WC, and BF% (skinfold) of the participants. The prevalence of hypertension was significantly higher among individuals with a BMI $\geq 30 kg/m^2$ compared to normal weight (BMI between $18.5–24.9 kg/m^2$) ($p<0.05$). Prevalence of high cholesterol was significantly higher among individuals with a BMI between 27.5-29.9kg/m^2 ($p<0.05$) and a BMI ≥30kg/m^2 ($p<0.01$) compared to normal weight. In addition, the prevalence of low HDL was significantly higher among individuals with a BMI ≥30kg/m^2 ($p<0.001$) and of high LDL was significantly higher among individuals with a BMI between 27.5-29.9kg/m^2 ($p<0.05$) and a BMI ≥30kg/m^2 ($p<0.01$) compared to normal weight. The prevalence of high TG was significantly higher among individuals with a BMI ≥30kg/m^2 compared to normal weight ($p<0.01$). Lastly, the prevalence of low VO_{2max} was significantly higher among individuals with a BMI between 25-29.9kg/m^2 ($p<0.05$), a BMI between 27.5-29.9kg/m^2 ($p<0.01$), and a BMI ≥30kg/m^2 ($p<0.001$) compared to normal weight. Results indicate that all six risk factors for cardiovascular disease were positively associated with BMI. These associations were stronger among individuals with a BMI ≥30kg/m^2.

Clark, Rene, Theurer, and Marshall[50] conducted a cross-sectional study on the association between BMI and general health/fitness among 218 active male firefighters (white, aged 18-58) of six municipal fire departments in north central Texas. Subjects were undergoing duty fitness evaluations during the time of data collection. Researchers collected height, weight, and BMI for each subject. Health and fitness status were measured through systolic BP, diastolic BP, cholesterol, HDL cholesterol, cholesterol/HDL ratio, TG, FVC% (forced vital capacity percent predicted), FEV1sec% (forced expiratory volume at one second percent predicted), VO_{2max}, and METS. Researchers also conducted routine laboratory tests (complete blood count, lipid profile, liver and kidney function test, electrolytes, urinalysis), resting 12 lead ECG, and spirometry. Body mass index was categorized in two ways. When categorizing BMI as low (<27kg/m^2), medium (between 27-30kg/m^2), and high (>30kg/m^2), researchers found significant differences between groups in diastolic BP (74.6±7.9 for low, 76.9±8.6 for medium, 79.5±7.8 for high, $p<0.05$), cholesterol (189.0±36.1 for low, 204.0±36.9 for medium, 204.7±35.1 for high, $p<0.05$), cholesterol/HDL ratio (4.2±1.0 for low, 4.9±1.5 for medium, 4.9±1.3 for high, $p<0.05$), triglycerides (112.1±60.0 for low, 176.3±163.2 for medium, 168.9±91.2 for high, $p<0.05$), VO_{2max} (47.6±4.3 for low, 44.1±4.1 for medium, 41.2±4.0 for high, $p<0.05$), and METS (13.5±1.2 for low, 12.5±1.2 for medium, 11.7±1.2 for high, $p<0.05$). When categorizing BMI as normal ($\leq$25kg/m^2), overweight (between 25-30kg/m^2), obese (between 30-39kg/m^2), and morbid ($\geq$39kg/m^2) according to WHO and adjusting for age, researchers found significant differences between groups in systolic BP (116.4±10.1 for normal, 122.6±11.5 for overweight, 123.2±10.0 for obese, 128.0±13.0 for morbidly obese, $p<0.05$), diastolic BP (73.3±8.4 for normal, 76.2±8.0 for overweight, 78.8±7.3 for obese, 88.8±7.6 for morbidly obese, $p<0.05$), cholesterol (173.5±25.0 for normal, 203.8±37.6 for overweight, 206.0±35.5 for obese, 188.4±23.9 for morbidly obese, $p<0.05$), cholesterol/HDL ratio (3.9±0.9 for normal, 4.7±1.4 for overweight, 5.1±1.3 for obese, 3.6±0.6 for morbidly obese, $p<0.05$), triglycerides (92.0±48.0 for normal, 156.8±132.2 for overweight, 171.3±91.8 for obese, 137.8±85.3 for morbidly obese, $p<0.05$), VO_{2max} (48.6±3.8 for normal, 44.7±5.8 for overweight, 41.7±3.9 for obese, 37.0±2.8 for morbidly obese, $p<0.05$), and METS (13.8±1.1 for normal, 12.7±1.8 for overweight, 11.91.1 for obese, 10.6±0.8 for morbidly obese, $p<0.05$). Results from both BMI categorizations indicate that as BMI increased, there was an increase in diastolic BP and decreases in VO_{2max} and METS. When BMI is categorized as low, medium, and high, results showed that cholesterol was lowest among the low BMI group, but almost the same between the medium and high BMI groups. The same trend was found with cholesterol/HDL ratio. When BMI was categorized according to WHO, both cholesterol, cholesterol/HDL ratio, and TG increased with increasing BMI until the morbidly obese category, which displayed a drop in all three.

Eastlake and colleagues[51] conducted a cross-sectional study evaluating the occupational exposures, lifestyle factors, and demographic characteristics of firefighters in relation to CVD risk factors. Subjects included 157 firefighters (117 full-time, 16 part-time, and 24 volunteer) in Hamilton County, Ohio. An online survey was used to collect data on occupational risk factors including particulates, heat stress, noise, dermal exposure, job stress, use of personal protective equipment; lifestyle risk factors including exercise, diet, smoking, drinking, video gaming; and demographic characteristics including age, race, height, weight, BMI, gender. Cardiovascular risk factors were assessed through a survey regarding health status, including diagnoses of heart disease, vascular disease, stroke, hypertension, diabetes, or high cholesterol. Results indicated that an increasing BMI was associated with high cholesterol (OR = 1.09 ± 0.08, p=0.03).

Fahs et al.[52] conducted a cross-sectional study on the effect of excess body weight on hemodynamic variables and arterial structure and function in 110 young and healthy firefighters. Researches collected data on height, weight, BMI, and WC for each participant, as well as data on hemodynamic variables (brachial BP, carotid BP, aortic BP, radial augmentation index, central pulse wave velocity), microvascular function (forearm blood flow, forearm vasodilatory capacity), and macrovascular structure and function (carotid intima media thickness, brachial flow-mediated dilation). Researchers categorized BMI into tertiles, where Group 1 had a BMI<25.9kg/m^2, Group 2 between 25.9-29.9kg/m^2, and Group 3 ≥29.5kg/m^2. After adjusting for age, results indicated that Groups 2 and 3 had greater systolic BP than Group 1 (122mmHg, 126mmHg, 130mmHg for Groups 1, 2, and 3, respectively, p<0.05). In addition, Group 3 had a greater mean arterial pressure than Group 1 (86mmHg and 92mmHg for Groups 1 and 3, respectively, p<0.05), as well as a greater carotid systolic BP than Group 1 (112mmHg and 120mmHg for Groups 1 and 3, respectively, p<0.05). Results indicated that a higher BMI was associated with increased systolic BP, mean arterial pressure, and carotid systolic BP.

Korre et al.[53] conducted a cross-sectional study regarding BMI and left ventricular mass (LVM) measured with echocardiography (ECHO) and cardiac magnetic resonance (CMR) among 393 male career firefighters from the Indianapolis Fire Department. Researchers also measured height and weight for BMI, BP, and HR. Results indicated that, when using ECHO, every one unit increase in BMI increased LVM by 0.55g/$m^{1.7}$ (SE = 0.1) (p<0.001). When using CMR, every one unit increase in BMI increased LVM by 0.45g/m$^{1.7}$ (SE = 0.0) ($p<0.001$). For both assessments, a one-unit increase in BMI was associated with an increased LVM by 0.45-0.55g/m$^{1.7}$.

Risavi and Staszko[54] conducted a cross-sectional study on the knowledge and prevalence of coronary artery disease risk factors, including systolic BP, diastolic BP, and physical activity, among 160 firefighters from 37 local fire departments in the Commonwealth of Pennsylvania. Anthropometric measurements including height, weight, BMI, and WC were collected. Results indicated that an increased BMI was associated with greater odds of hypertension (OR = 1.16, 95% CI = 1.097-1.237), and thus an incremental increase in BMI increased risk of hypertension risk by 16%.

Looking at military personnel, Hruby and colleagues[55] conducted a cross-sectional study on weight status upon entering the Army and cardiometabolic risk factors (CRF), such as hypertension, disorder of glucose or insulin metabolism, dyslipidemia, metabolic syndrome, overweight/obesity (among initially underweight and normal-weight soldiers). Soldiers who entered the Army between 2001 and 2011 were included in this study (n=731,014). Data was extracted from the Total Army Injury and Health Outcomes Database (TAIHOD), 2001–2011. Data included date of birth, race/ethnicity, education, marital status, height, weight, and BMI. Results showed that there was an increased incidence of metabolic syndrome among overweight (HR = 3.68, 95% CI = 2.55-5.30) and obese (HR = 10.85, 95% CI = 7.29-16.15) subjects compared to normal weight. There was also an increased incidence of impaired glucose/insulin disorder among overweight (HR = 1.18, 95% CI = 1.09-1.26) and obese (HR = 2.05, 95% CI = 1.86-2.25) subjects compared to normal weight. When looking at hypertension, result indicated a decreased incidence of hypertension among underweight subjects (HR = 0.63, 95% CI = 0.56-0.72), but an increased incidence of hypertension among overweight (HR = 1.59, 95% CI = 1.54-1.63) and obese (HR = 2.44, 95% CI = 2.36-2.53) subjects compared to normal weight. Similarly, for dyslipidemia, results indicated a decreased incidence among underweight subjects (HR = 0.72, 95% CI = 0.60-0.85), but an increased incidence of among overweight (HR = 1.56, 95% CI = 1.50-1.62) and obese (HR = 2.36, 95% CI = 2.24-2.48) subjects compared to normal weight. These results showed that being underweight, overweight, and obese had an effect on CRF, where being underweight was protective against hypertension and dyslipidemia, but being overweight or obese increased risk of impaired glucose/insulin disorder, hypertension, and dyslipidemia.

