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PREDICTORS OF ARTERIAL STIFFNESS IN LAW ENFORCEMENT OFFICERS

Jason Michael Keeler
University of Kentucky, jason.keeler@uky.edu
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Jason Michael Keeler, Student

Dr. Mark Abel, Major Professor

Dr. Heather Erwin, Director of Graduate Studies

PREDICTORS OF ARTERIAL STIFFNESS IN LAW ENFORCEMENT OFFICERS

DISSERTATION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Education at the University of Kentucky

BY

Jason Michael Keeler

Lexington, KY

Director: Dr. Mark Abel, Associate Professor of Exercise Physiology

Lexington, KY

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ABSTRACT OF DISSERTATION

PREDICTORS OF ARTERIAL STIFFNESS IN LAW ENFORCEMENT OFFICERS

The prevalence of cardiovascular disease (CVD) among law enforcement officers (LEOs) is slightly higher than the general population. Furthermore, the prevalence of CVD doubles among LEOs following retirement compared to the general population. The measure of arterial stiffness serves as an independent risk factor that has prognostic value for future incidence of CVD. However, there is limited research on lifestyle, occupational, and demographic factors that may be associated with increased arterial stiffness in LEOs. Therefore, the purpose of this investigation was to compare the level of arterial stiffness among LEOs versus the general population and to identify lifestyle, occupational, and demographic predictors of arterial stiffness in LEOs. Seventy male career LEOs between the ages of 24 to 54 years from Kentucky and southwest Ohio participated in this study. LEOs completed a variety of questionnaires related to health/occupational histories, occupational stress, and diet. LEOs' body composition (bioelectrical impedance), central and brachial blood pressures, and physical activity (triaxial accelerometers) were assessed. The dependent variable of arterial stiffness was measured by carotid-femoral pulse wave velocity (cfPWV). A variety of statistical techniques including 1 sample t-tests, Pearson product moment correlations, and multiple linear regression were utilized in study analyses, with a level of significance set at $p < 0.05$. Compared to the general population cfPWV was significantly lower among LEO's under 30 years of age (mean difference = $-0.6\ m \cdot s^{-1}$), but significantly higher among LEOs 50-55 years of age (mean difference = $1.1\ m \cdot s^{-1}$). Utilizing stepwise multiple linear regression, age, relative body fat, and diastolic blood pressure explained the most variance in LEO's cfPWV (adj. $R^2 = 0.56$, $p < 0.001$). The primary findings of this investigation demonstrate that arterial stiffness may progress more rapidly in LEOs compared to the general population and that LEOs should focus on maintaining appropriate levels of relative body fat and blood pressure to regulate arterial stiffness and risk of CVD.

KEYWORDS: Carotid-femoral pulse wave velocity (cfPWV)
Law Enforcement Officers (LEOs)
Cardiovascular disease (CVD)

Jason Michael Keeler
(Author's Signature)

4/4/2018
(Date)

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LAW ENFORCEMENT OFFICERS

BY

Jason Michael Keeler

Dr. Mark Abel

Director of Dissertation

Dr. Heather Erwin

Director of Graduate Studies

4/11/2018

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CHAPTER I: INTRODUCTION

The research presented in the following chapters represents work conducted by the primary author and investigator in order to satisfy the requirements for completion of a Ph.D. in Exercise Science from the University of Kentucky. These guidelines were set forth and reviewed by the Graduate School and members of the Dissertation Committee. This dissertation is presented in chapter format in an effort to demonstrate an organized research report. A detailed literature review of cardiovascular disease in law enforcement officers (LEOs) and the measurement of arterial stiffness occupy the second chapter. Chapter three details the methodology utilized to investigate arterial stiffness within male LEOs. Chapter four is comprised of the study's results and discussion. Lastly, Chapter 5 provides a summary and conclusions derived from the current research project.

Cardiovascular disease (CVD) is the leading cause of death in the United States (21). The development of CVD occurs over a lifetime, and is influenced by a variety of behavioral factors such as smoking, poor nutrition, physical inactivity, stress management, and others (21, 52, 56). One professional population that is particularly susceptible to CVD is law enforcement. The prevalence of CVD among active duty LEOs has been suggested to be similar to the general population (49). However, the prevalence of CVD doubles among LEOs following retirement compared to the general population (50, 80). The rapid progression of CVD in LEOs necessitates the investigation of CVD risk factors and assessments in this population. Earlier detection and intervention may delay the onset of CVD and/or reduce the occurrence of CVD among active and retired LEOs.

Investigators have studied the prevalence of several traditional CVD risk factors in LEOs (49, 50, 53, 80). The primary findings of these studies indicate that the prevalence of hypertension and obesity are higher in LEOs compared to the general population. In addition, many LEOs lack the necessary physical activity to maintain cardiovascular health (49, 50, 56, 80). Law enforcement officers also experience physical and psychological stress, some of which is associated with performing law enforcement shift work (16, 33). Chronic stress is correlated with an increased risk of CVD (16, 53). Due to the deleterious health consequences and health care costs associated with CVD, the Centers for Disease Control (CDC) and National Institute for Occupational Safety and Health (NIOSH) have created a goal to decrease CVD prevalence by 10% among LEOs over a two year period (46). The primary goals of the CDC's agenda focuses on conducting etiological studies of occupational risk factors and identification of work organizational factors that are associated with CVD risk.

Several investigations have described a variety of occupational risk factors and stressors that LEOs are exposed to regularly, which include sudden onset and chronic exposure of physical and psychological stressors (49, 51-54, 56). Psychological stress has been associated with vascular dysfunction, CVD, impaired sleep, and depression (33). Likewise, Varvarigou et al. demonstrated that physical stress, such as performing physically demanding occupational tasks (e.g., restraints/altercations, pursuits of suspects, and physical training), was associated with sudden cardiac death, by serving as a physiological trigger to those who are predisposed to CVD (70). Research in other tactical populations has noted that arterial stiffness increases during prolonged performance of occupational tasks (17). In fact, arterial stiffness, an independent predictor of cardiac events, is associated with sudden cardiac deaths among firefighters (17). Collectively, these CVD risk factors provide some insight into the cardiovascular health of LEOs, however utilization of direct measurements of cardiovascular health, such as arterial stiffness, would provide a clearer understanding of why LEOs are disproportionately at risk of CVD. In turn, appropriate interventions may be identified and employed.

The measurement of arterial stiffness provides practitioners with an objective assessment that is predictive of CVD (12, 29, 40, 41, 74). Arterial stiffness, as measured by carotid-femoral pulse wave velocity (cfPWV), has been found to predict cardiovascular events and all-cause mortality in numerous epidemiological studies (12, 29, 40, 41, 74). The assessment of central arterial stiffness can detect earlier changes in the vasculature compared to brachial (i.e., peripheral) blood pressure measurements (40). Central stiffness measurements have been found to be superior in predicting first cardiovascular events compared to typical brachial blood pressure measurements (74). Normal aging causes progressive escalation of arterial stiffness and hypertension (32), however excess body fat and a sedentary lifestyle further augment the increase in arterial stiffness and blood pressure (22). Another proposed accelerant of arterial stiffening is shift work, which was observed in a bus driver population (13). Shift work is also known for increasing traditional CVD risk factors within LEOs (77). To the best of our knowledge, the measure of arterial stiffness has not been performed in LEOs. The assessment of arterial stiffness will provide unique insight on how lifestyle and organizational stressors may be associated with the law enforcement occupation.

Identifying lifestyle, organizational, and demographic factors that are associated with arterial stiffness will provide healthcare clinicians with an understanding of how to identify LEOs who may be at greater risk for CVD. Furthermore, identification of risk factors will provide practitioners and police departments with information to develop appropriate interventions to reduce CVD risk. Therefore the purpose of this study was to compare the arterial stiffness of LEOs versus the general population and to identify lifestyle, occupational, and demographic predictors of arterial stiffness in LEOs. We hypothesized that cfPWV would be greater in LEOs than in the general population (relative to age & gender) and cfPWV would be positively correlated to age, relative fat mass, years spent on third (night) shift, perceived stress, and inversely correlated to daily time spent in moderate-to-vigorous physical activity.

The following are assumptions of the present study.

1. Subjects did not eat food or drink caffeinated beverages for three hours prior to testing.
2. Subjects provided accurate responses on questionnaires.

The following are delimitations of the present study.

1. Professional male law enforcement officers from Kentucky and southwest Ohio between the ages of 21 and 55 years were recruited to participate in the study.

The following are exclusion criteria for the present study.

1. Subjects were excluded from the study if they were a current smoker or reported any sign, symptom, or diagnosis of cardiovascular, pulmonary, or metabolic disease.

CHAPTER II: REVIEW OF LITERATURE

Cardiovascular Disease and Law Enforcement Officers

Law enforcement is recognized as a dangerous and stressful occupation, however to maintain peace and order, the United States is employing well over 1.3 million people in some aspect of law enforcement (51, 80). Law enforcement personnel includes patrol officers, detectives, jailers, dispatchers, and many more. Some of the dangers the police force have are higher mortality, suicide, and cancer rates compared to most other lines of work (24). The most evident dangers usually involve handling suspects, which could involve bodily injury or death (80). However, cardiovascular disease (CVD) is a hidden danger waiting to strike the deadliest blow to an unsuspecting officer at anytime. The National Occupational Research Agenda (NORA) highlights this point by outlining a goal of trying to reduce CVD among Law Enforcement Officers (LEOs) by 10% (46). NORA has generated sub goals to better understand how this disease affects the law enforcement population and how risk factors play a role in CVD prevention (46). New research could be vital for saving taxpayers' money and most importantly, the life of an unsuspecting officer.

The overall goal of this literature review is to describe how CVD affects LEO populations. One specific objective is to more clearly understand how the law enforcement occupation may predispose LEOs to CVD. Another objective is to identify potential links that exist between traditional risk factors associated with CVD in LEOs. Finally, this review will attempt to find avenues where research maybe lacking in cardiovascular health for this population. The ultimate goal of this review is to identify how researchers, clinicians, and LEOs can help decrease the prevalence of CVD among LEOs.

Stress and Cardiovascular Disease

The occupation of law enforcement has been portrayed on television as a physical, high intensity career that is full of chases, arrests, and hand-to-hand combat. However the reality is that policing is a largely sedentary career interspersed with infrequent bursts of vigorous activity (21, 52). The law enforcement profession exposes officers to additional stressors that may be associated with the development of CVD. These stressors may include but are not limited to sudden and unexpected physical stress, large amounts of psychological stress, stress associated with of shift work (i.e., circadian stress/dysfunction/desynchronization), and excess noise exposure (80).

Stress is a general term used to characterize events that lead to physiological, emotional, and mental reactions (39). The response to a stressor is typically viewed through the Fight or Flight Response, and the body responds positively or negatively via the General Adaptation Syndrome. When the body is exposed to a stressful situation, physiologically, the hypothalamo-pituitary-adrenal (HPA) axis and autonomic nervous system are activated to deal with the perceived threat. It is natural and necessary for the body to react this way, because the stress hormones (cortisol, epinephrine, and norepinephrine) released from the HPA axis produce physiological responses (i.e., increased heart rate and blood pressure) to help the body meet the physical demands of a perceived threat. Traditionally the body’s increase of cortisol triggers a negative feedback response to the hypothalamus, however prolonged exposure to perceive threats (i.e., social, environmental, etc.) can produce long-term alterations to the cognitive function of the brain and its stress response (39). Prolonged elevation of the adrenocortical and autonomic function has been shown to be harmful for general and mental health (39). The process of maintaining homeostasis is called allostasis, and the prolonged elevations of allostasis through adrenocortical and autonomic functions create an overload on the body called allostatic load (39). This allostatic load encompasses every stressor the body has to adapt to, including physical, psychological, and social stressors. Without proper rest and recovery the stressors generate larger allostatic loads, which prolongs allostatic processes. The allostatic load may also increase with perceived stressors, and the extent to which the allostatic load is increased depends on the individual's perception of the threat. If the threat is easily controlled the body should return homeostasis rather quickly, however, if the threat persists, it may prolong the process of allostasis and lead to allostatic overload. Allostatic overload can cause prolonged HPA axis and autonomic activity, which can cause the body to reach exhaustion, the final stage of the General Adaptation Syndrome (39). The exhaustion phase has detrimental effects like maladaptive pathophysiological conditions (e.g., atherosclerosis) (39). Since stress has such detrimental effects and is compounding in nature to lead to allostatic overload, it is imperative to understand what additional occupational stressors are imposed on LEOs.

Physical stressors, such as wearing protective equipment and performing patrolling tasks become routine, however physical altercations, chases, and arrests are unpredictable and require greater physical exertion. A study with Canadian police officers showed that normal police work averaged a 23 beats per minute ($b \cdot min^{-1}$) increase in heart rate above resting heart rate, with peak increases of 88-112 $b \cdot min^{-1}$ during unpredictable physical altercations (5). Zimmerman's review noted that sudden extreme and intense physical activities like performing arrests or chases could predispose LEOs to sudden CVD events (80). Varvarigou et al. showed that sudden cardiovascular events occur much more often during the physical exertion needed for altercations or pursuits in LEOs (70).

In addition to physical stress, psychological stress has been related to CVD and sudden cardiovascular events in a variety of populations including LEOs (16, 31, 33, 70). Although it is difficult to identify the exact mechanism for which stress may lead to CVD, vasculature changes like intimal-medial thickening, atherosclerotic changes, or hypertension might aid in the progression of CVD due to psychological stress (33). LEOs experience psychological stress on a regular basis (51, 80). Mental and emotional stressors come from a variety of sources, and when combined can play a role in the progression of CVD or posttraumatic stress syndrome (PTSD). PTSD is associated with the metabolic syndrome and CVD risk (80). The stresses presented to a LEO on-duty are either short-term stressors (altercations/chases) or organizational stressors (Figure 2-1).

Figure 2-1, shows four organizational areas of stress within the occupation of law enforcement. Ramey et al. developed this model utilizing a survey (n= 672) and focus group discussions (n=50) to identify constructs that were correlated to LEO's perceived stress (48). In brief, vital exhaustion, job strain, effort-reward imbalance, and social support contribute to the LEO's perceived stress. Vital exhaustion refers to feelings of fatigue, dejectedness, or irritability experienced by the LEO (52). A few examples include lack of routine, irregular hours, low morale, and lack of sleep/rest (52). "Job Strain" is characterized by the perception of control or ability to perform the necessary tasks and make critical decisions during the task (52). LEOs identified the heavy workload, lack of control, altercations with the public, and negative world view as examples for Job Strain stress (52). Effort-reward imbalance is the perceived lack of recognition LEOs receive for the amount of time and effort invested in occupational tasks (52). Lastly, the Lack of Social Support variable refers to perceived stress from insufficient social support on the job and by the immediate family members (52).

Figure 2-1: Model of organizational stressors (adapted from Ramey et al. (52)).

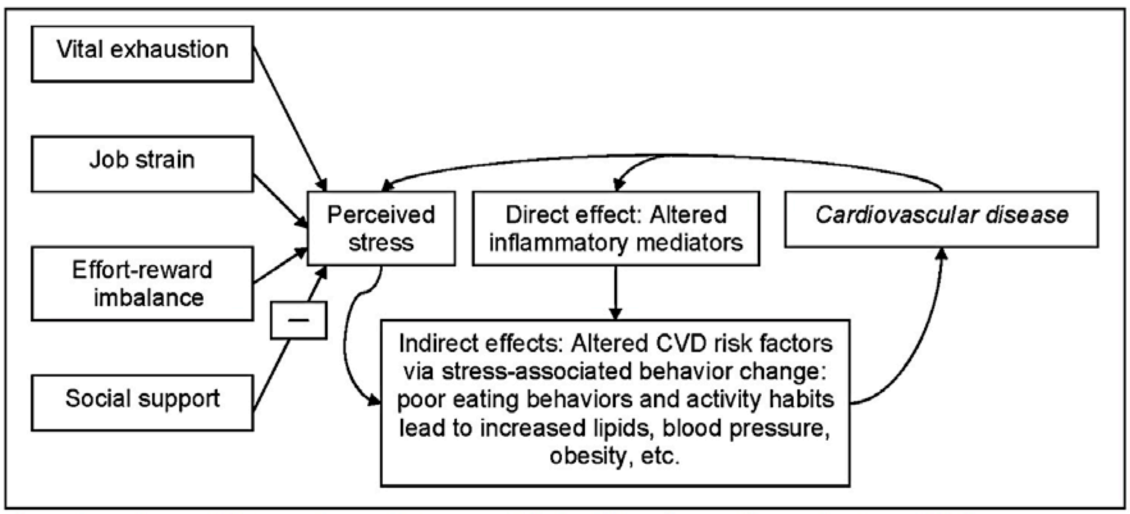

Figure. Conceptual model of organizational stressors and their relationship to cardiovascular disease (CVD).

One of the key contributors to the job strain and vital exhaustion components of Ramey and colleagues' model is the performance of shift work among LEOs. Shift work within law enforcement agencies allows for continuous policing of an assigned jurisdiction. However many studies have reported negative health effects associated with shift work, especially performing nightshift work (11, 13, 27, 35, 47, 48, 66, 69, 72, 73, 75, 77, 80). Shift work has been suggested to increase psychosocial stress, because it has inflexibility with work hours in shift organizations, it decreases work-life balance, and may increase perception of ability to recover from work shift (47). Within the policing realm evening and night shifts have had a tendency to face situations of higher stress on a more regular basis (35). These situations may have an enhanced element of psychological stress, when combined with the knowledge that operational performance is decreased with consecutive night shifts (63). Waggoner and colleagues noted decrements in driving, psychomotor vigilance, and an increase in sleepiness following consecutive night shifts (75). An investigation by Lammers et al. revealed that cortisol-awakening response levels increased in novice LEOs during the first 14 months of rotating work shifts (28). This investigation noted that about half of the LEOs started to reverse towards baseline levels, but half continued to have elevated cortisol levels. It was speculated that LEOs could possibly develop shift work tolerance, however further research is warranted to confirm this contention. Wirtz and coworkers' reported that law enforcement shiftwork experience was inversely associated with a decreased level of fitness for duty, and the reduced fitness levels were related to a rapid growth in health impairments in LEOs, independent of age (77).

Law enforcement officers are subjected to a variety of stimuli that may contribute to negative health and wellness outcomes over time. The increased load carriage can cause musculoskeletal injuries; while the sedentary nature of police work with sudden bursts of activity puts LEOs in dangerous situations that are out of their control. Organizational stressors and shift work also contribute to LEOs risk of CVD. It is critical that the LEO population is investigated to minimize or reduce the effects of these stressors.

Traditional Cardiovascular Disease Risk Factors in Law Enforcement Officers

Many researchers have noted a high prevalence of some traditional CVD risk factors among LEOs (21, 24, 49, 50, 52). It is important to identify which risk factors are most prevalent among LEOs and address those risk factors that are modifiable. Non-modifiable risk factors include age, gender, and family history (7, 46). Modifiable risk factors include hypertension, hyperlipidemia, obesity, tobacco use, diabetes, poor diet, and physical inactivity (7, 46). Although these two groups of risk factors both help predict CVD, the type of risk factor will have an inherent role in determining and reducing CVD risk. For example, the non-modifiable risk factors should not play a major role in the health disparity of police officers compared to general population. However the physically demanding job tasks and social perceptions have swayed the Law Enforcement profession towards a more masculine overweight/obese population (52, 53). One major risk factor for CVD in younger adults is being male (45). Given that approximately 85% of LEOs are male, there is an increased risk of CVD compared to the general population (50). On the other hand, the opportunities to change diet or physical activity are readily available. The modifiable risk factors have been looked at to help decrease the risk of CVD in law enforcement, but have failed to drastically decrease the health disparity that exists between LEOs and the general population (49, 52, 56, 80).

Hypertension, excess body mass, and lack of physical activity are three modifiable risk factors noted to have a higher prevalence among LEOs, however a quantifiable metric is needed to more clearly describe the relative risk of CVD. The American College of Sports Medicine (ACSM) has developed a standard for stratifying CVD risk using modifiable and non-modifiable risk factors. According to ACSM there are eight major risk factors, which can be seen in Table 2-1 (45). Summation of the positive risk factors allows for risk stratification. Low risk equates to being asymptomatic with one or zero CVD risk factors. Moderate risk equates to being asymptomatic with two or more CVD risk factors. High risk equates to having a known cardiovascular, metabolic, or pulmonary disease or having one or more symptoms of cardiovascular, metabolic, or pulmonary disease. These standards, along with the standards for blood pressure set by the American Heart Association (previous standards: normal blood pressure < 120/80 mmHg, hypertension ≥140/90 mmHg, new standards: normal blood pressure <120/80, hypertension stage-1 >130/80), provide a solid base of risk factors associated with CVD (7). A description of the prevalence of CVD risk factors among LEOs is provided below.

Table 2-1. American College of Sports Medicine Cardiovascular Risk Factors (40).

	Risk Factor	Risk Factor Description
1	Age	Men ≥ 45 years; Women ≥ 55 years
2	Family History	Myocardial infarction or sudden death in immediate family before 55 years of age in father or other male first-degree relative or before 65 years of age in mother or other female first-degree relative
3	Cigarette Smoking	Current smoker, those who have quit in the past six months
4	Obesity	BMI ≥ 30 $kg \cdot m^{-2}$
5	Hypertension	Systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg
6	Dyslipidemia	Total cholesterol ≥200 $mg \cdot dL^{-1}$
7	Pre-Diabetes	Fasting glucose ≥ 100$mg \cdot dL^{-1}$ and < 126 $mg \cdot dL^{-1}$
8	Sedentary Lifestyle	< 30 minutes of moderate intensity physical activity on at least 3 $days \cdot week^{-1}$ for at least 3 months

The first CVD risk factor is hypertension, however the prevalence of hypertension among LEOs compared to the general population's prevalence has been debated in a couple of studies. In one study by Ramey et al., 27.4% of Milwaukee LEOs surveyed had hypertension compared to a 17.6% noted in the general population of Wisconsin (52). A study completed by Kales et al. on first responders (LEOs, firefighters, emergency medical services), noted that the prevalence of hypertension among LEOs was between 21-27%, however there were no data provided from the general population for comparison (26). The interesting aspect of this study is how officers and firefighters were classified. Part of the study said anything less than 160 mmHg systolic and less than 90 mmHg diastolic was listed as an acceptable range for the tactical population of interest (26). To contrast, the ACSM would consider a blood pressure under 120/80 mmHg as normal with anything under 140/90 mmHg being acceptable. The discrepancy between the two acceptable ranges can cause a misinterpretation of the data, especially when just evaluating the prevalence between categorical classifications of hypertension.

Although many studies concur that the prevalence of hypertension is greater in LEO compared to the general population, one large study reported an opposite trend. Specifically, Joseph and colleagues noted a decreased prevalence of age-adjusted hypertension in Buffalo, NY LEOs compared to the general population in Western New York State (24). Law Enforcement Officers did show a slightly higher mean blood pressure for both systolic (+ 3.1 mmHg) and diastolic (+1.7 mmHg) measures, but both group means were within acceptable ranges for the previous American Heart Association standards (25). Although the prevalence of hypertension among active LEOs is mixed, the prevalence of hypertension in retirement is significantly greater compared to the general population (50, 80). Due to the use of different hypertension thresholds, the prevalence of hypertension among LEOs may be underestimated, which warrants continual identification and clarification of hypertension amongst LEOs.

The second prevalent CVD risk factor among LEOs is excessive body weight. Approximately 66% of the general population of America is overweight or obese according to body mass Index (BMI) (80). A review of CVD risk factors among LEOs indicates that approximately 71-89% of LEOs were classified as overweight or obese (80). Similarly, Ramey et al. reported that 79% of the officers in Wisconsin and Hawaii were overweight or obese (56). More specifically, Hartley et al. noted 41.5% of LEOs were overweight and 40.5% were obese (21). In the Hartley et al. study 40.0% of general population was overweight, and 32.1%were obese (21). The aforementioned studies present evidence that there is a prevalence of increased body weight for LEOs compared to the general population, which is a well-defined risk factor of CVD.