Cancer

There were no included studies related to BMI and cancer in tactical populations.

Diabetes

One included study was related to BMI and diabetes. This study was conducted in military personnel. Paris and colleages[56] conducted a case-control study looking into type 2 diabetes mellitus (T2DM) among active-duty soldiers in the Army, Navy, Air Force, and Marines. There were 419 cases and 1627 controls that were matched 4-1 by age, sex, branch of service, entry date, and time in service. Data were collected on cases and controls who were in the military between January 1997 and August 2000. Researchers used the Defense Manpower Data Center to collect data on height, weight, BMI, education, race, rank, and blood pressure. Results indicated that T2DM was associated with a higher BMI (mean BMI for cases = 24.0±3.3; mean BMI for controls = 23.1±2.9, $p<0.0001$). In addition, there were increased odds of T2DM with a BMI between 25.0-29.9kg/m2 (OR = 2.0, 95% CI = 1.4-3.0, $p<0.001$) and with a BMI ≥30kg/m2 (OR = 3.0, 95% CI = 1.4-6.4, $p<0.01$). This study indicated that a BMI in the overweight and obese categories was associated with an increased risk of T2DM.

Occupational/Physical Performance

There were five included studies related to occupational/physical performance. One study was conducted in law enforcement officers, two in firefighters, and two in military personnel. Of these five studies, four were cross-sectional and one was a prospective cohort study. Performance was measured through a variety of methods, including VO_{2max}, rate of perceived exertion (RPE), HR, blood lactate, respiratory exchange ratio, physical fitness assessments, and job disability.

Related to law enforcement officers, Dawes et al.,[57] conducted a cross-sectional study on the association between BMI and Defensive Tactics (DEFTAC) Drills in 24 male highway patrol officers in Colorado. Researchers collected height, weight, BMI, and duty weight for each participant. Outcome measures included drill scores, time, rating of perceived exertion (RPE), average HR, average % HR, peak HR, peak % HR, and blood lactate. Researchers found no significant differences in performance variables when comparing healthy and overweight participants. When looking at exertion and performance among the healthy weight group, there was a moderate positive relationship between RPE and time ($r=0.600$, $p\leq0.05$), blood lactate and score ($r=0.590$, $p\leq0.05$), and time and score ($r=0.699$, $p\leq0.01$). When looking at the overweight group, there was a moderate positive relationship between blood lactate and peak % age-predicted maximum HR ($r=0.597$, $p\leq0.05$), RPE and peak % age-predicted maximum HR ($r=0.629$, $p\leq0.05$), and weight and time ($r=0.675$, $p\leq0.05$). These results indicated that when comparing healthy weight and obese groups a higher weight was associated with higher exertion and poorer performance, however, there were no significant differences in performance variables between healthy and overweight subjects.

Looking at firefighters, Houck and colleagues[58] conducted a cross-sectional study on physical fitness in 80 (76 men, 4 women) active-duty urban or wildland firefighters in New Mexico. Data were collected as part of the firefighters' annual health assessment required by their employer. Researchers also collected BF%, BP, and BMI data. Physical fitness was evaluated through VO_{2max}, respiratory exchange ratio, maximum grip strength, YMCA bench press, sit-and-reach, and Margaria-Kalamen test. Results indicated that VO_{2max} was moderately negatively correlated with BMI (r=-0.497). In addition, participants in Q1 (highest VO_{2max}) and Q2 for VO_{2max} had a significantly lower BMI when compared to Q4 (lowest) VO_{2max} ($p<0.05$). These results showed that as BMI increased VO_{2max} decreased, and those with the highest VO_{2max} scores had lower BMIs.

Soteriades et al.[59] conducted a prospective cohort study examining the association between obesity and risk of job disability among 358 firefighters from six regional hazardous materials teams in the Commonwealth of Massachusetts. Weight, height, BMI, age, sex, job type (technician, support member), smoking history, blood pressure, blood glucose, and total cholesterol were collected at baseline and at each follow-up. Firefighters were followed for a maximum of 6 years. Short-term or permanent job disability was verified by the Massachusetts' Office of Hazardous Materials Response and included placement on 'injured on-duty' status, termination of duty, resignation, premature retirement, or death. Researchers categorized BMI as normal ($<25kg/m^2$), overweight ($25\text{-}30kg/m^2$), and obese ($\geq30kg/m^2$). Results indicated that firefighters in the highest BMI category had a 50-70% increase risk of job disability. More specifically, firefighters above the median BMI ($28.5kg/m^2$) had a 70% increased risk of job disability compared to firefighters with a BMI below the median (HR = 1.69, 95% CI = 1.02-2.80). Researchers found significant differences in prevalence of hypertension between the three BMI categories ($p<0.01$), with a majority being in the overweight category (n=31), followed by the obese category (n=29). Lastly, a BMI $\geq30.2kg/m^2$ was found to be associated with a two-times increased risk of job disability (HR = 1.98, 95% CI = 1.06-3.72). These results showed that a higher BMI was associated with a greater risk of job disability.

Looking at military personnel, Pierce et al.,[60] conducted a cross-sectional study on the association between BMI and physical fitness assessments in 321 (275 men, 46 women) active-duty soldiers from an infantry brigade combat team. Researchers collected data on age, height, weight, and BMI for each participant. Physical fitness assessments included muscular strength (hex bar deadlift, bench press), muscular power (sled drag, sled push, medicine ball power throw), muscular endurance (bench press endurance, goblet kettlebell squat endurance), and speed/agility (400-m run, 300-yd shuttle run, Illinois agility test). Two other measures of physical fitness were through a series of obstacles that represented Common Soldiering Tasks (CSTs) and Warrior Tasks and Battle Drills (WTBDs) and through recent Army Physical Fitness Test (APFT) scores. Researchers categorized BMI into tertiles based on gender. For men, BMI teriles were T1 (18.6-23.8kg/m^2), T2 (23.9-26.5kg/m^2), and T3 (26.6-34.9kg/m^2). For women, the tertiles were T1 (16.9-22.1kg/m^2), T2 (22.1-25.4kg/m^2), and T3 (25.6-28.8kg/m^2). Researchers found that male and female soldiers with a higher BMI, as indicated by being in T2 and T3, performed better than T1 on lower and upper body muscular strength and lower body muscular power ($p \leq 0.05$), but didn't perform as well as T1 in speed/agility ($p \leq 0.05$). When looking specifically at men, researchers found that a higher BMI positively influenced lower and upper body muscular power and upper body muscular endurance ($p \leq 0.05$), but negatively influenced speed/agility ($p \leq 0.05$). However, in women, a higher BMI was associated with increased lower body muscular endurance ($p \leq 0.05$). For APFT performance, researchers found that women in T2 and T3 completed significantly less sit-ups than T1 ($p<0.01$). Men in T2 and T3 had significantly higher 2-mile run times than T1 ($p<0.01$), and similarly, women in T3 had significantly higher 2-mile run times than T1 ($p=0.025$). These results indicated that a higher BMI was positively associated with muscular strength and power, but negatively associated with speed/agility and 2-mile run times in both men and women.

Teyhen et al.[61] conducted a cross-sectional study on the association of being overweight, smoking, physical inactivity, and history of injury with physical performance 1466 (1380 men, 86 women) active-duty service members (combat, combat service, and combat service support) in the Military Power, Performance, and Prevention trial. Researchers collected self-reported data on physical inactivity, height, weight, BMI, smoking, and prior injury. Physical performance tests included triple-crossover hop for distance, 6-m timed-hop test, Functional Movement Screen, Lower Quarter Y-Balance test (YBT-LQ), Upper Quarter Y-Balance test (YBT-UQ), and 3-event APFT. Results indicated that subjects with a BMI ≥27.5 performed poorer on all tests ($p<0.001$) except the 2-minute push-up test ($p=0.2$), showing that a higher BMI was associated with poorer performance on most tests.

Injury

Twelve included studies were related to injury. Of these 12 studies, one was conducted in law enforcement officers, two in firefighters, and nine in military personnel. There were five retrospective cohorts, four prospective cohorts, two cross-sectional, and one secondary analysis. Injuries were assessed through questionnaires, screening medical records, and the Defense Manpower Data Center and Defense Medical Surveillance System (DMSS).

Looking first at law enforcement officers, Mota et al.,[62] conducted a cross-sectional study on the prevalence of overweight and obesity and the factors associated with work-related musculoskeletal injury and physical activity levels in 1323 (708 men, 615 women) probation officers in North Carolina. A health history questionnaire was used to collect data on demographics including age, sex, body mass, stature, BMI, physical activity, rural/urban work location, and years of employment. Musculoskeletal injury data was also assessed through a questionnaire. Results indicated that, of the 96 officers who sustained a work-related musculoskeletal injury within the past year, 5.5% were normal weight, 6.1% were overweight, 7.2% were class I obese, 7.9% were class II obese, and 13.5% were class III obese. Being in the class III obese category was associated with increased odds of work-related musculoskeletal injury compared to being in the normal weight category (OR = 2.56, 95% CO = 1.19-5.51, p=0.008). These results showed that obesity may be an indicator of increased risk for musculoskeletal injury on the job.