In addition to increased obesity, the surprising misclassification of LEOs into obese or non-obese groups might necessitate the use of more accurate body composition assessment techniques. Alasagheirin et al. evaluated the misclassification of LEOs based on BMI, and showed that about 30% of LEOs in their sample were classified as healthy, when they were truly overweight or obese according to the specification of ≥25% body fat (for males) as determined by dual x-ray absorptiometry (DXA) (3). Only 14% of the officers were misclassified as overweight or obese according to BMI, when they should have been classified in the healthy range according to relative body fat (3). However, given a net 16% under classification, and the apparent high prevalence of obesity among LEOs, it would be advantageous for a more sophisticated body composition assessment technique to be used when assessing CVD risk in LEOs. The use of DXA or bioelectrical impedance analysis might enhance the accuracy of estimating the prevalence of obesity among LEOs.

The third most prevalent CVD risk factor among LEOs is a sedentary lifestyle (21, 49, 52, 56, 77, 80). This would seem contrary to general perception, because of the physically demanding tasks potentially required of LEOs. While unpredictable episodes of intense activity do occur, the majority of the time LEOs are sitting in a patrol car or at a desk (56, 80). Stamford noted that the requirements of police work were not sufficient to maintain physical fitness, and concluded that routine police work should be viewed as sedentary in nature (62). Zimmerman noted that criminal offenders of similar age were likely to be more fit than the arresting LEO (80). Ramey et al. used accelerometers to quantify physical activity levels in campus and municipal LEOs for 3 active duty days and 1 off-duty day (56). In the study, there was a notable increase in the physical activity level of both LEO types during off-duty days, and campus police officers were more active than municipal LEOs overall (56). Ramey et al. noted an average activity level of 1.6 METs during active duty days, which would be equivalent to a desk or sedentary job (56). Ramey and coworkers' study also noted inverse relationships between obesity versus accumulated physical activity (estimate energy expenditure and step counts) and age versus physical activity (56). Ramey et al. speculated that the inverse relationship between age and physical activity might be due to job task requirements for higher-ranking officers (56).

The three described risk factors may play a role in the possibility of developing the metabolic syndrome, which is another highly associated risk factor and predictor of

CVD and all-cause mortality (7). The metabolic syndrome is characterized by presenting three or more of the following risk factors: abdominal obesity measured by waist circumference (> 102 cm), dyslipidemia (≥ $150 mg\cdot dL^{-1}$), low high density lipoprotein (< 40 $mg\cdot mL^{-1}$ for men or <50 mg·mL-1 for women), elevated blood pressure (≥130 mmHg systolic; ≥ 85 mmHg diastolic), and elevated fasting blood glucose (≥100 $mg\cdot mL^{-1}$) (80). Evaluation of metabolic syndrome in LEOs is limited. Violanti et al. evaluated 98 officers during different shifts. There was a greater prevalence of metabolic syndrome risk factors in the midnight shift officers compared to day shift officers; however, there does not appear to be a difference in the prevalence of metabolic syndrome between LEOs versus the general population (72).

Non-Traditional Cardiovascular Disease Risk Factors in Law Enforcement Officers

The relationship between shift work and CVD has been investigated by several studies and these investigations have discovered a variety of adverse consequences for employees involved in shift work (5, 11, 13, 27, 35, 47, 48, 66, 72). The late night or early morning shifts are of primary concern. These shifts have shown greater prevalence traditional CVD risk factors among several populations, including LEOs. Although shift work has not been directly related to CVD, it has been shown to perpetuate traditional CVD risk factors and has a weak association to CVD morbidity (47).

Puttonen and colleagues believe the connection between shift work and CVD might be closely related to circadian stress, which refers to physiological, behavioral, and psychosocial consequences associated with changes in circadian rhythm (47). This assertion supports Ramey's Organizational Stressor Model, which suggests that increased stressors augment CVD risk factors. Negative behavioral stressors associated with shift work include poor sleep quality and quantity, increased smoking rates, poorer nutrition, weight gain, and physical inactivity (47, 48, 66, 77). Physiological outcomes of stressors associated negatively with shift work include increased inflammation, increased blood pressure, and increased sympathetic tone (5, 11, 35, 47, 66, 77, 80). Lastly, the psychosocial consequences include decrements in work-life balance, decreased time to recover from work, and an increase in work stress (5, 11, 15, 27, 35, 47). Increased stress from a variety of these areas culminates into greater CVD risk for shift work employees including LEOs.

As Puttonen et al. outlined, circadian stress has physiological consequences that can impact CVD risk including arterial stiffness (47). A primary consequence is the dysregulation of endocrine, immune and autonomic function (47). These dysregulations stem from the behavior and psychosocial changes associated with shiftwork, and the mind-body connection through the HPA-axis (39). The stress hormone cortisol is of primary importance when evaluating changes in circadian rhythm. Cortisol’s impact on the awakening cycle and immune function/dysfunction has been documented in a variety of investigations (39, 65, 76). In the LEO population, short-term shift work caused lower levels of cortisol during the awakening cortisol response, which is explained by reaching the exhaustive phase of the general adaptation syndrome(76). The decrement in cortisol leaves LEOs at greater risk for posttraumatic stress disorder (PTSD) and CVD risk factors (39, 76). Even though there is a decrement in cortisol during the awakening cycle, cortisol levels tend to stay more elevated throughout the day (61). Constantly elevated cortisol levels leads to increased inflammation and reduced immune function, which can ultimately lead to arterial stiffening (42, 61). Misalignment of the circadian rhythm through behavior and social modification can cause detrimental effects on the cardiovascular system, and ultimately increasing the risk of CVD.

Although there is a compelling amount of evidence indicating CVD risk factors are higher in LEOs (49-53, 55, 56, 80), a comprehensive review found that CVD incident rates were lower (80). That study stated LEOs are less likely to die of CVD while active in service versus the general population (80). This study also pointed out how this could be a case of the “healthy worker effect,” since unhealthy individuals are less likely to pass the physical, medical, emotional stresses of the recruiting examinations (80). Another aspect of the healthy worker effect is the possibility of early retirement, because of the inability to perform job related tasks safely (50). A few studies looked at the presence of CVD after retirement, which might help investigators understand if the healthy worker effect is a plausible explanation for lower CVD incident rates during active service. According to previous research, officers’ are at a significantly greater risk of CVD incidents during retirement (50, 52, 80). Specifically, Ramey et al. stated that retired officers are at 1.7 times greater risk of developing CVD compared to the general population (50). The dramatic increase in the prevalence of CVD upon retirement raises questions regarding the causes of CVD and the timing of the onset of CVD and its risk factors.

Cardiovascular disease risks are prevalent in LEOs. A male dominant employee base brings an inherent increase in risk of cardiovascular disease, while certain modifiable risk factors also increase the risk. LEOs have a notable increase in hypertension and excess body fat, which increase the risk for developing CVD. The limited physical activity during duty may also play an important role in the later development of CVD. The metabolic syndrome has not been investigated thoroughly enough to determine its role in CVD development for LEOs. Lastly the occupational stresses imposed impacts the susceptibility of officers developing CVD through an altered allostatic process. Although these factors may contribute to the development of CVD, none show how the body's vasculature system is changing during a LEO's career span. Measuring arterial stiffness cross-sectionally and longitudinally may provide new insight regarding vascular changes across the career span.

Arterial Stiffness

The condition of arterial stiffening is a known contributor to the development of CVD and all cause mortality (8, 40, 79). This review discusses relevant literature regarding the development and progression of arterial stiffening. The primary objective is to discuss the basic pathology behind vascular changes, and how pulse wave velocity assesses arterial stiffness. The second objective is to understand how shift work, physical activity, and stress affect arterial stiffness. The final objective will focus on arterial stiffness research in tactical populations. These objectives provide a detailed description of how arterial stiffness occurs, progresses, and its contribution to CVD within tactical populations.

Basic Physiology and Pathology of Arterial Stiffness

The first step in understanding the progression of stiffening arteries is to focus on the basic physiology of the cardiovascular system. The vasculature of the body at the most basic level is a series of elastic tubes, which allows the circulation of blood throughout the cardiovascular system. London and Pannier state that the arteries have two primary functions. The first being the “conduit function (34, 40).” This is the basic function of transporting the blood throughout the body. The second function proposed was the “cushioning or dampening function (34).” This function in the aortic regions serves as regulator of pressures and blood flow to the rest of the arterial tree by distension of the arteries (34). The heart is the second major aspect of the cardiovascular system, and it is the motor that drives blood flow. The interdependent nature of the vasculature and heart allows for adaptions of one to aid in the shortcomings of the other, to continue the orchestration of a harmonious flow of blood to meet the bodily demands for oxygen and nutrients. This relationship is important when considering what happens to the cardiovascular system during arterial stiffening.

Arterial stiffness is a notable reduction of the arterial tree’s ability to expand and recoil with changing pressures during the heart’s contractile cycle (12, 29). Another definition of arterial stiffness by Stoner et al. is, “a term that collectively describes distensibility, compliance, and elastic modulus of the arterial vascular system (63).” Both definitions focus on the arterial tree’s ability to change, which is made possible by the heterogenic construction of the arteries within the arterial tree (29, 63, 79). The ratio of collagen to elastin increases within the walls of the vasculature, as the arterial tree proceeds more distally. The aortic region of the arterial tree is composed of larger amounts of elastin to allow expansion of the aorta to provide a cushioning effect due to the large intravascular pressures created during systole. The peripheral arteries contain more collagen to maintain shape and structure (34, 79). The aortic section is known to incur the largest change over time due to hemodynamic forces and extrinsic factors (79).

This change is primarily due to the fracturing and/or damaging of the elastin and the increase of collagen fibers in the tunica media layer (34, 79).

Hemodynamic forces and extrinsic factors work concurrently to cause damage to the arteries as people age. Aging is positively associated with increases in arterial stiffness (32, 41, 68). Excessive hemodynamic forces cause elevated shear forces against the endothelial layer of the arteries. The excessive stress can cause micro-fractures of epithelium, increased collagen, increased inflammation, and increases in the permeability of the endothelium (79). This increased permeability allows greater access to the tunica media for extrinsic insults like NaCl, lipids, inflammatory cells, and angiotensin, which can accelerate arterial stiffening (79). The increase in pressure and extrinsic factors causes dysfunctional regulation of elastin and collagen remolding in the extracellular matrix of the arterial walls. The progressive increase in collagen and decrease of normal functioning elastin causes a thickening of the vasculature wall. Most notably the intima-medial layer of the artery can double or triple in size over a 70-year span (ages 20-90 years) (79). The growth of the intima-medial occurs through several changes to the extracellular matrix of the vasculature wall.

As the body ages, remolding of the vasculature is regulated by matrix metalloproteases (MMPs). Collagenolytic and elastinolytic MMPs initiate the degradation of collagen and elastin, to allow for remolding of the proteins. This process should occur slowly to enable proper remolding, with the ultimate goal to maintain a proper ratio of collagen to elastin for each region of the arterial tree. However, the remolding process becomes dysfunctional because the hemodynamic stresses and extrinsic factors up-regulate MMPs and inflammatory cells. MMP-2 and MMP-9 are of primary interest to researchers now, because these two have expressed a negative relationship with the arterial stiffness measure of pulse wave velocity (12). The up-regulation allows improper cross-linking, mineralization, and alterations to the collagen, elastin and other extracellular matrix proteins (79).

Advanced glycation end products (AGEs) are seen as a main culprit that promotes dysfunctional regulation. When AGEs cross-link with either collagen or elastin proteins, a stronger and stiffer scaffolding protein is generated (79). Over time, as the number of AGE-collagen and AGE-elastin cross linkages grow, the artery becomes more ridged. The AGE cross linkages would not be of any concern if regulation were the same as with normal collagen or elastin linkages, however AGE cross linkages are less susceptible to hydrolytic turnover (12, 79). Eventually arterial wall thickness increases due to the buildup of normal functioning proteins and the increases of AGE-linked collagen and elastin. AGEs also affect endothelial function by decreasing nitric oxide release, promoting oxidative substance release, and increasing stress signaling through the immunoglobulin superfamily receptors (12, 79). The body's inflammatory response is a primary controller of the MMPs regulation, through macrophage and neutrophil expression. As stated above AGEs increase the inflammatory response. That response increases expression of p12(ras), NF-kB, oxidant radical formation, pro-inflammatory cytokines, growth factors, and vascular adhesion molecules (79). All of these mediators can increase vascular stiffness through MMPs, contribute to endothelium dysfunction, worsen response to vascular injury, affect angiogenesis, and promote atherosclerotic plaques (79). Along with up regulation of MMPs, the down regulation or cessation of nitric oxide is a main contributor to arterial stiffness. Nitric oxide is reduced by reactive oxygen species caused by stress, hormones, and AGEs (79). The decrease is also linked to increases in vascular smooth muscle cell tone, which can occur due to impaired endothelial function, oxidant stress, and high sodium intake (79). In summary, there are numerous pathophysiological mechanisms that contribute to vascular dysregulation and produce arterial stiffness.