Looking next at firefighters, Jahnke, Poston, Haddock, and Jitnarin[63] conducted a prospective cohort study evaluating obesity as a risk factor for incident injury among 301 male firefighters and from 11 career fire departments in the Missouri Valley region. Researchers measured height, weight, BMI, BF%, and WC, and provided questionnaires and rating scales to collect data on physical activity, tobacco use, problematic alcohol use, on-duty sleepiness, and depression. Follow-up was completed at nine months for career firefighters and six months for volunteer firefighters. Injury and musculoskeletal injury were assessed using a questionnaire. Researchers found that there was an increased odds of incident musculoskeletal injury in obese subjects compared to normal weight subjects (OR = 5.2, 95% CI = 1.1-24.5), and that there were no significant increases in odds of incident injury or incident musculoskeletal injury in overweight subjects compared to normal weight. These results showed that obesity was associated with an increased odds of incident musculoskeletal injury.

Kuehl et al.[64] conducted a prospective cohort study evaluating impact of lifestyle factors and BMI on injury and workers' compensation claims. Subjects were 433 firefighters who participated in the Promoting Healthy Lifestyles: Alternative Models' Effects (PHLAME) worksite wellness program in fire departments in Oregon and Washington. Researchers collected data on medical history, physical measures (height, weight, BMI), demographics, diet, physical activity, team support, and general health, and followed subjects over the course of seven years. A survey was used to collect data on injury and workers' compensation claims occurring five years after the PHLAME intervention. There were significant differences in prevalence of elbow/hand injury between the three BMI categories 0.8% of 105, 3.7% of 219, and 5.9% of 69 for prevalence of elbow/hand injury among normal, overweight, and obese BMI categories, respectively) ($p<0.05$). Results indicated that there were no significant differences in injury of other parts of the body, aside from the elbow/hand, among the three BMI categories.

In regard to military personnel, Eagle and colleagues[65] conducted a prospective cohort study regarding the association between anthropometric, physiological, and strength characteristics and ankle injury in 140 male Special Tactics Operators in the US Air Force. Researchers measured body composition (BF%, body mass, fat free mass, height, BMI) with an air-plethysmography chamber (BODPOD). Ankle injury was assessed through medical chart review of injuries using the Armed Forces Health Longitudinal Technology Application. Results indicated that the injured group displayed higher BMIs ($p=0.01$) than non-injured group and that BMI significantly predicted ankle injury (OR = 2.24, 95% CI = 1.23-4.08, $p=0.011$). These results showed that BMI was associated with increased odds of injury.

Henderson and colleagues[66] conducted a cross-sectional study on injury incidence and risk factors among 726 Army soldiers who just completed basic combat training and advanced individual training at Fort Sam Houston, TX. Subjects answered a questionnaire on demographics (race/ethnic group, gender), and lifestyle (physical activity before entering the army, tobacco use, alcohol use in the past year, use of birth control for females). Height, weight, and BMI were collected from battalion personnel records after the start of training. Medical records were screened for injury data. Researchers found that there were no significant differences in injury incidence among men and women based on BMI category.

Hruby et al.[67] conducted a secondary analysis on BMI and musculoskeletal injury and connective tissue disorder (MID) data among 736,608 active-duty Army soldiers entering the Army between 2002 and 2011. This study extracted data from the Total Army Injury and Health Outcomes Database (TAIHOD), 2001–2011. Data included date of birth, race/ethnicity, education, marital status, height, weight, and BMI. Post-accession incident MIDs were identified by ICD-9 codes. Body mass index was categorized as underweight (<18.5kg/m^2), normal weight (between 18.5-25kg/m^2), overweight (between 25-30kg/m^2), and obese (≥30kg/m^2). Results indicated an increased risk of MID in underweight (HR = 1.07, 95% CI = 1.05-1.09), overweight (HR = 1.11, 95% CI = 1.11-1.12), and obese subjects (HR = 1.33, 05% CI = 1.32-1.35) compared to normal weight subjects. When looking at MIDs in specific areas of the body, researchers found a decreased risk of hip MID in underweight subjects (HR = 0.94, 95% CI = 0.89- 0.99), but an increased risk in overweight (HR = 1.17, 95% CI = 1.15-1.19) and obese subjects (HR = 1.45, 95% CI = 1.45-1.53) compared to normal weight subjects. Researchers also found an increased risk of knee MID in overweight (HR = 1.13, 95% CI = 1.12-1.14) and obese (HR = 1.36, 95% CI = 1.34-1.38); an increased risk of upper leg MID in underweight (HR = 1.06, 95% CI = 1.01-1.11), overweight (HR = 1.06, 95% CI = 1.04-1.07), and obese subjects (HR = 1.28, 95% CI = 1.25-1.32); and an increased risk of lower leg/ankle MID in underweight (HR = 1.06, 95% CI = 1.03-1.08), overweight (HR = 1.12, 95% CI = 1.11-1.13), and obese subjects (HR = 1.36, 95% CI = 1.34-1.37) compared to normal weight subjects. Finally, an increased risk of foot/toe MID was observed in overweight (HR = 1.15, 95% CI = 1.13-1.16) and obese subjects (HR = 1.40, 95% CI = 1.37-1.43) compared to normal weight subjects. These results showed that being underweight, overweight, or obese was associated with increased risks of musculoskeletal injury and connective tissue disorders.

Jones et al.[68] conducted a retrospective cohort study on the association between physical fitness and BMI on musculoskeletal injury among 184,670 (143,398 male, 41,272 female) trainees entering Army basic training. Age and gender data were collected from the Defense Manpower Data Center and Defense Medical Surveillance System (DMSS). Height, weight, BMI, and AFPT scores collected from the Training and Doctrine Command. Data on musculoskeletal injuries were collected from the DMSS. Researchers classified BMI as quintiles among men and women. For men, the quintiles were Q1 (BMI<21.7kg/m^2), Q2 (BMI between

21.6-23.8kg/m^2), Q3 (BMI between 23.9-25.9kg/m^2), Q4 (BMI between 26.0-28.3kg/m^2), and Q5 (BMI >28.3kg/m^2). For women, the quintiles were Q1 (BMI<20.7kg/m^2), Q2 (BMI between 20.8-22.6kg/m^2), Q3 (BMI between 22.6-24.2kg/m^2), Q4 (BMI between 24.3-25.6kg/m^2), and Q5 (BMI >25.6kg/m^2). Among men, the lowest risk of injury (8.5%) was found among those in the fastest run quintile (Q1) and BMI Q3, whereas the highest risk of injury (26.6%) was found among those in the slowest run (Q5) and BMI Q1. For women, the lowest risk of injury (24.6%) was found among those in the fastest run quintile (Q1) and BMI Q3, and the highest risk of injury (63.1%) was found among those in the slowest run (Q5) and BMI Q1. Results indicated that being in the lowest BMI category was associated with the highest risk of injury, whereas having a BMI in the middle category was associated with the lowest risk of injury.

Knapik and colleagues[69] conducted a retrospective cohort study on the risk factors associated with discharge from the military among 1240 basic trainees from two battalions (nine companies). Researchers reviewed medical records of each trainee and obtained injury data, physical characteristics (height, weight, BMI), Army Physical Fitness Test (APFT) scores, and demographic data. Discharge from the military was assessed via discharge packets from the two battalions. Body mass index was categorized as quartiles based on gender. For men, Q1 was between 16.43-21.28kg/m^2, Q2 between 21.29-23.64kg/m^2, Q3 between 23.65-26.80kg/m^2, and Q4 between 26.81-38.12kg/m^2. For women, Q1 was between 15.81-20.54kg/m^2, Q2 between 20.55-22.98kg/m^2, Q3 between 22.99-25.01kg/m^2, and Q4 between 25.02-33.21kg/m^2. Researchers found no significant differences in discharge incidence among BMI quartiles in both men and women (X^2 p=0.92 and 0.10, respectively).

Knapik et al.[70] conducted a retrospective cohort study on injury rates and injury risk factors among 518 men and 43 women U.S. Army soldiers in Fort Bragg, North Carolina, with a military occupational specialty code of 63B, classified as “light wheel-vehicle mechanics.” Researchers reviewed medical records for physical characteristics including height, weight, and

BMI and ethnicity. Deployment data was collected from the Defense Manpower Data Center. Medical records were screened for injury data. Due to the small proportion of women in the study, these data were only reported for men. Researchers categorized BMI as quartiles, where Q1 was between 16.0-23.3kg/m^2, Q2 between 23.4-25.7kg/m^2, Q3 between 25.8-28.1kg/m^2, and Q4 between 28.2-38.0kg/m^2. Compared to the reference (BMI between 16.0-23.3kg/m^2), increased risk of injury with BMI between 23.4-25.7kg/m^2 (HR = 1.71, 95% CI = 1.16-2.51, $p<0.01$), between 25.8-28.1kg/m^2 (HR = 2.35, 95% CI = 1.60-3.46, $p<0.01$), and between 28.2-38.0kg/m^2 (HR = 2.0, 95% CI = 1.36-2.95, $p<0.01$). Compared to the reference, increased risk of any time-loss injury with BMI between 23.4-25.7kg/m^2 (HR = 1.81, 95% CI = 1.15-2.83, $p<0.01$), between 25.8-28.1kg/m^2 (HR = 2.57, 95% CI = 1.66-3.97, $p<0.01$), and between 28.2-38.0kg/m^2 (HR = 2.31, 95% CI = 1.48-3.58, $p<0.01$). Results indicated that as BMI increased, risk of injury increased, but the increase was highest among those with a BMI between 25.8-28.1kg/m^2.

Knapik et al.[71] conducted a retrospective cohort study on the associations between age, physical characteristics, and race/ethnicity and injury among 583,651 (475,745 men, 107,906 women) US Army basic trainees. Researchers reviewed databases at the Armed Forces Health Surveillance Center (AFHSC) to identify basic trainees and their age, race/ethnicity, gender, and physical characteristics (height, weight, BMI). Injury data were collected from the DMSS. Results indicated that men with a BMI <18.5kg/m^2 had increased odds of stress fractures compared to normal weight (OR = 1.78, 95% CI = 1.60-1.98, $p<0.01$), but there were no significant differences in odds of stress fractures among the overweight and obese BMI categories compared to the normal weight category. In addition, women with a BMI <18.5kg/m^2 had increased odds of stress fractures compared to normal weight (OR = 1.31, 95% CI = 1.19-1.45, $p<0.01$), but women with a BMI between 25.0-29.9kg/m^2 had decreased odds of stress fractures compared to normal weight (OR = 0.87, 95% CI = 0.83-0.92, $p<0.01$). Finally, women with a

BMI $\geq$30.0kg/m^2 had decreased odds of stress fractures compared to normal weight (OR = 0.82, 95% CI = 0.68-0.99, p=0.04). Results indicated that being underweight was associated with an increased risk of stress fractures, but being overweight or obese was protective against stress fractures.

Rappole and colleagues[72] conducted a retrospective cohort study on the associations between age, aerobic fitness, and BMI and injury risk among 1099 male Army soldiers in an operational brigade. Researchers collected self-reported personal characteristics such as date of birth, height, weight, BMI, and physical fitness based on the 2-mile run times from most recent APFT. Injury data was self-reported through electronic surveys. Researchers found that injury increased linearly as age, 2-mile run times, and BMI increased ($p<0.01$). In addition, the injury risk of subjects with BMIs $\geq$29.1kg/m^2 was significantly higher than for those with BMIs $\leq$23.9 kg/m^2 (RR = 1.39, $p<0.001$), 24.0–26.5 kg/m^2 (RR = 1.40, $p<0.001$), and $\leq$26.6–29.0 kg/m^2 (RR = 1.30, p=0.001). These results showed that as BMI increased, risk of injury increased.

Reynolds et al.[73] conducted a prospective cohort study on the associations between occupational demands and exposures on injury among 125 construction engineers and 188 combat artillery soldiers in the 10th Mountain Division, Fort Drum, NY. Height, weight, BMI, and physical fitness data were obtained from the APFT three months prior to study. Injury data were collected through medical records. Subjects were followed over the course of one year. Results showed that, among both construction engineers and combat artillery soldiers with a BMI $\geq$ 25kg/m^2, 58.6% were injured and 41.4% were uninjured and that, among those with a BMI <25kg/m^2, 41.2% were injured and 58.8% were uninjured. Results indicated that there was an increased odds for overuse muscle strains and ligament sprains with a BMI$\geq$25.0kg/m^2 compared to those with a BMI <25.0kg/m^2 (OR = 2.1, 95% CI = 1.2-3.4). These results showed that being overweight or obese was associated with increased odds of injury.

Overall

Overall, these studies indicated that being underweight, overweight, and obese were associated with CVD, diabetes, performance, and injury. In regard to CVD, results showed that an increasing BMI was associated with increased risk of CVD risk factors, including hypertension and dyslipidemia. Results from the military study also indicated that being underweight was protective against hypertension and dyslipidemia. Similarly, for diabetes, research indicated that a higher BMI was associated with an increased risk of T2DM.

Performance results related to BMI were not as consistent as with CVD. One study conducted in law enforcement officers found no significant differences in performance variables between healthy and overweight subjects. Studies conducted in firefighters indicated that an increase in BMI was associated with a decrease in VO_{2max} and an increased risk of job disability. One study in military personnel indicated that a higher BMI was associated with poorer performance on most tests. The other military study indicated that a higher BMI was positively associated with muscular strength and power, but negatively associated with speed/agility.

Similarly, for injury, results were not consistent. Two studies in military personnel found no significant differences in injury incidence and discharge incidence among BMI categories. A majority of the studies indicated that an increasing BMI was associated with general injury and musculoskeletal injury. On the other hand, one study, conducted in military personnel, showed that being underweight was associated with increased risks of stress fractures, whereas being overweight or obese was protective.

Quality

Based on the AND EAL Checklist, the overall quality of articles was neutral, with 18 studies receiving this rating. Eight studies were rated positively, and one study received a negative rating. Neutral studies were consistent in limitations, as most did not have multiple study groups, did not use blinding for data collection, and were not clear on bias due to funding or sponsorship. The one negative rating was given due to lack of multiple groups and blinding, as well as lack of clarity regarding bias selecting participants, study limitations, and funding or sponsorship.

Table 1: Studies investigating the relationship between BMI and health and occupational performance outcomes of law enforcement officers, firefighters, and military personnel

Author, year	Design	Tactical population, sample size & characteristics	Intervention / exposure & duration / follow-up period	Outcome measures	Results
Cardiovascular Disease					
Anderson et al., 2016[47]	Cross-sectional	448 sworn law enforcement officers of the Iowa Department of Public Safety	Questionnaire on sociodemographic status, medical history, physical activity, and smoking history To assess BMI as an independent variable, researchers used a modified metabolic syndrome classification, which excluded BMI from metabolic syndrome criteria	- Modified metabolic syndrome (MMetS) measured through metabolic risk factors (systolic blood pressure, diastolic blood pressure, serum triglycerides, HDL cholesterol, plasma glucose, height, weight, BMI)	- Law enforcement officers with metabolic syndrome had a higher prevalence of overweight and obesity compared to those without metabolic syndrome (98.4% vs 73.5%, respectively, P<0.0001 for trend) - After adjusting for age, race, gender, smoking history, and physical activity, law enforcement officers in the overweight BMI category had 6.52-fold increased odds of metabolic syndrome compared to normal BMI (OR = 6.52, 95% CI = 1.49-28.57) - After adjusting for age, race, gender, smoking history, and physical activity, law enforcement officers in the obese BMI category had 10.46-fold increased odds of metabolic syndrome compared to normal BMI (OR = 10.46, 95% CI = 2.38-46.05)
Andrew et al., 2013[48]	Cross-sectional	360 law enforcement officers from the Buffalo Police Department	DEXA for fat mass, bone mass, and lean mass Height, weight, BMI, and waist	- Measured heart rate variability (HRV) using electrocardiograms (ECG); log	- Weak positive association between BMI and HR (r=0.120) - Weak negative association between BMI and LnHF and LnLF HRV (r=-0.098 and -0.096, respectively) - 10% of LnHF HRV due to BMI

		who were in the Buffalo Cardio-Metabolic Occupational Police Stress cohort	circumference measured by certified staff 7-day Physical Activity Recall questionnaire	transformations of low-frequency (LnLF) and high-frequency (LnHF) HRV	after controlling for age, sex, and anthropometrics (R^2 = 0.1012)
Choi et al., 2016[49]	Cross-sectional	355 firefighters (347 men, 8 women) in Southern California who participated in the Firefighter Obesity Research: Workplace Assessment to Reduce Disease (FORWARD) study	Height, weight, BMI, WC, and BF% (via skinfold) were measured Questionnaire was used to collect data on medication use for heart problems, hypertension, hyperlipemia, and DM and on tobacco use Questionnaire for age, sex, race/ethnicity, education, job title (rank-and-file firefighters, firefighter apparatus engineers, engineers, firefighter captains, firefighter chiefs), and exercise frequency	- CVD risk factors (hypertension, high cholesterol, low HDL, high LDL, high TG, low VO_{2max})	- Prevalence of hypertension significantly higher among individuals with a BMI ≥30kg/m^2 compared to normal weight ($p<0.05$) - Prevalence of high cholesterol significantly higher among individuals with a BMI between 27.5-29.9kg/m^2 ($p<0.05$) and a BMI ≥30kg/m^2 ($p<0.01$) compared to normal weight - Prevalence of low HDL significantly higher among individuals with a BMI ≥30kg/m^2 compared to normal weight ($p<0.001$) - Prevalence of high LDL significantly higher among individuals with a BMI between 27.5-29.9kg/m^2 ($p<0.05$) and a BMI ≥30kg/m^2 ($p<0.01$) compared to normal weight - Prevalence of high TG significantly higher among individuals with a BMI ≥30kg/m^2 compared to normal weight ($p<0.01$) - Prevalence of low VO_{2max} significantly higher among individuals with a BMI between 25-29.9kg/m^2 ($p<0.05$), a BMI between 27.5-29.9kg/m^2 ($p<0.01$), and a BMI ≥30kg/m^2 ($p<0.001$) compared to normal weight
Clark et al., 2002[50]	Cross-sectional	218 active male firefighters (white, aged 18-58)	Height, weight, BMI	- Health status (systolic BP, diastolic BP, cholesterol, HDL,	- When categorizing BMI as low (<27kg/m^2), medium (between 27kg/m^2 and 30kg/m^2), and high (>30kg/m^2): - Significant differences

		of six municipal fire departments in north central Texas undergoing duty fitness evaluations		cholesterol/HDL ratio, triglycerides, FVC% (forced vital capacity percent predicted), FEV_{1sec}% (forced expiratory volume at one second percent predicted), VO2max, and METS - Routine laboratory tests (complete blood count, lipid profile, liver and kidney function test, electrolytes, urinalysis), booth audiometry, resting 12 lead EKG, spirometry, and visual acuity	between groups in: o Diastolic BP: 74.6±7.9 for low, 76.9±8.6 for medium, 79.5±7.8 for high ($p<0.05$) o Cholesterol: 189.0±36.1 for low, 204.0±36.9 for medium, 204.7±35.1 for high ($p<0.05$) o Cholesterol/HDL ratio: 4.2±1.0 for low, 4.9±1.5 for medium, 4.9±1.3 for high ($p<0.05$) o Triglycerides: 112.1±60.0 for low, 176.3±163.2 for medium, 168.9±91.2 for high ($p<0.05$) o VO_{2max}: 47.6±4.3 for low, 44.1±4.1 for medium, 41.2±4.0 for high ($p<0.05$) o METS: 13.5±1.2 for low, 12.5±1.2 for medium, 11.7±1.2 for high ($p<0.05$) - When categorizing BMI as normal (≤25kg/m^2), overweight (between 25kg/m^2 and 30kg/m^2), obese (between 30kg/m^2 and 39kg/m^2), and morbid (≥39kg/m^2) according to WHO and adjusting for age: - Significant differences between groups in: o Systolic BP: 116.4±10.1 for normal, 122.6±11.5 for overweight, 123.2±10.0 for obese, 128.0±13.0 for morbidly obese ($p<0.05$)