Arterial Stiffness Measurement

Clinical evaluations of the cardiovascular system tend to rely on the measurement of different arterial pressures. The most common measurement is brachial blood pressure, which is preformed routinely in doctors' visits, health screenings, and even at the grocery store pharmacy (34). Brachial blood pressure is a measure of the peripheral arteries, and this pressure can help diagnosis hypertension and risk for CVD after it has past a certain point. However central arterial pressure measurements can provide earlier feedback to classify risk. Increased aortic arterial stiffness measured by Carotid Femoral Pulse Wave Velocity (cfPWV) is a biomarker for increased risk for cardiovascular events (like myocardial infarction and heart failure), stroke, dementia, renal disease, and total mortality (9, 29, 37, 63, 79).

Clinical implications of arterial stiffening include increases in systolic, diastolic, mean arterial, and pulse pressures, as well as increases in arterial wall thickness and cfPWV (29, 37, 79). Arterial stiffness describes the distensibility, compliance, and elastic modulus of the arterial system. A major consequence of increased central stiffness is the increase of afterload pressures placed on the heart's aortic valve. The increase in afterload, results in greater pressure demands from the heart to open the aortic valve (12, 29). The increase in afterload is attributed to a combination of decreased compliance/distension of the arterial walls and a faster return of the reflected pulse wave following narrowing/splitting of the arterial tree (12, 29). As the large elastic central arteries feed into the small arteries of the periphery, the change in vessel diameter causes the pulsatile wave to reflect back towards the aorta, and with increased arterial stiffness the speed at which the reflected wave travels increases. The increased stiffness of the artery is of primary concern, while the faster return of the reflected wave is a consequence of increased stiffness. In a healthy person, distension of compliant arterial walls in the aortic regions creates a decrease in the afterload. The body benefits from the distension, because the elastic recoil of the arterial walls become a potential energy source that will be utilized during diastole to continue systemic circulation (34). The diastolic coronary perfusion phase of the cardiac cycle, is vital to enable increased circulation of blood to the coronary arteries (34). Without the perfusion time, the cardiac muscles are under nourished and are at greater risk for acute injuries.

The measurement of arterial stiffness has been derived from the fundamental elements of hemodynamics, hydraulic theories, and elastic mechanical theories (29). With these fundamental elements in mind a few different approaches have been made with in an attempt to find the best model for prediction of CVD. This review will focus on the carotid-femoral pulse wave velocity (cfPWV) technique, because it has been shown to be reproducible and reliable (6). In fact, the European Society of Hypertension and European Society of Cardiology suggests aortic PWV measurements be taken to assess CVD risk in any population because of the reliability and reproducibility (74). In addition, the cfPWV measurement's relationship with CVD may be stronger than the assessment of peripheral pressures, because of the more direct connection with the left ventricle, coronary arteries, and the carotid artery's pulse wave (14). Another reason cfPWV measurement may be a superior assessment is because of the phenomenon of pressure amplification, which demonstrates that there is an increase in pressures of the periphery compared to the central aortic arteries due to the peripheries being more ridged in nature leading to an overestimation of the central pressures (29).

Carotid-femoral pulse wave velocity is the criterion measure of arterial stiffness. The measurement value is representative of the elastic nature of aortic regions covered. Carotid-femoral pulse wave velocity is derived from dividing the pulse's traveled distance by the change in time. This value demonstrates the velocity of the traveling pulse. The measurements of the pressure waves are taken at the carotid and femoral arteries. The distance measured is from the carotid to the sternal notch, the sternal notch to the navel, and finally the navel to the femoral artery. Prior to testing, Laurent et al. noted subjects must refrain from smoking 3 hours before, drinking alcohol 10 hours before, and must be supine for at least 10 minutes prior to measurement (29). The SphygmoCor (AtCor Medical, Australia) is an automatic recording device used to measure cfPWV. Asmar et al. validated the cfPWV measurement by comparing them to manual measurements, finding a nonsignificant mean difference of .20± 0.45 $m \cdot s^{-1}$ with the automated device's value being slightly lower, (6). Asmar et al. also found strong intra-tester (ICC = 0.94) and inter-tester (ICC =0.89) reliability while using the automated device (6). The SphygmoCor uses the foot-to-foot velocity method, which measures the amount of time it takes the between the R-wave of the ECG until the pulse reaches the measurement site (carotid or femoral artery). A foot is considered the end of diastole, and is visually shown on the device as the beginning of the sharp increase in pressure during systole. The distance and transit time between the two feet is used to calculate cfPWV (29).

As stated before, the left ventricular afterload is affected by the PWV and the aortic wave reflections. The wave reflections are typically measured using radial artery tonometry and a transfer function to calculate the aortic pressure waveform (29). The degree to which the reflected wave affects the afterload is demonstrated through the use of the augmentation index. The augmentation index is the subtraction of the second systolic peak minus the first systolic peak, divided by the pulse pressure and multiplied by one hundred, to be expressed as a percent of the pulse pressure (29). Larger augmentation index values are indicative of faster returning reflective waves. Positive values indicate the return of the reflected waves during systole, while negative values denote the return of reflected waves during diastole. The return of the reflected waves causes an increase in aortic pressure. The elevated diastolic pressure from slower returning waves allows increased coronary perfusion (32). Carotid femoral pulse wave velocity and the augmentation index help discern how the vasculature is affecting the workload of the heart. Although the relevance of the augmentation index has been disputed, others view the augmentation index and cfPWV as vital tools that have been linked to predicting cardiovascular events and all cause mortalities in many epidemiological studies of high-risk subjects and general populations (12, 29, 40, 41, 74).

The Effects of Law Enforcement Officer Cardiovascular Disease Risk Factors on Arterial Stiffness

Arterial stiffness measures help assess CVD risk, but understanding its relationship to other risk factors noted in tactical populations can provide information about why LEOs incur CVD at a greater rate upon retirement. Investigations into arterial stiffness have not been performed in law enforcement populations, but have assessed other populations who share similar risk factors. It was noted earlier that LEOs tend to be overweight, lack physical activity, and perform shift work (49-53, 55, 56). Most of these variables have been shown to impact arterial stiffness in other populations.

Obesity is a major risk factor for CVD, which subsequently has a profound effect on arterial stiffness and cfPWV measurements (29, 79). Changes in adipokine concentrations have been linked to obesity, which can have an additive effect on arterial stiffness. Decrements in the plasma protein adiponectin have been linked to obesity, insulin resistance, type 2 diabetes, and hypertension (58). Adiponectin is produced by adipose tissue and possesses anti-inflammatory, antiproliferative, antiatherogenic, and insulin-sensitizing mechanisms (58). With limited adiponectin, nitric oxide synthesis expression decreases, which decreases the protective effects of nitric oxide and thus decreases the vessel's ability to vasodilate. Low levels of adiponectin have been associated with increased arterial stiffness, however the extent of the exact mechanisms are still being investigated (58). Another adipokine affected by obesity is leptin. Obese individuals have elevated leptin levels in the plasma, which are known to increase aldosterone, sodium retention volume expression and increased blood pressure (58). High levels of leptin also contributes to production of vascular smooth muscle cell proliferation, endothelial oxidative stress, and reactive oxidative species formation (58). The microenvironment changes of the vasculature aid in the development of artery stiffening because they reduce nitric oxide, hinder aortic mechanical function, and increase blood pressures (58).

Another major consequence of obesity could be the inaccuracy of distance measurements between the carotid and femoral artery, thus producing measurement error in the cfPWV assessment. Measurement of sites maybe exaggerated due to a large girth at the abdomen or chest. This added distance would attenuate any increases in velocity due to the exaggeration of the distance travelled. Therefore the investigator must measure as straight as possible, which might be best if the flexible tape is held tautly above the surface of the skin to diminish arcing caused by larger girths. Obesity has the potential to change velocity values due to inaccurate measurements, but that can be corrected or minimized through various techniques (29).

Hypertension has a strong link to arterial stiffening, so much so that a few researchers question which occurs first. Mitchell's review focused on this topic and found that arterial stiffening measured by cfPWV occurs prior to hypertension (40). It has been noted that acute rises in blood pressure can cause acute/chronic increases in arterial stiffness in subjects (12). Sustained rises of blood pressure may accelerate structural changes within the vasculature walls, because hypertensive individuals have elevated stiffness compared to age-matched controls (12). Treating hypertension with medications may help decrease high blood pressures, but it has a less impactful reduction on arterial stiffness, compared to arterial structural changes (12). Anti-hypertensive medication will also distort wave reflections and produce lower PWV readings that do not represent the actual stiffness of the arteries (29).

Another risk factor of note in LEOs is lack of physical activity, which is believed to have an inverse relationship with arterial stiffness. O'Donovan et al. reported an inverse relationship between regular physical activity at any intensity versus augmentation index and PWV in hypertensive patients (43). Another investigation by MacAnaney et al. found similar results, however they found body fat to be strong driver of the relationship (36). The investigators concluded that those who participated in more physical activity had less body fat and thus less stiffness than those who were sedentary (36). A third study looking at physical activity in Korean office workers reported that there is no correlation between physical activity and stiffness, but there was a significant correlation between sedentary time and stiffness in just women (20). This study was interesting in the fact that is used a questionnaire to assess physical activity levels, which is a subjective assessment. Further research is warranted using an objective assessment of physical activity. In summary, there may be a relationship between physical activity and arterial stiffness; however, the confounding effects of body fat and age must be accounted for to more clearly understand its independent relationship.

The only investigation looking into shift work focused on Professional Asian Bus Drivers. This study used the brachial-ankle PWV assessment for a regional view of stiffness. Chen et al. found an increase of 3.6 $cm \cdot s^{-1}$ (0.36 $m \cdot s^{-1}$) in PWV for every year of shift driving (13). This small increase can add up over time and along with additional stressors placed on LEOs, there could be even greater increases in arterial stiffness. Even though this is the only shift work investigation that could be found looking at arterial stiffening, there is a considerable amount of evidence presented earlier that may indicate shift work contributes to arterial stiffening.

The last and most important determinant of arterial stiffness is age. Throughout life the remolding of the vasculature occurs, and depending on the effectiveness of that remolding, the vasculature can become stiffer or remain more compliant. Several studies note a linear increase of cfPWV values until the age of 60 years (40, 41, 79). Following the age of 60 years, there tends to be a rapid exponential increase in the cfPWV (40, 41, 79). Age is a strong predictor variable of cfPWV independent of all other variables (40). This fact makes age an important factor in understanding how arterial stiffness is affecting LEOs.

Arterial Stiffness measures in Tactical Populations

Tactical populations consist of first responders, paramilitary, and military units. Investigations of CVD have been prevalent among these populations, but the investigations of regional vascular health are limited. This review identified a few articles that assessed regional aortic stiffness or pulse wave analysis in firefighters and military personnel.

Firefighters are known to have a greater risk of sudden cardiovascular events than the general population, because of the strenuous nature of the job and the environmental extreme conditions (17, 19, 44). Fahs et al. evaluated the acute effects of firefighting on arterial stiffness and blood flow. Their investigation found that after a 3-hour firefighting activity, subjects significantly increased heart rate, aortic diastolic blood pressure, augmentation index (at 75 $b \cdot min^{-1}$), aortic PWV, carotid minimum and maximum diameter, core temperature, and significantly decreased brachial and aortic pulse pressure (17). These changes were similar to what has been observed in heavy resistance or aerobic training (17). Fahs et al. speculated that a combination of thermal, metabolic, and psychological stresses caused the significant changes. Gaughan et al.'s investigation did not evaluate PWV, but did assess other pulse wave analysis parameters. The investigators reported a 10.5% increase in the augmentation index for every one-unit increase of the oxidative stress score (19). Oxidative stress scores were based on urine concentration of 8-isoprotane assays, which might be related to artherogenesis (19). The last investigation on firefighter arterial stiffness looked at aspirin's effects on changes in peripheral arteries. The main finding of their study showed that low dose aspirin ingested prior to physical exertion or firefighting tasks improved augmentation index (at 75 $b \cdot min^{-1}$)(19). Although firefighting and policing are different, both populations are civil servants that must react to alarms and situations within seconds. It could be concluded that LEOs would likely experience similar vascular and pressure changes during job task duties.