						○ Diastolic BP: 73.3±8.4 for normal, 76.2±8.0 for overweight, 78.8±7.3 for obese, 88.8±7.6 for morbidly obese ($p<0.05$) ○ Cholesterol: 173.5±25.0 for normal, 203.8±37.6 for overweight, 206.0±35.5 for obese, 188.4±23.9 for morbidly obese ($p<0.05$) ○ Cholesterol/HDL ratio: 3.9±0.9 for normal, 4.7±1.4 for overweight, 5.1±1.3 for obese, 3.6±0.6 for morbidly obese ($p<0.05$) ○ Triglycerides: 92.0±48.0 for normal, 156.8±132.2 for overweight, 171.3±91.8 for obese, 137.8±85.3 for morbidly obese ($p<0.05$) ○ VO_{2max}: 48.6±3.8 for normal, 44.7±5.8 for overweight, 41.7±3.9 for obese, 37.0±2.8 for morbidly obese ($p<0.05$) ○ METS: 13.8±1.1 for normal, 12.7±1.8 for overweight, 11.91.1 for obese, 10.6±0.8 for morbidly obese ($p<0.05$)

Eastlake et al., 2015[51]	Cross-sectional	157 firefighters (117 full-time, 16 part-time, and 24 volunteer) in Hamilton County, Ohio	Online survey used to collect data on occupational risk factors (particulates, heat stress, noise, dermal exposure, job stress, use of personal protective equipment), lifestyle risk factors (exercise, diet, smoking, drinking, video gaming) and demographic characteristics (age, race, height, weight, BMI, gender)	- Cardiovascular risk factors - Survey asked about health status, including diagnoses of heart disease, vascular disease, stroke, hypertension, diabetes, or high cholesterol	- Increasing BMI associated with high cholesterol (OR = 1.09 ± 0.08, p=0.03)

Fahs et al., 2009[52]	Cross-sectional	110 young (mean age 29.7±8.0 years), healthy firefighters	Collected height, weight, BMI, and waist circumference	- Hemodynamic variables (brachial BP, carotid BP, aortic BP, radial augmentation index, central pulse wave velocity)
				- Microvascular function (forearm blood flow, forearm vasodilatory capacity)
				- Macrovascular structure and function
					- Categorized BMI into tertiles: Group 1 (<25.9kg/m^2), Group 2 (25.9-29.9kg/m^2), Group 3 (≥29.5kg/m^2)
					- After adjusting for age:
					  - Groups 2 and 3 had greater systolic BP than Group 1 (122mmHg, 126mmHg, 130mmHg for Groups 1, 2, and 3, respectively, p<0.05)
					  - Group 3 had a greater mean arterial pressure than Group 1 (86mmHg and 92mmHg for Groups 1 and 3, respectively, p<0.05)
					  - Group 3 had greater carotid systolic BP than Group 1 (112mmHg and 120mmHg for Groups 1 and 3, respectively, p<0.05)

				(carotid intima media thickness, brachial flow-mediated dilation)	

Korre et al., 2016[53]	Cross-sectional	393 male career firefighters from the Indianapolis Fire Department	Collected height, weight, and BMI
			Measured blood pressure and heart rate
			Questionnaire collecting information on smoking status, history of heart rhythm problems, family history of cardiac problems, and moderate to vigorous physical activity level in minutes per week.
			Berlin Questionnaire to assess obstructive sleep apnea risk
				- Measured left ventricular mass (LVM) with echocardiography (ECHO) and cardiac magnetic resonance (CMR)	- When using ECHO:
					  - For every one unit increase in BMI, LVM increases by $0.55g/m^{1.7}$ (SE = 0.1) (p<0.001)
					- When using CMR:
					  - For every one unit increase in BMI, LVM increases by $0.45g/m^{1.7}$ (SE = 0.0) (p<0.001)

Risavi et al., 2016[54]	Cross-sectional	160 firefighters from 37 local fire departments in the Commonwealth of Pennsylvania	Collected anthropometric measurements, including height, weight, BMI, WC, and blood pressure Demographics survey	- Risk factors of coronary artery disease (systolic BP, diastolic BP, exercise frequency)	- Increased BMI is associated with greater odds of hypertension (OR = 1.16, 95% CI = 1.097-1.237)

			collected fire department affiliation, age, gender, years of service, marital status, race, and physical activity		
Hruby et al., 2017[55]	Cross-sectional	731,014 soldiers who entered the Army between 2001 and 2011	Data extracted from the Total Army Injury and Health Outcomes Database (TAIHOD), 2001–2011 Data included date of birth, race/ethnicity, education, marital status, height, weight, and BMI	- Cardiometabolic risk factors (hypertension, disorder of glucose or insulin metabolism, dyslipidemia, metabolic syndrome, overweight/obesity (among initially underweight and normal-weight soldiers)	- Increased incidence of metabolic syndrome among overweight (HR = 3.68, 95% CI = 2.55-5.30) and obese (HR = 10.85, 95% CI = 7.29-16.15) subjects compared to normal weight - Increased incidence of impaired glucose/insulin disorder among overweight (HR = 1.18, 95% CI = 1.09-1.26) and obese (HR = 2.05, 95% CI = 1.86-2.25) subjects compared to normal weight - Decreased incidence of hypertension among underweight subjects (HR = 0.63, 95% CI = 0.56-0.72) compared to normal weight - Increased incidence of hypertension among overweight (HR = 1.59, 95% CI = 1.54-1.63) and obese (HR = 2.44, 95% CI = 2.36-2.53) subjects compared to normal weight - Decreased incidence of dyslipidemia among underweight subjects (HR = 0.72, 95% CI = 0.60-0.85) compared to normal weight - Increased incidence of dyslipidemia among overweight (HR = 1.56, 95% CI = 1.50-1.62) and obese (HR = 2.36, 95% CI = 2.24-2.48) subjects compared to normal weight
Cancer					
No studies involving BMI and cancer in tactical populations were included.					
Diabetes					
Paris et al.,	Case-control	419 active-duty cases	Data collected on	- Type 2 diabetes	- T2DM associated with a higher BMI (mean BMI for cases =

2001[56]		and 1,627 active-duty controls (Army, Navy, Air Force, Marines)	cases and controls in the military between January 1997 and August 2000 Used the Defense Manpower Data Center to collect height, weight, BMI, education, blood pressure Collected information on race and rank Matched cases and controls by age within 1 year, sex, branch of service (Army, Navy, Air Force, Marines), date of entry into the military within the same month, and active duty as the time of diagnosis	mellitus (T2DM)	24.0±3.3; mean BMI for controls = 23.1±2.9, p<0.0001) - Increased odds of T2DM with BMI between 25.0-29.9kg/m^2 (OR = 2.0, 95% CI = 1.4-3.0, p<0.001) - Increased odds of T2DM with BMI ≥30kg/m^2 (OR = 3.0, 95% CI = 1.4-6.4, p<0.01)
Occupational/ Physical Performance					
Dawes et al., 2018[57]	Cross-sectional	24 male highway patrol officers in Colorado	Age, height, weight, BMI, and duty weight (weight in full gear) were collected	- Defensive Tactics (DEFTAC) Drills [score, time, rate of perceive exertion (RPE), average HR,	- No significant differences in performance variables when comparing healthy and overweight participants - Relationships between exertion and performance for the healthy weight group: - RPE and time – moderate positive relationship

				average % HR, peak HR, peak % HR, blood lactate]	(r=0.600, p≤0.05) - Blood lactate and score – moderate positive relationship (r=0.590, p≤0.05) - Time and score – moderate positive relationship (r=0.699, p≤0.01) - Relationships between exertion and performance for the overweight group: - Blood lactate and peak % age-predicted maximum HR – moderate positive relationship (r=0.597, p≤0.05) - RPE and peak % age-predicted maximum HR – moderate positive relationship (r=0.629, p≤0.05) - Weight and time – moderate positive relationship (r=0.675, p≤0.05)
Houck et al., 2020[58]	Cross-sectional	80 (76 men, 4 women) active-duty urban or wildland firefighters in New Mexico	Data were collected as part of the firefighters' annual health assessment required by their employer. Collected BF%, BP, and BMI	- Physical fitness (VO_{2max}, respiratory exchange ratio, maximum grip strength, YMCA bench press, sit-and-reach, and Margaria-Kalamen test)	- VO_{2max} moderately negatively correlated with BMI (r=-0.497) - Participants in Q1 VO_{2max} had a significantly lower BMI when compared to Q4 VO_{2max} (p<0.05) - Q2 VO_{2max} had a significantly lower BMI than Q4 (p<0.05)
Soteriades et al., 2008[59]	Prospective cohort	358 firefighters from six regional hazardous materials teams in the Commonwealth of Massachusetts	Firefighters were followed for a maximum of 6 years (between 0.3-6.5 years) Weight, height, BMI, age, sex, job type	- Short-term or permanent job disability (placement on 'injured on-duty' status, termination of duty, resignation, premature retirement or	- Categorized BMI as normal (<25kg/m^2), overweight (25-30kg/m^2), and obese (≥30kg/m^2) - Firefighters in the highest BMI category had a 50-70% increase risk of job disability - Firefighters above the median BMI (28.5kg/m^2) had a 70% increased risk of job disability compared to below the median (HR

			(technician, support member), smoking history, blood pressure, blood glucose, and total cholesterol were collected at baseline and at each follow-up	death) verified by the Massachusetts' Office of Hazardous Materials Response	= 1.69, 95% CI = 1.02-2.80) - Significant differences in prevalence of hypertension between the 3 BMI categories ($p<0.01$) - BMI $\geq 30.2 kg/m^2$ associated with two times increased risk of job disability (HR = 1.98, 95% CI = 1.06-3.72)

Pierce et al., 2017[60]	Cross-sectional	321 (275 men, 46 women) active-duty soldier volunteers from an infantry brigade combat team	Collected data on age, height, weight, and BMI	- Physical fitness assessments [muscular strength (hex bar deadlift, bench press), muscular power (sled drag, sled push, medicine ball power throw), muscular endurance (bench press endurance, goblet kettlebell squat endurance), and speed/agility (400-m run, 300-yd shuttle run, Illinois agility test)], Common Soldiering Tasks (CSTs) and Warrior Tasks and Battle Drills (WTBDs), and recent APFT scores	- Categorized BMI into tertiles based on gender:
					  - Men: T1 (18.6-23.8kg/m^2), T2 (23.9-26.5kg/m^2), T3 (26.6-34.9kg/m^2)
					  - Women: T1 (16.9-22.1kg/m^2), T2 (22.1-25.4kg/m^2), T3 (25.6-28.8kg/m^2)
					- Male and female soldiers with higher BMI, T2 and T3, performed better than T1 on lower and upper body muscular strength and lower body muscular power ($p\leq 0.05$), but didn't perform as well as T1 in speed/agility ($p\leq 0.05$)
					- Higher BMI in men positively influenced lower and upper body muscular power and upper body muscular endurance ($p\leq 0.05$), but negatively influenced speed/agility ($p\leq 0.05$)
					- Higher BMI in women was associated with increased lower body muscular endurance ($p\leq 0.05$)
					- APFT performance by BMI tertile:
					  - Women in T2 and T3 completed significantly less sit-ups than T1 ($p<0.01$)

					- Men in T2 and T3 had significantly higher 2-mile run times than T1 ($p<0.01$) - Women in T3 had significantly higher 2-mile run times than T1 ($p=0.025$)
Teyhen et al., 2016[61]	Cross-sectional	1466 (1380 men, 86 women) active-duty service members (combat, combat service, and combat service support) in the Military Power, Performance, and Prevention trial	Collected data on physical inactivity, height, weight, BMI, smoking, and prior injury	- Physical performance tests (triple-crossover hop for distance, 6-m timed-hop test, Functional Movement Screen, Lower Quarter Y-Balance test (YBT-LQ), Upper Quarter Y-Balance test (YBT-UQ), and 3-event APFT)	- Subjects with a BMI ≥27.5 performed poorer on all tests ($p<0.001$) except the 2-minute push-up test ($p=0.2$)
Injury					
Mota et al., 2019[62]	Cross-sectional	1323 (708 men, 615 women) probation officers in North Carolina	Health history questionnaire for demographics (age, sex, body mass, stature, BMI), physical activity, rural/urban work location, and years of employment	- Musculoskeletal injury assessed using questionnaire	- Of the 96 officers who sustained a work-related musculoskeletal injury within the past year, 5.5% were normal weight, 6.1% were overweight, 7.2% were class I obese, 7.9% were class II obese, and 13.5% were class III obese - Being in the class III obese category was associated with increased odds of work-related musculoskeletal injury compared to being in the normal weight category (OR = 2.56, 95% CI = 1.19-5.51, $p=0.008$)
Jahnke et al., 2013[63]	Prospective cohort	301 male firefighters and from 11 career fire department	Follow-up completed at 9±1 months for career firefighters and 6±1	- Injury and musculoskeletal injury assessed using questionnaire	- Increased incident musculoskeletal injury in obese subjects compared to normal weight (RR = 5.2, 95% CI = 1.1-24.5) - No significant increase in

		s in the Missouri Valley region	months for volunteer firefighters Height, weight, BMI, BF%, and WC measurements were taken Questionnaires and scales to determine physical activity, tobacco use, problematic alcohol use, on-duty sleepiness, and depression		incident injury or incident musculoskeletal injury in overweight subjects compared to normal weight
Kuehl et al., 2012[64]	Prospective cohort	433 firefighters who participated in the Promoting Healthy Lifestyles: Alternative Models' Effects (PHLAME) worksite wellness program in fire departments in Oregon and Washington	7-year follow-up period Collected information on medical history, physical measures (height, weight, BMI), demographics, diet, physical activity, team support, and general health	- Injury and workers' compensation claims occurring 5 years after the PHLAME intervention reported in survey	- Significant differences in prevalence of elbow/hand injury between the three BMI categories (0.8% of 105, 3.7% of 219, and 5.9% of 69) for prevalence of elbow/hand injury among normal, overweight, and obese BMI categories, respectively) ($p<0.05$)
Eagle et al., 2019[65]	Prospective cohort	140 male Special Tactics Operators in the US Air Force	1-year follow up period Measured body composition (BF%, body mass, fat free mass, height, BMI) with BODPOD	- Ankle injury assessed through medical chart review of injuries using the Armed Forces Health Longitudinal Technology	- Injured group displayed higher BMIs ($p=0.01$) - BMI significantly predicted ankle injury (OR = 2.2, 95% CI = 1.23-4.08, $p=0.011$)

			Measured VO_{2max} , anaerobic capacity, and isometric strength	Application	
Henderson et al., 2000[66]	Cross-sectional	726 Army soldiers who just completed basic combat training and advanced individual training at Fort Sam Houston, TX	Questionnaire on demographics (race/ethnic group, gender), lifestyle (physical activity before entering the army, tobacco use, alcohol use in the past year, use of birth control for females), and "split option" program Height, weight, and BMI collected from battalion personnel records after the start of training	- Injury data collected via medical records	- No significant differences in injury incidence among men and women based on BMI category
Hruby et al., 2016[67]	Secondary analysis	736,608 active-duty Army soldiers entering the Army between 2002 and 2011	Data extracted from the Total Army Injury and Health Outcomes Database (TAIHOD), 2001–2011 Data included date of birth, race/ethnicity, education,	- Post-accession incident musculoskeletal injury and connective tissue disorder (MID) identified by ICD-9 codes	- BMI categorized as underweight (<18.5kg/m2), normal weight (18.5-25kg/m2), overweight (25-30kg/m2), and obese (≥30kg/m2). - Increased risk of MID in underweight (HR = 1.07, 95% CI = 1.05-1.09), overweight (HR = 1.11, 95% CI = 1.11-1.12), and obese (HR = 1.33, 95% CI = 1.32-1.35) compared to normal weight - Decreased risk of hip MID in underweight compared to normal weight (HR = 0.94, 95%

			marital status, height, weight, and BMI		CI = 0.89- 0.99) - Increased risk of hip MID in overweight (HR = 1.17, 95% CI = 1.15-1.19) and obese (HR = 1.45, 95% CI = 1.45-1.53) compared to normal weight - Increased risk of knee MID in overweight (HR = 1.13, 95% CI = 1.12-1.14) and obese (HR = 1.36, 95% CI = 1.34-1.38) compared to normal weight - Increased risk of upper leg MID in underweight (HR = 1.06, 95% CI = 1.01-1.11), overweight (HR = 1.06, 95% CI = 1.04-1.07), and obese (HR = 1.28, 95% CI = 1.25-1.32) compared to normal weight - Increased risk of lower leg/ankle MID in underweight (HR = 1.06, 95% CI = 1.03-1.08), overweight (HR = 1.12, 95% CI = 1.11-1.13), and obese (HR = 1.36, 95% CI = 1.34-1.37) compared to normal weight - Increased risk of foot/toe MID in overweight (HR = 1.15, 95% CI = 1.13-1.16) and obese (HR = 1.40, 95% CI = 1.37-1.43) compared to normal weight

Jones et al., 2017[68]	Retrospective cohort	184,670 (143,398 male and 41,272 female) trainees entering Army basic training	Age and gender data collected from the Defense Manpower Data Center and Defense Medical Surveillance System (DMSS) Height, weight, BMI, and AFPT scores collected from the Training and Doctrine Command	- Musculoskeletal injury data documented in DMSS	- BMI classified as quintiles:
					  - Men: Q1 (BMI<21.7kg/m^2), Q2 (BMI between 21.6-23.8kg/m^2), Q3 (BMI between 23.9-25.9kg/m^2), Q4 (BMI between 26.0-28.3kg/m^2), Q5 (BMI >28.3kg/m^2)
					  - Women: Q1 (BMI<20.7kg/m^2), Q2 (BMI between 20.8-22.6kg/m^2), Q3 (BMI between 22.6-24.2kg/m^2), Q4 (BMI between 24.3-25.6kg/m^2), Q5 (BMI >25.6kg/m^2)
					- Men:
					  - Lowest risk of injury (8.5%) among those in the

					- fastest run quintile (Q1) and BMI Q3
					- Highest risk of injury (26.6%) among those in the slowest run (Q5) and BMI Q1
					- Women:
					  - Lowest risk of injury (24.6%) among those in the fastest run quintile (Q1) and BMI Q3
					  - Highest risk of injury (63.1%) among those in the slowest run (Q5) and BMI Q1