One military study looked at the effects of a long-term military mission on arterial stiffness, inflammatory markers, and vitamin D levels. Salum et al. recruited 65 well-trained Estonian soldiers, who were deployed for 6 months to Afghanistan. Following deployment, there were no significant changes in aortic PWV, but significant increases occurred in inflammatory markers (59). Increased inflammatory markers have been related to elevated PWV values, which lead to the authors hypothesis of soldiers having elevated PWV values (79). The presence of elevated inflammatory markers caused the authors to postulate that the effects of long-term strenuous physical workload and high levels of vitamin D augmented the anticipated change in arterial stiffness (59). The soldiers also demonstrated high levels of cardiorespiratory fitness with a mean VO_{2max} 53.8 ± 6.1 $ml \cdot kg^{-1} \cdot min^{-1}$, which could have also attenuated arterial stiffness adaptations (59). Police officers' cardiorespiratory fitness level expectations are very low compared to this value. The Lexington, KY police department asks for officers to perform a 1.5-mile run under 17 minutes and 56 seconds to be adequate for service. Using performance time prediction equations that would be equivalent to a $VO_{2\,max}$ of 33 $ml \cdot kg^{-1} \cdot min^{-1}$. That time is also seen as either poor or very poor for men, depending on age, based on the Cooper Institute's 1.5-mile run/walk Age and Gender Based Standards for Law Enforcement. The lower expectations of cardiorespiratory fitness may suggest that LEOs are at an increased risk of greater arterial stiffness.

Conclusion

Law enforcement officers suffer from elevated rates of adverse health outcomes, including obesity, psychological stress, depression, diabetes, and heart disease. Cardiovascular disease might be the most predominant adverse health outcome when viewing active duty and retired LEOs, because of the increased rates of traditional risk factors including hypertension, obesity, sedentary work, and diabetes. Along with shift work stresses and high levels of psychological stress, LEOs' bodies create a perfect petri dish for a cardiovascular event. Traditional risk factors give a sense of who may be at risk, however more objective measures could provide pivotal information in cardiovascular disease risk. The use of cfPWV to assess arterial stiffness could provide that objective information.

CHAPTER III: METHODS

Experimental Design

This study utilized a cross sectional design to compare arterial stiffness in LEOs versus the general population and to identify predictors of arterial stiffness in a cohort of professional LEOs. Regarding the comparison of arterial stiffness in LEOs versus the general population, the subjects' occupation served as the independent variable and cfPWV served as the dependent variable. Regarding the prediction of arterial stiffness, age, body composition, shift outcomes, perceived stress, physical activity outcomes, chronotyping, and sleep outcomes served as the independent variables and cfPWV served as the dependent variable.

Subjects

A convenience sample of 70 professional LEOs participated in this study. To qualify for the study, subjects had to be male professional LEOs between 21 and 55 years of age. Subjects were free of CVD according to the American College of Sports Medicine Guidelines (45). Subjects provided written informed consent prior to participation in the study. Also, the subjects were informed that participation in the study would not affect their employment status or union membership, and that they were free to withdraw from the study at any time. The study was approved by the University's Institutional Review Board (IRB) prior to subject recruitment and data collection.

Procedures

Subjects participated in one testing session lasting approximately 2.5 hours, located in the University's Exercise Physiology Laboratory or an alternative IRB approved location (i.e., police department, station, or training facility). Subjects abstained from consuming caffeine and food for at least three hours before testing.

Questionnaires

After written consent was provided, the subjects completed a physical activity readiness questionnaire (PAR-Q), a general health history questionnaire, and a work/personal history questionnaire (i.e., identification of age, race/ethnicity, rank, job duties, years in military, living arrangement, amount of time spent on certain shifts, and physical activity questions). Any sign, symptom, or diagnosis of cardiovascular, pulmonary, or metabolic disease listed on the health history questionnaire excluded the subject from participation in the study. To determine Chronotype - sleep/wake time preferences subjects completed the Horne-Ostberg Morningness-Eveningness Questionnaire which has an internal consistency of ICC = 0.83 (23). To assess occupational stress levels, subjects also completed the Operational Police Stress Questionnaire (PSQ-Op; ICC = 0.92) and the Organizational Police Stress Questionnaire (PSQ-Org; ICC = 0.92) (38). The PSQ-Op and PSQ-Org specifically assess the perceived stressors related to policing using a 7-point Likert-type scale. The PSQ questionnaires use the descriptive anchors of 1 (no stress at all) to 7 (a lot of stress).

Anthropometrics

Subjects were asked to wear athletic clothing for anthropometric assessments including a t-shirt and athletic shorts. Height was measured, without shoes (to the nearest 0.1 cm) using a portable stadiometer (HM200P, Charder Medical, Taichung City, Taiwan). Body mass was measured (to the nearest 0.1 kg) using an electronic scale (Health O Meter, Newell Brands, Hoboken, New Jersey). Circumference measurements were taken (to the nearest 0.1 cm) at the waist, abdomen, and hip according to American College of Sports Medicine guidelines (45). Specifically, circumference measurements were performed at the end of a normal exhalation and taken in rotational order. Each circumference was repeated until 2 trials were within 1 cm. The waist circumference measurement was located at the narrowest part of the torso below the rib cage. The abdomen circumference was taken at the level of the umbilicus. The hip circumference was taken while standing with the feet together at the greatest protuberance of the gluteus maximus. Measurements were taken against the skin, except for the hip measurement, which was performed over athletic shorts.

Body Composition

Subjects' body composition was measured with a dual-frequency bioelectric impedance analyzer (BIA; Bodystat 1500; Bodystat Ltd., Isle of Man, UK). Subjects assumed a supine position on a non-conductive surface with the limbs slightly abducted from the body and hands placed in a pronated position. Surface sensor electrodes were placed on the subject's right side. One electrode was placed on the posterior aspect of the wrist, bisecting the radial and ulnar head. A second electrode was placed on the anterior side of the ankle bisecting the lateral and medial malleoli. A third electrode was placed at the base of metacarpal joint and a fourth electrode at the base of the phalangeal joint. A series of standardized low-level electrical currents (5 and 50 kHz) were released, and the voltage drop due to the impedance was detected across the sensor. The manufacturer's proprietary prediction equation was used to estimate the subjects' body composition. The prediction equation estimates percent fat and has been validated against Dual-energy X-ray absorptiometry (r = 0.88; (64)).

Dietary Quality

Each subject completed a web-based National Institute of Health Diet History Questionnaire, focused on recall of food frequency patterns over the previous year. Assessment of dietary quality was in relation to the United States Dietary Guidelines, and is expressed in a 12-component composite Healthy Eating Index (HEI) score (Range: 0-100). Higher HEI scores represent superior dietary quality. Nutritional analyses were performed with a computer program (Diet*Calc Analysis Program, National Cancer Institute, Silver Spring, MD), while the HEI component and composite scores were calculated on SAS 9.4 (SAS Institute, Cary, NC). Twelve subjects were excluded from the dietary analysis due to failure to fully complete the questionnaire.

Physical Activity Monitoring

Daily physical activity outcomes were evaluated while on- and off-duty over one week with the use of a research grade triaxial accelerometer (GT3X, ActiGraph Inc., Pensacola, FL). The accelerometer was worn on the waistband on the subjects' right side at the midaxillary line during waking hours to provide physical activity data via step and activity counts. The activity count data were utilized to quantify volume, intensity, frequency, and duration of subjects' physical activity. Freedson and coworkers' (18) physical activity intensity (i.e., activity count) thresholds were applied to quantify time spent in sedentary, light, moderate, and vigorous intensity categories. The ActiGraph GT3X has been validated to quantify step counts and physical activity time, while also demonstrating inter-device reliability (r = 0.90-0.99) (1, 60). All data were downloaded to a personal computer, and evaluated using the manufacturer's software (ActiLife Version 6, ActiGraph, Pensacola, FL). Additionally, subjects were asked to keep a written physical activity log to confirm the duration of these activities and provide a qualitative context.

Accelerometer data were sampled at 30 Hz and collapsed into 10-second epochs. Wear and non-wear time data were identified through ActiLife's proprietary procedure via the Troiano algorithm (2). Thirteen subjects were excluded from the physical activity analysis for not wearing the accelerometer for a minimum of 10 hours on at least 4 days. Thus, 57 subjects' data were utilized for physical activity analyses with an average wear time of 7.1± 1.4 days.

Pulse Wave Analysis Measurements

Carotid-femoral pulse wave velocity (cfPWV) is the criterion measurement of arterial stiffness and was assessed via transcutaneous tonometry of the carotid and femoral arteries with simultaneous ECG recording utilizing the SphygmoCor System (AtCor, Sydney, Australia) (74). This measurement has been shown to be reliable within a tactical population (r = 0.88) (67). The test-retest reliability of this measure in this sample was r = 0.84 (n=70). The subjects assumed a supine position with each measurement performed on the right side of the body. Three electrodes were placed on the chest to measure heart rhythm. Body hair was shaved prior to electrode placement and alcohol wipes were used to clean and remove excess oils from the skin. The subject rested in the supine position for 10-15 minutes prior to the measurement. The carotid and femoral measurement sites were palpated to find the strongest pulse, and identified with a washable marker. The linear distance from the carotid site, to the sternal notch, to the navel, and then to the femoral site were measured with an inelastic tape measure and input into the SphygmoCor software. Tonometry measurements were conducted with the SphygmoCor System at the carotid and femoral artery sites.

Pulse wave analysis measurements were performed with transcutaneous tonometry at the radial artery, using the SphygmoCor System following manufacturer's guidelines. Central aortic pulse pressures were estimated through the use of validated transfer functions (29). Pressure waveform measurements were only accepted if the operator index was greater than 80%, per manufacturer recommendations. Specifically, the operator index is a proprietary score in the SphymoCor System used to measure the reproducibility and strength of the radial pulse signal. In addition, heart rate variability was assessed during a five-minute sampling period using measures of Root Mean Square of Successive Differences (RMSSD) and standard deviation of normal to normal (SDNN) R-R intervals.

Statistical Analysis

Basic statistics (i.e., mean ± standard deviation) were used to describe demographic and outcome variables. One sample T-tests were performed to determine if differences existed in pulse wave velocity values between LEOs and age-matched counterparts from the general population. Pearson Product Moment Correlations were used to assess relationships between independent variables and the dependent variables of central pressures and cfPWV. Furthermore, a one-way ANOVA was used to assess the main effect of age classification on cfPWV. Tukey HSD post-hoc analysis was used when main effects were identified. The normality of cfPWV outcomes within age strata was assessed using the Shapiro-Wilks test. Multivariate linear regression was utilized to identify significant predictors of cfPWV values within LEOs. Backward-stepwise regression analyses were performed on hypothesized variables (age, body fat, time on third shift, stress questionnaire scores, and time spent in moderate-to-vigorous physical activity) to provide the strongest predictor of cfPWV. Stepwise regression analyses were utilized to determine the predictability of cfPWV from all lifestyle, demographic and occupational variables collected. For the regression analyses, the predicted values were plotted against the residual values. None of the described regression models produced visual patterns when predicted values were plotted against the residual values, indicating linear regression was an appropriate model for interpretation. Multicollinearity was controlled utilizing a variance inflation factor limit of ten. All analyses were performed using JMP® (Version 11. SAS Institute Inc., Cary, NC) statistical software. The level of significance for all statistical analyses were set at $p < .05$.