Knapik et al., 2001[69]	Retrospective cohort	1240 basic trainees from two battalions (9 companies)	Reviewed medical records of each trainee and obtained injury data, physical characteristics (height, weight, BMI), Army Physical Fitness Test (APFT) scores, and demographic data	- Discharge from the military assessed via discharge packets from the two battalions	- BMI categorized as quartiles based on gender:
					  - Men: Q1 (16.43-21.28kg/m^2), Q2 (21.29-23.64kg/m^2), Q3 (23.65-26.80kg/m^2), Q4 (26.81-38.12kg/m^2)
					  - Women: Q1 (15.81-20.54kg/m^2), Q2 (20.55-22.98kg/m^2), Q3 (22.99-25.01kg/m^2), Q4 (25.02-33.21kg/m^2)
					- No significant differences in discharge incidence among BMI quartiles in both men and women (X^2 p=0.92 and 0.10, respectively)

Knapik et al., 2007[70]	Retrospective cohort	518 men and 43 women U.S. Army soldiers in Fort Bragg, NC with a military occupational specialty code of 63B, classified as "light wheel-vehicle mechanics"	Reviewed medical records for physical characteristics (height, weight, BMI) and ethnicity Collected deployment data from the Defense Manpower Data Center	- Injury assessed through medical records	- BMI categorized as quartiles: Q1 (16.0-23.3kg/m^2), Q2 (23.4-25.7kg/m^2), Q3 (25.8-28.1kg/m^2), Q4 (28.2-38.0kg/m^2) - Compared to the reference (BMI = 16.0-23.3kg/m^2), increased risk of injury with BMI between 23.4-25.7kg/m^2 (HR = 1.71, 95% CI = 1.16-2.51, p<0.01), between 25.8-28.1kg/m^2 (HR = 2.35, 95% CI = 1.60-3.46, p<0.01), and between 28.2-38.0kg/m^2 (HR = 2.0, 95% CI = 1.36-2.95, p<0.01) - Compared to the reference (BMI = 16.0-23.3kg/m^2), increased risk of any time-loss injury with

					BMI between 23.4-25.7kg/m^2 (HR = 1.81, 95% CI = 1.15-2.83, p<0.01), between 25.8-28.1kg/m^2 (HR = 2.57, 95% CI = 1.66-3.97, p<0.01), and between 28.2-38.0kg/m^2 (HR = 2.31, 95% CI = 1.48-3.58, p<0.01) - Due to the small proportion of women in the study, these data were only reported for men.
Knapik et al., 2012[71]	Retrospective cohort	583,651 (475,745 men and 107,906 women) US Army basic trainees	Reviewed databases at the Armed Forces Health Surveillance Center (AFHSC) to identify basic trainees and their age, race/ethnicity, gender, and physical characteristics (height, weight, BMI)	- Injury data collected from the DMSS	- Men with a BMI <18.5kg/m^2 had increased odds of stress fractures compared to normal weight (OR = 1.78: 1.60-1.98, p<0.01) - There were no significant differences in odds of stress fractures among the overweight and obese BMI categories compared to the normal weight category in men - Women with a BMI <18.5kg/m^2 had an increased odds of stress fractures compared to normal weight (OR = 1.31: 1.19-1.45, p<0.01) - Women with a BMI between 25.0-29.9kg/m^2 had a decreased odds of stress fractures compared to normal weight (OR = 0.87: 0.83-0.92, p<0.01) - Women with a BMI ≥30.0kg/m^2 had a decreased odds of stress fractures compared to normal weight (OR = 0.82: 0.68-0.99, p=0.04)
Rappole et al., 2017[72]	Retrospective cohort	1099 male Army soldiers in an operational brigade	Collected self-reported personal characteristics (date of birth, height, weight, BMI) and physical fitness (2-mile run times from most recent APFT)	- Injury data self-reported through electronic surveys	- Injury increased linearly as age, 2-mile run times, and BMI increased (p<0.01) - Injury risk of subjects with BMIs ≥29.1kg/m^2 was significantly higher than for those with BMIs ≤23.9 kg/m^2 (RR = 1.39, p<0.001), 24.0–26.5 kg/m2 (RR = 1.40, p<0.001), and ≤26.6–29.0 kg/m2 (RR = 1.30, p=0.001)

Reynolds et al., 2002[73]	Prospective cohort	125 construction engineers and 188 combat artillery soldiers in the 10th Mountain Division, Fort Drum, NY	1-year follow-up Collected data on age, ethnicity, and smoking history using a questionnaire Height, weight, BMI, and physical fitness data obtained from APFT three months prior to study	- Injury data collected through medical records	- Among both construction engineers and combat artillery soldiers with a BMI $\geq 25kg/m^2$, 58.6% were injured and 41.4% were uninjured - Among both construction engineers and combat artillery soldiers with a BMI $<25kg/m^2$, 41.2% were injured and 58.8% were uninjured - Increased risk for overuse muscle strains and ligament sprains with BMI$\geq$25.0kg/m^2 compared to those with BMI<25.0kg/m^2 (OR = 2.1, 95% CI = 1.2-3.4)

Table 2: Quality assessment of studies investigating the relationship between BMI and health and occupational performance outcomes of law enforcement officers, firefighters, and military personnel using the Academy of Nutrition and Dietetics quality criteria checklist[46]

Authors, Year	Design	Tactical Population	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	QA
Cardiovascular Disease													
Anderson et al., 2016[47]	Cross-sectional	Law enforcement officers	Y	Y	Y	Y	N	Y	Y	Y	Y	U	Pos
Andrew et al., 2013[48]	Cross-sectional	Law enforcement officers	Y	Y	N/A	Y	N	Y	Y	Y	U	N	Neu
Choi et al., 2016[49]	Cross-sectional	Firefighters	Y	Y	N/A	Y	N	Y	Y	Y	Y	Y	Neu
Clark et al., 2002[50]	Cross-sectional	Active male firefighters	Y	Y	N/A	U	N	Y	Y	Y	Y	N	Neu
Eastlake et al., 2015[51]	Cross-sectional	Full-time, part-time, and volunteer firefighters	Y	Y	N/A	Y	N	Y	Y	Y	Y	Y	Neu
Fahs et al., 2009[52]	Cross-sectional	Firefighters	Y	Y	Y	U	N	Y	Y	Y	Y	N	Pos
Korre et al., 2016[53]	Cross-sectional	Career firefighters	Y	Y	N/A	Y	N	Y	Y	Y	Y	U	Neu
Risavi et al., 2016[54]	Cross-sectional	Firefighters	Y	Y	N/A	Y	N	Y	Y	Y	Y	U	Neu
Hruby et al., 2017[55]	Cross-sectional	Soldiers entering the army between 2001 and 2011	Y	Y	N/A	Y	N	Y	Y	Y	Y	Y	Neu
Cancer													
Diabetes													

Paris et al., 2001[56]	Case-control	Active-duty soldiers	Y	Y	Y	Y	N	Y	Y	Y	N	N	Pos
Occupational/ Physical Performance													
Dawes et al., 2018[57]	Cross-sectional	Male highway patrol officers	Y	Y	N/A	Y	N	Y	Y	Y	U	N	Neu
Houck et al., 2020[58]	Cross-sectional	Active-duty urban and wildland firefighters	Y	Y	N/A	Y	N	Y	Y	Y	U	Y	Neu
Soteriades et al., 2008[59]	Prospective cohort	Firefighters	Y	Y	N/A	Y	N	Y	Y	Y	Y	N	Neu
Pierce et al., 2017[60]	Cross-sectional	Active-duty soldier volunteers	Y	U	N/A	Y	N	Y	Y	Y	U	U	Neg
Teyhen et al., 2016[61]	Cross-sectional	Active-duty service members	Y	Y	Y	Y	N	Y	Y	Y	Y	U	Pos
Injury													
Mota et al., 2019[62]	Cross-sectional	Probation officers	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Pos
Jahnke et al., 2013[63]	Prospective cohort	Career firefighters	Y	Y	Y	Y	N	Y	Y	Y	U	U	Pos
Kuehl et al., 2012[64]	Prospective cohort	Firefighters	Y	Y	N/A	Y	N	Y	Y	Y	Y	Y	Neu
Eagle et al., 2019[65]	Prospective cohort	Male Special Tactics Operators	Y	Y	Y	Y	N	Y	Y	Y	Y	U	Pos
Henderson et al., 2000[66]	Cross-sectional	Army soldiers who just completed BCT and AIT	Y	Y	N/A	Y	N	Y	Y	Y	Y	N	Neu
Hruby et al., 2016[67]	Secondary analysis	Active-duty Army soldiers	Y	Y	N/A	Y	N	Y	Y	Y	Y	U	Neu
Jones et al., 2017[68]	Retrospective cohort	Basic trainees	Y	Y	N/A	Y	N	Y	Y	Y	U	Y	Neu
Knapik et al., 2001[69]	Retrospective cohort	Basic trainees	Y	Y	N/A	Y	N	Y	Y	Y	Y	N	Neu
Knapik, et al., 2007[70]	Retrospective cohort	Army soldiers	Y	Y	N/A	Y	N	Y	Y	Y	U	N	Neu
Knapik et al., 2012[71]	Retrospective cohort	Basic trainees	Y	Y	N/A	Y	N	Y	Y	Y	Y	N	Neu
Rappole et al., 2017[72]	Retrospective cohort	Male army soldiers	Y	Y	N/A	U	N	Y	Y	Y	Y	Y	Neu
Reynolds et al., 2002[73]	Prospective cohort	Construction engineers and combat artillery soldiers	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Pos

Q1 = Question 1:Was the research question clearly stated?

Q7 = Were outcomes clearly defined and the measurements valid and reliable?

Q2 = Question 2: Was the selection of study subjects/patients free from bias?
Q3 = Were study groups comparable?