CHAPTER IV: RESULTS AND DISCUSSION

Results

A total of 70 male LEOs from seven police departments participated in this investigation. Descriptive characteristics of the study's sample are displayed in Table 4-1. The subjects' mean BMI was classified as overweight and borderline obese according to a mean BMI of 29.4 ± 4.5 $kg \cdot m^{-2}$. Furthermore, the subjects' mean relative body fat (i.e., 22.8 ± 5.6%) falls between the 20^{th} and 30^{th} percentile relative to age and gender (45). The subjects' mean HEI score (60.3 ± 12.6) was between the 75^{th} and 90^{th} percentile relative to the general population (45). The subjects' mean daily moderate-to-vigorous physical activity was 7.4 ± 11.0 $min \cdot d^{-1}$). The subjects' Chronotypes classifications included the following distribution: 57.1% (n=40) were classified as neither type, 22.9% (n=16) were classified as moderate morning type, 4.3% (n=3) were classified as definite morning type, and 15.7% (n=11) were classified as moderate evening type. Descriptive outcomes of resting cardiovascular measurements are presented in Table 4-2. Table 4-3 displays a comparison of mean PWV by age strata, between 70 male LEOs and normative values from the European Society of Cardiology. One sample T-tests revealed that LEOs under 30 years of age had significantly lower average PWV than the normative value ($p = 0.0018$). LEOs in the 4^{th} and 5^{th} decades of life demonstrated no significant differences compared to the normative values. However, the 50-55 yr. group had a significantly higher average PWV than the normative value ($p = 0.0003$).

Table 4-1. Descriptive characteristics of 70 male law enforcement officers.

Variable	Mean	±	SD
Age (yr)	37.1	±	7.7
LEO experience (yr)	11.0	±	7.6
Height (cm)	179.2	±	6.8
Body mass (kg)	94.5	±	16.4
BMI ($kg \cdot m^{-2}$)	29.4	±	4.5
Waist circumference (cm)	94.3	±	11.1
Abdominal circumference (cm)	97.9	±	12.2
Hip circumference (cm)	104.9	±	8.0
Fat mass (kg)	22.2	±	9.3
Relative body fat (%)	22.8	±	5.6
Fat-free mass (kg)	72.3	±	8.5
Fat-free mass (%)	77.2	±	5.6
Months on first shift	45.5	±	55.8
Months on second shift	47.1	±	43.2
Months on third shift	35.5	±	42.0
PSQ-Op	61.9	±	18.4
PSQ-Org	57.8	±	18.0
PSQ-total	119.7	±	33.7
HEI (n = 58)	60.3	±	12.6
Steps per day (n = 57)	6977	±	2181
MVPA per day (min) (n = 57)	7.4	±	11.0

LEO: Law enforcement officer; BMI: Body mass index; PSQ-Op: operational police stress questionnaire score; PSQ-Org: organizational police stress questionnaire score; PSQ-total: combined score of operational and organizational police stress questionnaires; HEI: Healthy Eating Index Score; MVPA: moderate-to-vigorous physical activity.

Table 4-2. Resting cardiovascular measurements of 70 male law enforcement officers (Mean ± SD).

cfPWV ($m \cdot s^{-1}$)	6.72	±	1.36
Systolic blood pressure (mmHg)	129.77	±	11.15
Diastolic blood pressure (mmHg)	83.84	±	8.00
Pulse pressure (mmHg)	45.93	±	9.00
Aortic systolic pressure (mmHg)	114.54	±	10.21
Aortic diastolic pressure (mmHg)	84.63	±	7.91
Aortic pulse pressure (mmHg)	29.91	±	6.43
Aortic AIx	8.66	±	12.78
Aortic AIx75	0.93	±	12.87
RMSSD	49.62	±	33.02
SDNN	60.60	±	25.43

cfPWV: carotid-femoral pulse wave velocity; Aortic AIx: aortic augmentation index; Aortic AIx75: aortic augmentation index at heart rate 75 beats per minute; RMSSD: root mean squared of successive differences of neighboring R-R intervals; SDNN: Standard deviation of normal to normal R-R intervals.

Table 4-3. Comparison of average pulse wave velocity in the general population versus the 70 male law enforcement officers (LEOs) by age strata.

Age (yr)	PWV* ($m \cdot s^{-1}$) Male LEOs (n=70)				PWV* ($m \cdot s^{-1}$) General population† (n=1455)			Mean Difference ($m \cdot s^{-1}$)	Rel. Diff. (%)	p-value
<30	[a]5.6	±	0.74	(n = 15)	6.2	±	0.75	-0.6	-10.2	0.002
30-39	6.6	±	1.13	(n = 28)	6.5	±	1.35	0.1	1.5	0.644
40-49	7	±	1.13	(n = 22)	7.2	±	1.30	-0.2	-2.8	0.411
50-55	[a]9.4	±	0.67	(n = 5)	8.3	±	1.90	1.1	12.4	< 0.001

*Values represent mean ± standard deviation. †Normative values adapted from Reference Values for Arterial Stiffness' Collaboration, 2010 (57). Significance set at $p < 0.05$. [a]Significant difference between LEOs and normative values for age strata. PWV: pulse wave velocity; Rel. Diff.: Relative difference between groups calculated as: ((LEO value – General population value) / LEO value) X 100.

Table 4-4 displays comparisons of descriptive and cardiovascular measures by decade of life in 70 male law enforcement officers. Significant main effects across age strata were noted in age ($F (3, 66) = 175.30$, $p < 0.0001$), LEO experience ($F (3, 66) = 34.01$, $p < 0.0001$), relative body fat ($F (3, 66) = 3.29$, $p = 0.0260$), aortic augmentation index ($F (3, 66) = 9.28$, $p < 0.0001$), aortic augmentation index at heart rate 75 $b \cdot min^{-1}$ ($F (3, 66) = 10.11$, $p < 0.0001$), and cfPWV ($F (3,66) = 17.86$, $p < 0.001$) such that greater values were noted with increased age. Post-hoc analyses revealed that LEOs under the age of 30 years had significantly fewer years of experience, and significantly lower relative body fat than the 50-55 yr group ($p = 0.0206$). Post-hoc analysis also revealed that LEOs under the age of 30 yr had significantly lower cfPWV compared to the 30-39 yr group ($p = 0.029$), the 40-49 yr group ($p < 0.001$), and the 50-55 yr group ($p < 0.001$). The LEOs in the 6^{th} decade of life had the highest mean cfPWV ($9.4\ m \cdot s^{-1}$), and were significantly higher than all other groups ($p < 0.0001$). There was no effect of age on systolic or diastolic blood pressure across age strata.

Table 4-4. Comparison of descriptive and cardiovascular measures by age strata in 70 male law enforcement officers (Mean ± SD).

	< 30 yr (n=15)			30-39 yr (n=28)			40-49 yr (n=22)			50-55 yr (n=5)		
Age (yr) (a,b,c,d,e,f)	27.27	±	1.33	34.57	±	3.19	43.91	±	2.67	51.40	±	1.67
LEO experience (yr) (a,b,c,d,e,f)	3.97	±	1.23	8.14	±	4.78	16.77	±	5.61	23.20	±	8.41
BMI ($kg \cdot m^{-2}$)	29.57	±	4.59	28.79	±	4.33	29.43	±	4.50	32.16	±	5.19
Relative body fat (%) (c)	20.71	±	6.07	22.15	±	5.11	23.65	±	4.54	28.86	±	7.03
Waist circumference (cm)	92.46	±	11.29	93.41	±	11.16	94.36	±	10.09	104.98	±	11.73
Systolic blood pressure (mmHg)	130.07	±	11.61	128.64	±	12.22	129.95	±	9.82	134.40	±	10.95
Diastolic blood pressure (mmHg)	81.73	±	7.11	83.89	±	8.83	83.91	±	7.19	89.60	±	8.41
AIx (b,c,d)	0.96	±	11.90	4.54	±	10.72	17.30	±	11.03	16.87	±	8.47
AIx75 (b,c,d)	-8.24	±	11.91	-2.47	±	10.04	9.69	±	11.82	9.00	±	7.05
Aortic systolic pressure (mmHg)	111.89	±	8.11	112.43	±	11.52	117.23	±	9.16	122.47	±	7.56
Aortic diastolic pressure (mmHg)	82.36	±	6.78	84.50	±	9.04	84.91	±	6.50	91.00	±	8.61
RMSSD (n: 12,28,20,5)	68.74	±	33.93	49.69	±	35.04	42.50	±	29.45	31.82	±	11.14
SDNN (n: 12,28,20,5)	72.51	±	27.44	60.99	±	23.07	56.12	±	28.56	47.80	±	8.82
cfPWV ($m \cdot s^{-1}$) (a,b,c,e,f)	5.60	±	0.74	6.60	±	1.13	7.00	±	1.13	9.40	±	0.67

Significance set at $p < 0.05$. LEO: Law Enforcement Officer; BMI: Body Mass Index; AIx: aortic augmentation index; AIx75: aortic augmentation index at heart rate 75 beats per minute; RMSSD: root mean squared of successive differences; SDNN: standard deviation of normal-to-normal R-R intervals; cfPWV: carotid-femoral pulse wave velocity. a = significant difference between the < 30 yr group and the 30-39 yr group;, b = significant difference between the < 30 yr group and the 40-49 yr group; c = significant difference between the < 30 yr group and the 50-5 yr group; d = significant difference between the 30-39 yr group and the 40-49 yr group; e = significant difference between the 30-39 yr group and the 50-55 yr group; f = significant difference between the 40-49 yr group and the 50-55 yr group.

Bivariate correlations between arterial stiffness versus demographic, anthropometric, lifestyle, and occupational variables are presented in Table 4-5. There was a significant positive correlation between age and cfPWV ($r = 0.57$, $p < 0.0001$). This relationship suggests that as age increases cfPWV also increases. There were significant positive correlations between cfPWV versus years served in law enforcement ($r = 0.60$, $p < 0.0001$) and relative body fat ($r = 0.60$, $p < 0.0001$). These findings indicate that arterial stiffness increases with an increase of years served in law enforcement and increased body fat percentage. A significant positive correlation was also identified between the two predictor variables of years served in law enforcement and relative body fat ($r = 0.34$, $p = 0.0035$). These findings suggest that there is an increase in percent body fat with an increase in years of service in law enforcement. Other significant positive relationships were also identified between cfPWV versus all other variables except the three police stress questionnaire variables (PSQ-op, PSQ-org, and PSQ-total).

Table 4-5. Bivariate correlation matrix of carotid-femoral pulse wave velocity verses demographic, occupational, anthropometric, and cardiovascular outcomes in 70 law enforcement officers.

	Age	LEO yrs.	Yrs. 1st Shift	Yrs. 2nd Shift	Yrs. 3rd Shift	PSQ-org	PSQ-op	PSQ-total	BMI	% BF	WC	SBP	DBP	Aortic SBP	Aortic DBP	AIx 75	RMSSD	HEI Total	Steps	MVPA
LEO yrs.	0.79*																			
Yrs. 1st Shift	0.59*	0.68*																		
Yrs. 2nd Shift	0.48*	0.52*	0.12																	
Yrs. 3rd Shift	0.27	0.52*	0.12	-0.11																
PSQ-org	0.19	0.23	0.14	0.12	0.20															
PSQ-op	0.01	-0.01	0.01	-0.08	0.09	0.71*														
PSQ-total	0.11	0.11	0.08	0.02	0.15	0.92*	0.93*													
BMI	0.10	0.19	0.18	0.15	0.10	0.07	0.06	0.07												
% BF	0.30*	0.34*	0.33*	0.19	0.15	0.09	0.06	0.08	0.86*											
WC	0.19	0.31*	0.22	0.20	0.18	0.07	0.07	0.08	0.91*	0.90*										
SBP	0.01	0.23*	0.21*	0.13	0.13	0.26	0.06	0.17	0.55*	0.46*	0.51*									
DBP	0.16	0.43*	0.19*	0.32*	0.25*	-0.02	-0.07	-0.05	0.6*	0.48*	0.64*	0.60*								
Aortic SBP	0.23*	0.47*	0.41*	0.27	0.22	0.19	-0.02	0.09	0.67*	0.61*	0.64*	0.88*	0.76*							
Aortic DBP	0.20*	0.47*	0.23*	0.33*	0.26*	0.02	-0.08	-0.03	0.61*	0.51*	0.66*	0.62*	0.98*	0.78*						
AIx 75	0.54*	0.53*	0.40*	0.35*	0.24	0.02	-0.15	-0.07	0.34*	0.44*	0.32*	0.08	0.32*	0.47*	0.33*					
RMSSD	-0.39*	-0.18	-0.09	-0.15	-0.08	-0.02	0.15	0.07	0.10	0.06	0.06	0.22	0.07	0.16	0.06	-0.14				
HEI Total (n=58)	0.05	0.08	0.01	0.06	0.17	-0.07	-0.11	-0.10	-0.06	-0.21	-0.16	0.01	-0.08	0.00	-0.08	-0.06	-0.13			
Steps (n=57)	0.21	0.20	0.16	-0.01	0.24	-0.05	-0.09	-0.07	-0.27	-0.20	-0.24	-0.22	-0.16	-0.20	-0.10	0.04	-0.19	0.41		
MVPA (n=57)	0.07	0.06	0.01	-0.11	0.08	-0.09	-0.04	-0.07	-0.19	-0.23	-0.25	-0.06	0.00	-0.10	-0.02	-0.10	-0.17	0.26	0.73*	
cfPWV	0.57*	0.60*	0.43*	0.32*	0.31*	0.10	-0.02	0.04	0.43*	0.60*	0.53*	0.36*	0.46*	0.54*	0.49*	0.50*	0.54*	-0.11	-0.12	-0.11

*Indicates significant correlation ($p < .05$).

LEO yrs.: years served as Law Enforcement Officer, PSQ-org : Organizational Police Stress Questionnaire score, PSQ-op: Operational Police Stress Questionnaire Score, PSQ-total: Combined score of PSQ-org and PSQ-op, BMI: Body Mass Index, % BF: Relative body fat (%), WC: waist circumference, SBP: brachial systolic blood pressure, DBP: Brachial Diastolic Blood Pressure, Aortic SBP: Aortic Systolic Blood Pressure, Aortic DBP: Aortic Diastolic Blood Pressure, AIx75: aortic augmentation index at heart rate 75 beats per minute, RMSSD: root mean squared of successive differences, HEI Total: Healthy Eating Index Score, Steps: Average steps per day, MVPA: moderate-to-vigorous physical activity, cfPWV: carotid-femoral pulse wave velocity ($m \cdot s^{-1}$).

Bivariate correlations demonstrated that two of the strongest correlates of cfPWV were relative body fat and age (Table 4-5). Relative body fat and age were also correlated with each other. Thus, to describe the independent effects of relative body fat on cfPWV, a one-way ANCOVA was performed, with age serving as the covariate. Relative body fat was stratified into three groups (i.e., obese, overweight, & normal weight), according to normative data standards from the ACSM (4). There was a main effect for body fat classification on cfPWV. Post-hoc analyses revealed that the obese group had a greater cfPWV than the normal body weight group for relative body fat ($F(3,66) = 22.56$, $p < 0.001$; mean difference = 1.46 $m \cdot s^{-1}$). Furthermore, the obese group had a greater cfPWV than the overweight group ($F(3,66) = 22.56$, $p = 0.001$; mean difference = 0.45 $m \cdot s^{-1}$). Likewise, to describe the independent effects of body mass index on cfPWV, a one-way ANCOVA was performed, with age serving as the covariate. There was a main effect for BMI. Post-hoc analyses revealed that the obese group had greater cfPWV than the normal BMI group for BMI ($F(3,66) = 16.38$, $p < 0.001$; mean difference = 1.16 $m \cdot s^{-1}$).

Table 4-6. Comparison of cfPWV according to body composition category in 70 male law enforcement officers.

Relative Body Fat (%)	n	cfPWV ($m \cdot s^{-1}$)*	Age*
Obese (> 25) (a,b)	21	7.81 ± 1.40	39.90 ± 7.75
Overweight (21-25) (b)	25	6.54 ± 1.13	36.76 ± 7.93
Normal (<21) (a)	24	5.96 ± 0.91	35.13 ± 7.10
Body Mass Index ($kg \cdot m^2$)	**n**	**cfPWV ($m \cdot s^{-1}$)***	**Age***
Obese (≥30) (a)	27	7.23 ± 1.66	36.96 ± 8.96
Overweight (25-29.9)	35	6.54 ± 1.04	37.91 ± 6.74
Normal (≤24.9) (a)	8	5.82 ± 0.85	34.38 ± 7.69

cfPWV: carotid-femoral pulse wave velocity; * mean ± standard deviation. Significance set at $p < 0.05$. a = a significant difference in cfPWV between obese and normal weight groups for respective assessment of body composition; b: a significant difference in cfPWV between obese and overweight groups for respective assessment of body composition. There was no significant difference in age for any group (Percent body fat: $p = 0.11$, Body mass index: $p = 0.51$).

Table 4-7 displays the five strongest multiple linear regression models without interaction effects used to predict cfPWV in male LEOs, with the hypothesized occupational and lifestyle factors of age, percent body fat, years of employment on third shift, combined score of the police stress questionnaires, and time spent in moderate-to-vigorous activity per day. As model A demonstrates, age and relative body fat explain 51% of the variance in cfPWV, and these are the two primary variables for all regression models. Absolute fat-mass, and BMI were run in these models, but relative fat explained greater variance, and therefore it was utilized in the models. The addition of other variables only slightly increased the explained variance for models B, C, and D. Model E shows that the addition of daily moderate-to-vigorous physical activity diminished the variance explained by the regression model.

Table 4-7. Backwards multiple linear regression models predicting aortic stiffness (cfPWV) with hypothesized occupational and lifestyle factors in 70 male law enforcement officers.

	A	B	C	D	E
Constant	1.2928*	1.4117*	1.4814*	1.6775*	2.0947*
	(0.646)	(0.643)	(-0.730)	(0.730)	(0.892)
Age	0.0754**	0.0695**	0.0762**	0.0702**	0.0748**
	(0.016)	(0.016)	(0.016)	(0.016)	(0.018)
%BF	0.1153**	0.1129**	0.116**	0.1136**	0.1061**
	(0.022)	(0.021)	(0.022)	(0.022)	(0.025)
Time on 3rd Shift (months)		0.0044		0.0047	0.0034
		(0.003)		(0.003)	(0.004)
PSQ-total			-0.0019	-0.0027	-0.0047
			(0.003)	(0.003)	(0.004)
MVPA per day (minutes)					-0.0017
					(0.003)
R-squared	0.526	0.543	0.528	0.548	0.506
Adjusted R-squared	0.512	0.523	0.507	0.520	0.458
No. Observations	70	70	70	70	57

*p < 0.05, **p < 0.001; significance of model coefficients, (standard error); %BF: relative body fat; PSQ-total: Combined score of PSQ-org and PSQ-op; MVPA per day: moderate to vigorous physical activity per day in minutes; No. Observations: number of observations.

Table 4-8 displays five stepwise linear regression models using all collected variables and two-way interaction variables to predict cfPWV in male LEOs. The addition of brachial diastolic blood pressure provided an increase of explained variance in models A and B. Model C reflects a significant interaction effect of age and perceived stress score on cfPWV. The interaction displays that as age’s effect of cfPWV is dependent on the amount of perceived stress an officer has. There is a significant interaction effect between age and percent body fat in model C. This interaction suggests that increased relative body fat later in life is associated with greater increases cfPWV. Model D demonstrates a significant interaction between moderate-to-vigorous activity and time spent on third shift, despite not predicting cfPWV independently. The interaction shows that the effect of time on third shift on cfPWV is dependent on the daily time spent in moderate-to-vigorous activity. Model E demonstrates the predictive power of using years in law enforcement compared to the hypothesized age variable in Table 4-9. There is slightly more explained variance using the years in law enforcement variable compared to the age variable.

Table 4-8. Stepwise multiple linear regression models with interactions predicting aortic stiffness (cfPWV) with occupational and lifestyle factors in male law enforcement officers.

	A	B	C	D	E
Constant	-1.1834 (1.239)	-1.0693 (1.224)	1.3894 (0.708)	1.9230* (0.782)	3.3546* (0.477)
Age	0.0749** (0.015)	0.0731** (0.015)	0.0754** (0.015)	0.0736** (0.018)	
%BF	0.0905** (0.024)	0.0891** (0.023)	0.1201** (0.021)	0.0930** (0.026)	0.1088** (0.022)
PSQ-total			-0.0021 (0.003)		
MVPA				-0.0036 (0.003)	
DBP	0.0365* (0.016)	0.0357* (0.016)			
Time on 3rd shift				0.0042 (0.004)	
Age*PSQ-total			-0.0010* (0.000)		
Age*%BF		0.0042 (0.002)	0.0061* (0.003)		
Time on 3rd shift*MVPA				0.0002* (< 0.001)	
Yrs. LEO					0.0804** (0.016)
R-squared	0.562	0.581	0.585	0.537	0.539
Adjusted R-squared	0.542	0.555	0.553	0.492	0.525
No. Observations	70	70	70	57	70

*p < 0.05, ** p < 0.001; significance of model coefficients (standard error); %BF: percent body fat; PSQ-total: combined score of PSQ-org and PSQ-op; MVPA: daily moderate-to-vigorous physical activity (min); DBP: brachial diastolic blood pressure; Yrs. LEO: years in law enforcement.

Bivariate correlations demonstrated a significant relationship between cfPWV and brachial blood pressures (Table 4-5), so LEOs were stratified into normotensive (brachial blood pressure $\leq$ 140/90 mmHg) and hypertensive (brachial blood pressure >140/90 mmHg) groups based on previous American Heart Association guidelines. The normotensive group demonstrated significantly lower cfPWV than the hypertensive group after controlling for the effect of age ($F(2,67) = 36.71$, $p < 0.001$; mean difference = 1.44 $m \cdot s^{-1}$). Table 4-9 provides a comparison of descriptive and cardiovascular characteristics in normotensive versus hypertensive LEOs.

Table 4-9. Comparison of descriptive and cardiovascular characteristic in normotensive versus hypertensive law enforcement officers (Means ± SD).

	Normotensive (n=50)	Hypertensive (n=20)	p-value
Age (yr)	36.8 ± 7.4	37.9 ± 8.7	0.635
Yrs. LEO (yr)	9.9 ± 6.9	14.0 ± 8.8	0.071
% BF*	21.2 ± 4.7	26.9 ± 5.6	<0.001
SBP (mmHg)*	124.8 ± 7.1	142.3 ± 9.5	<0.001
DBP (mmHg)*	80.4 ± 4.6	92.4 ± 8.5	<0.001
cSBP (mmHg)*	110.2 ± 7.3	125.4 ± 8.2	<0.001
cDBP (mmHg)*	81.2 ± 0.8	93.3 ± 1.3	<0.001
cfPWV ($m \cdot s^{-1}$)*	6.31 ± 1.1	7.75 ± 1.4	<0.001
Aortic AIx75	-0.03 ± 12.8	3.4 ± 13.0	0.330

*Significance set at $p < 0.05$; Yrs. LEO: years served as Law Enforcement Officer; % BF: relative body fat; SBP: brachial systolic blood pressure; DBP: diastolic blood pressure; cSBP: central systolic blood pressure; cDBP: central diastolic blood pressure; cfPWV: carotid-femoral Pulse Wave Velocity; Aortic AIx75: aortic augmentation index at a heart rate of 75 beats per minute.

Bivariate correlations demonstrated a significant relationship between cfPWV and brachial blood pressures (Table 4-5), so LEOs were stratified into normotensive (brachial blood pressure ≤ 130/80 mmHg) and hypertensive (brachial blood pressure >130/80 mmHg) groups based on the new American Heart Association guidelines (7). The normotensive group demonstrated significantly lower cfPWV than the hypertensive group ($F(1,68) = 9.32$, $p = 0.003$; mean difference = 1.0 $m \cdot s^{-1}$). Table 4-10 provides a comparison of descriptive and cardiovascular characteristics in normotensive versus hypertensive LEOs.