Q4 = Was method of handling withdrawals described?
Q5 = Was blinding used to prevent introduction of bias?
Q6 = Were intervention/therapeutic regimens/exposure factor or procedure and any comparison(s) described in detail? Were intervening factors described?

Q8 = Was the statistical analysis appropriate for the study design and type of outcome indicators?
Q9 = Are conclusions supported by results with biases and limitations taken into consideration?
Q10 = Is bias due to study's funding or sponsorship unlikely?

Y = yes; N = no; N/A = not applicable; UC = unclear

Pos = positive; Neu = neutral; Neg = Negative
RCT = Randomized controlled trial

CHAPTER V

DISCUSSION & CONCLUSIONS

Results of this systematic review indicate that BMI is directly associated with CVD, diabetes, and injury, and negatively with occupational and physical performance among tactical populations, including law enforcement officers, firefighters, and military personnel. Specifically, for CVD, as BMI increased, researchers also found an increase in CVD risk factors. In law enforcement officers, an increase in BMI was associated with an increased risk of MMetS, as well as a small decrease in HRV, both of which are risk factors for CVD.[47.48] Among firefighters, results indicated that having a higher BMI was strongly associated with risk factors for CVD, including hypertension,[49,54] high systolic BP,[52] high mean arterial pressure,[52] high carotid systolic BP,[52] high cholesterol,[49,50,51] low HDL cholesterol,[49] high cholesterol/HDL ratio,[50] high LDL cholesterol,[49] high TG,[49,50] low VO_{2max},[49] and increased LVM.[53] However, one notable finding from Clark et al.[50] was that the morbidly obese BMI category displayed a drop in cholesterol, cholesterol/HDL ratio, and TG, showing that the relationship between BMI and these three risk factors may not be linear when categorizing BMI according to WHO classification. For military personnel, being underweight was protective against hypertension and dyslipidemia, while being overweight or obese was associated with an increased risk of hypertension and dyslipidemia, as well as impaired glucose and insulin response.[55]

Type 2 diabetes was another disease of interest in regard to BMI in tactical populations. Only one study was included in this review regarding BMI and T2DM, and it was conducted in military personnel.[56] Researchers found that having a BMI in the overweight and obese categories was associated with an increased risk of T2DM, which is consistent with previous research indicating that a higher BMI is associated with T2DM risk.[74]

For occupational and physical performance, although outcome measures widely varied, results among firefighters and military personnel were similar, but differed among law enforcement officers. When looking specifically at law enforcement officers, results indicated that there were no significant differences in performance variables between healthy and overweight subjects, indicating that BMI did not play a role in performance outcomes.[57] In contrast, two studies in firefighters found that an increase in BMI was associated with a decrease in VO_{2max},[58] a strong indicator of physical fitness, and an increase in job disability.[59] In military personnel, several studies found that a higher BMI both positively and negatively affected performance. In regard to muscular strength and muscular power, having a higher BMI was beneficial, likely due to higher muscle mass, however, it was not beneficial when it came to speed/agility and endurance tests, likely for the same reason.[60,61] Thus, the results in military personnel indicate that having a higher BMI may be beneficial when it comes to the strength and power aspects of the job, but detrimental to endurance, speed, and agility aspects of the job.

Finally, for injury among tactical populations, results were inconsistent, but a majority indicated that having a higher BMI was associated with an increased risk of injury. One study in law enforcement officers, one study in firefighters, and five studies in military personnel agreed that a higher BMI was associated with an increased risk of injury and musculoskeletal injury.[62,63,65,67,70,72,73] In addition, studies in military personnel found that being underweight was also a risk factor of injury. Two studies found that being underweight increased the risk of musculoskeletal injury[67] and stress fractures.[71] Furthermore, being in the lowest BMI category was found to be associated with the highest risk of injury among military personnel.[68] However, two studies in military personnel indicated that there were no differences in injury incidence or discharge incidence based on BMI,[66,69] and one study in firefighters indicated that the only injury significantly associated with BMI was injury of the elbow/hand.[64] These studies indicate that increased risk of injury is likely with higher BMI, but also that there is a need for more research regarding BMI and injury among tactical populations.

As previous research has shown, being underweight, overweight, and obese are associated with negative health effects, as well as negative effects on physical and occupational performance.[12-14] Therefore, we see the most benefits to health and performance among those who are classified as normal weight based on BMI. A majority of research on BMI and health and performance outcomes is focused on the general population, so understanding these associations in tactical populations can help fill this gap in the research. This systematic review aimed to determine the relationship between BMI and health and occupational performance in tactical populations to work to fill that gap. After reviewing the literature and summarizing and critically analyzing the results, we can see that BMI does play a role on health status and performance in law enforcement officers, firefighters, and military personnel.

Previous research indicates that the relationship between BMI and mortality is U- or J-shaped, showing that the lowest risk of mortality is found among those in the healthy weight category.[36] Similar results were seen for health outcomes among tactical populations. Many of the studies reviewed in law enforcement officers, firefighters, and military personnel found that having a higher BMI was associated with increased risk of negative health outcomes, including CVD and T2DM. In contrast, being underweight was found to be protective against hypertension and dyslipidemia, showing that J-shaped relationship between being underweight and health. In addition, a prospective cohort study conducted by Attard and colleagues[14] found that BMI was significantly higher among those with diabetes, hypertension, and inflammation. Similar to the present study, results indicated that an increase in BMI increased odds of diabetes and hypertension.

For performance outcomes, previous research suggests that being both underweight and overweight may negatively affect performance.[15] Furthermore, strength and endurance has been found to be negatively impacted by being underweight, and mobility has been found to be negatively impacted by obesity.[15,16,36] These results are similar to the results of the present study, as being normal weight in tactical populations was often indicative of better performance. For those in the underweight BMI category, previous research is consistent with the results of the current systematic review, which displays an increased risk for musculoskeletal injuries and stress fractures, specifically among military personnel. However, evidence regarding performance among overweight and obese individuals in tactical populations is not as clear, as results indicated that an increasing BMI has positive and negative effects on performance. Specifically, it was often seen that being in the normal weight BMI category was ideal for optimal performance, and that decreases in performance were seen with increases in BMI, however, one exception was seen in military personnel. Results from Pierce et al.[60] indicated that a higher BMI was found to be beneficial in regard to muscular strength and power.

Strengths

Strengths of included studies include that ten of the 27 studies were cohort studies, which are considered to be a stronger form of non-intervention study designs. According to the AND

QCC, all studies clearly stated the research question, adequately described the exposure factor, clearly defined the outcomes and used valid and reliable measurements, and used appropriate statistics. In addition, a majority of the included studies were unbiased in the selection of subjects and adequately described the method of handling withdrawals. Individual studies have their own unique strengths, but due to the heterogeneity of the studies, it is difficult to synthesize those strengths here.

Some strengths of this systematic review include the use of two databases, the PRISMA checklist. And the AND QCC. Searching two databases, PubMed and SCOPUS, helped to ensure that a wide range of articles were screened and increased the likelihood of including more of the available literature on the topic. Using the PRISMA checklist reduced bias in selecting and evaluating research articles included in this review. The AND QCC is a structured and comprehensive method of determining the quality of published research. It allows reviewers to objectively rate the quality of selected studies. Finally, methods established *a priori*, therefore eliminating any bias that may be present within the methodology.

Limitations

Limitations of included studies include that, according to the AND QCC, no studies used blinding to prevent bias and it was unclear if some studies were biased from funding or sponsorship.

The present systematic review also has some limitations. As seen by the results, included studies were not consistent in their outcome measurements, making it difficult to draw final conclusions on the associations between BMI and outcomes of interest. In order to include more studies with similar outcome measures, it may have been necessary to use a larger time frame but doing so may lead to the limitation of using outdated research. In addition, this study is only conducted in law enforcement officers, firefighters, and military personnel within the United

States, therefore these results may not be accurately generalized to other tactical populations, or tactical populations across the globe. Finally, the included studies were limited to cross-sectional, prospective and retrospective cohorts, case-controls, and secondary data analyses, therefore we are unable to imply causation between BMI and health and performance outcomes. Additionally, the review was only conducted by one researcher. We plan to include an additional independent researcher to carry out the review methodology in the near future to strengthen this review.

Directions for Future Research and Implications for Practice

Future studies may look to different study designs, such as randomized controlled trials and cohort studies, so that researchers can determine if BMI has a stronger, even causal, effect on health and performance outcomes. In addition, it would be beneficial to conduct more studies among law enforcement officers in the United States related to BMI and health and performance, as there were only four studies, out of the 27 included studies, conducted in this specific tactical population. Since this population is known to have high rates of overweight and obesity, similarly to firefighters, it would be beneficial to public health practitioners to see more research on the associations between BMI and health and performance in law enforcement officers. Finally, there were no studies included in this systematic review on BMI and cancer in tactical populations. The literature indicates that these populations are exposed to cancer risks daily, therefore, seeing more studies on how BMI may be associated with cancer risk in these populations may be beneficial.

Results and implications of this systematic review may be beneficial for use by public health practitioners. These results can guide public health practitioners when making diet and lifestyle recommendations for tactical populations, as well as serve as a basis for where interventions in tactical populations are needed. Implications for leaders of tactical populations include considering implementation of regular body composition assessments to ensure health, high occupational performance, and injury prevention.

Conclusions

In conclusion, increased BMI was associated with negative health and performance outcomes among tactical populations. As public health practitioners, it is important to understand the relationship between BMI and outcomes of interest to the populations with which we work. For tactical populations, being in the normal weight category was associated with better health and performance outcomes, thus public health practitioners should focus efforts on improving nutrition and increasing physical activity to promote a healthy BMI among these individuals.

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VITA

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