Table 4-10. Comparison of select outcomes in normotensive/elevated versus hypertensive law enforcement officers (Mean ± SD)

	Normotensive / Elevated (n=22)			Hypertension Stage 1 or Higher (n=48)			p-value
Age (yr)	36.6	±	7.4	37.4	±	8.0	0.689
Yrs. LEO* (yr)	7.1	±	5.6	12.8	±	7.8	0.003
% BF*	19.7	±	4.1	24.2	±	5.6	0.001
SBP (mmHg)*	120.6	±	4.7	134.0	±	10.7	<0.001
DBP (mmHg)*	76.8	±	3.1	87.1	±	7.5	<0.001
cSBP (mmHg)*	105.7	±	5.0	118.6	±	9.4	<0.001
cDBP (mmHg)*	78.0	±	2.7	87.7	±	7.6	<0.001
cfPWV ($m \cdot s^{-1}$)*	6.0	±	1.1	7.0	±	1.4	0.003
Aortic AIx75	-2.50	±	12.4	2.5	±	12.9	0.129

* Significance set at p<0.05; Yrs. LEO: years served as Law Enforcement Officer; % BF: percent body fat, SBP: brachial systolic blood pressure; DBP: diastolic blood pressure; cSBP: central systolic blood pressure; cDBP: central diastolic blood pressure; cfPWV: carotid-femoral Pulse Wave Velocity; Aortic AIx75: aortic augmentation index at heart rate 75 beats per minute.

Years of employment on third shift was dichotomized by stratifying the groups based on the median values (24 months = 2 yr.), which resulted in individual subsample sizes of n = 41 (≥2 yr.) and n =29 (< 2 yr.). There were no differences between the third shift groups' ages ($p = 0.22$) and relative body fat ($p = 0.58$). Likewise, there was no difference between third shift groups' cfPWV ($p = 0.11$), which suggests that increased age and relative body fat are likely responsible for the increased in cfPWV.

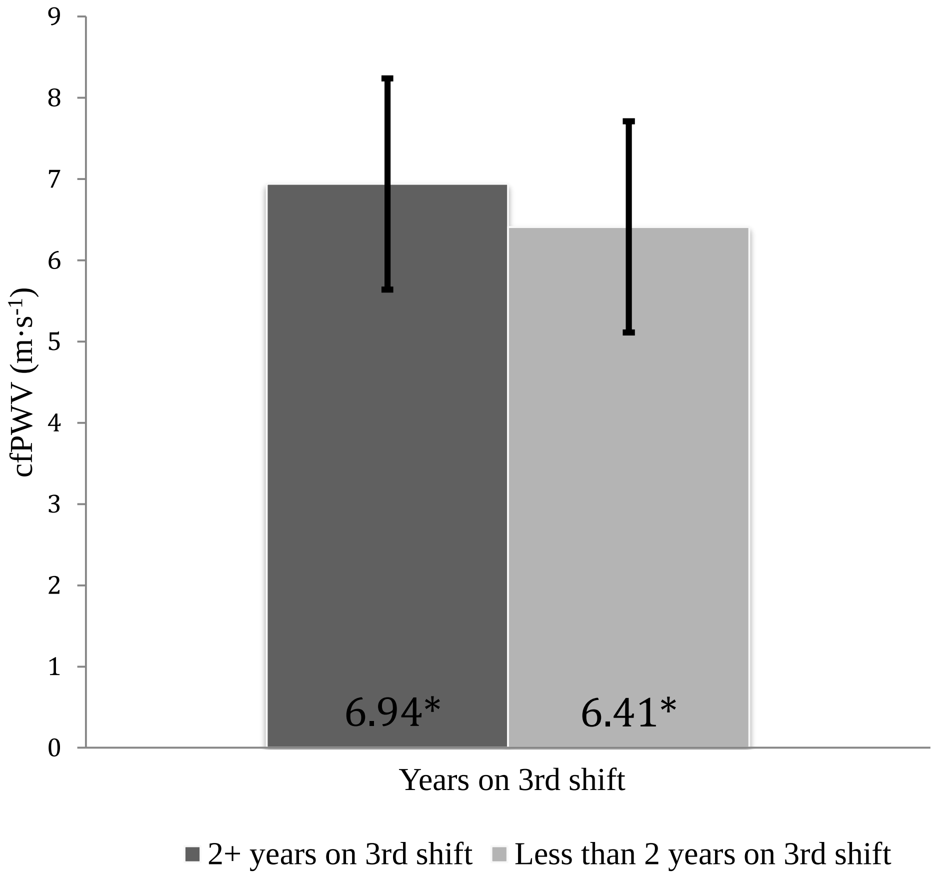

Figure 4-1: Comparison of cfPWV by years of employment on third shift in 70 male law enforcement officers. cfPWV: carotid-femoral pulse wave velocity; *mean; error bars represent ±1 standard deviation.

Discussion

The first purpose of this study was to compare the arterial stiffness of LEOs to the general population. We hypothesized that cfPWV would be greater in LEOs than age-matched counterparts from the general population. Interestingly, the <30 yr old cohort had a significantly lower cfPWV compared to the age-matched reference group. There was no difference in the cfPWV between LEOs and the general population within 30-39 and 40-49 yr old cohorts. However, the cfPWV of the ≥50 yr old LEO cohort in the present study was 1.1 $m \cdot s^{-1}$ greater than the age-matched reference group ($p < 0.001$; Table 4-3). Despite the cross-sectional nature of this descriptive comparison, this apparent rise in arterial stiffness over the life-span of LEOs is concerning, because of the increased risk of a cardiovascular event. Vlachopoulos et al. performed a meta-analysis that demonstrated that an increase of 1 $m \cdot s^{-1}$ in cfPWV corresponded to an increased risk of 14% for all cardiovascular events, 15% increased risk for cardiovascular mortality, and a 15% increased risk of all-cause mortality (74). Furthermore, it was reported that an increase of 1 standard deviation in cfPWV (i.e., cfPWV = 3.4 $m \cdot s^{-1}$) increased those risk outcomes to 47%, 47%, and 42%, respectively (74). In the Framingham Heart Study Mitchell et al. also demonstrated that higher PWV values were associated with increased cardiovascular disease risk (41).

The < 30 yr LEO cohort's lower cfPWV compared to the general population is intriguing and maybe, in part, attributed to "the healthy worker effect." The healthy worker effect occurs when unhealthy or potentially unhealthy workers are selectively omitted through demands imposed by occupational necessities. To become a LEO, recruits typically participate in several months of physical training (PT) in an academy to meet academy and/or department physical test requirements (80). Indirectly, these requirement increase the health of the LEO cohort compared to the general population. Wu et al. demonstrated improved fitness and body composition outcomes in cadets following a 20-week training period (78). Training academies may effectively reduce arterial stiffness, because resistance and endurance training in pre-hypertensive adults have been shown to reduce peripheral arterial stiffness, central blood pressures, and augmentation index (8). On the other hand, the significantly higher cfPWV in the ≥ 50 yr cohort begs the question of what is causing the acceleration in arterial stiffness beyond that of the general population over the 20-year career span.

In light of the apparent increase in arterial stiffness among LEOs over the career span, the second purpose of this investigation was to identify demographic, lifestyle, and occupational predictors of arterial stiffness. We hypothesized that cfPWV would be positively correlated with age, fat mass, time spent on 3rd shift, perceived stress, and inversely correlated with daily time spent in moderate–to-vigorous physical activity. Carotid-femoral pulse wave velocity was positively correlated with age, fat mass and time spent on third shift (Table 4-5). Interestingly, there were no correlations between Police Stress Questionnaire and physical activity outcomes versus cfPWV in this investigation (Table 4-5). Regression analysis demonstrated that age, relative body fat, diastolic blood pressure, years in law enforcement and some interactions of those variables (Tables 4-7 and 4-8) explained the most variance in cfPWV.

Aging has been established as a primary risk factor for CVD, and is highly associated with increased arterial stiffness (32, 68, 71, 74, 79). Several studies note a linear increase in cfPWV until the age of 60 yr (40, 41, 79). Following the age of 60 yr, there tends to be a rapid exponential increase in cfPWV (40, 41, 79). This increase is hypothesized to be due to the cyclical hemodynamic stresses that are placed on arterial structures, particularly elastin, which causes fracturing and improper remolding of the arterial matrix (12). This occurs independently of atherosclerotic plaque accumulation, however in some individuals' atherosclerotic plaque accumulation may also be contributing factor to increased cfPWV. This cross-sectional investigation concurs with previous findings indicating that greater cfPWV values are associated with older LEOs (Table 4-3 and Table 4-5). These results suggest that a function of time causes an unavoidable progression in arterial stiffening, however the degree to which this progression occurs could be modulated through other demographic, lifestyle, and occupational variables.

Given the extended period of time one spends in an occupation over a lifetime, factors associated with the occupation can have negative health consequences. The occupation of law enforcement has demonstrated a clear relationship of increasing the prevalence of traditional risk factors for negative health outcomes, like CVD, stroke, heart attack, post traumatic stress syndrome, amongst others (50, 51, 53, 55, 56, 80). Although it is impossible to completely measure and decompose all behavioral and environmental factors into quantitative variables, the positive correlation between cfPWV and years served as a LEO (Table 4-5 &Table 4-8, Model E) suggests that occupational factors associated with law enforcement may predispose officers to poorer health outcomes, especially the risk of CVD. The increased explained variance from Model E in Table 4-8 compared to Model A in table 4-7 might indicate that time spent serving in law enforcement is a better predictor of cfPWV than just age for this population. However since years served as a LEO, is a function of time, like age, it would be remiss not to report the correlation between the age and LEO yrs. ($r = 0.79$, $p < 0.0001$).

The lack of significant arterial stiffening in LEOs who participated in third shift for greater than two years was surprising, as previous studies has demonstrated how police shift work (on third shift or late night shift) has created an environment that may promote poor health habits (48-53, 55, 80). This investigation noted that there was a significant positive correlation with time spent on third shift and increased cfPWV. However no significant difference in cfPWV between LEOs working for more than 2 years on third shift versus LEOs working less than two years on third shift. However the group mean average cfPWV was up 0.53 $m \cdot s^{-1}$, which is a greater increase compared to Chen et al.'s cross-sectional study found an increase in pulse wave velocity of 0.036 $m \cdot s^{-1}$ per year of shift work bus driving (13). Although these populations seem drastically different, they have two major similarities in the fact that they both perform shift work for prolong periods of time and the both jobs are sedentary in nature (55, 56). Shift work investigations using cfPWV are lacking, but they may help provide a clearer picture of how occupational factors may influence cardiovascular health.

This investigation utilized multiple linear regressions and found that the years of experience on 3rd shift and daily physical activity did not independently predict cfPWV, however the interaction of the two variables significantly explained a portion of the variance (Table 4-8, Model D). The interaction demonstrated that cfPWV increases with time spent on third shift when accumulated time spent in MVPA is low, but the officers who spent more time in MVPA while being on third shift actually attenuated the increases of cfPWV. The nature and impact of this relationship needs to be more comprehensively evaluated through future research, but it alludes to the fact that MVPA may play a role in how other variables influence cfPWV values and ultimately health outcomes.

Following the time-based variables of age and years served in law enforcement, this investigation found that relative body fat was positively correlated to arterial stiffness (Tables 4-5, 4-7, 4-8). That is, as the relative adiposity of a LEO increases, cfPWV also increases. Excess body fat is a well-known accelerant of the arterial stiffening process (22, 58). This investigation agreed with previous research, and found that relative body fat ($r = 0.60$, $p<0.05$) and BMI ($r = 0.43$, $p<0.05$) were positively correlated with cfPWV. The stronger association of relative body fat compared to BMI, because BMI was not retained in the regression analyses (Tables 4-7 and 4-8), could be due to the miss interpretation of lean muscle as fat in the BMI equation. Since BMI is solely based on height and weight measures, BMI estimations cannot distinguish between fat and fat-free mass. This evidence supports Alasagheirin’s inquiry calling for a direct measure of fat mass in LEOs instead of BMI, because BMI’s misclassification can add or reduce the risk stratification of health outcomes for officers (3). This misclassification could hinder prevention timeframes, by delaying early interventions, and thus causing greater harm to an unsuspecting officer.

This investigation demonstrated a significant difference in average cfPWV values based on relative body fat classifications (Table 4-6). Specifically, the obese group (mean

= 7.81 m·s^{-1}) had an average cfPWV of nearly 2 m·s^{-1} higher than that of the normal weight group (mean = 5.96 m·s^{-1}), despite no difference in the LEO's age. Thus, a 2 m·s^{-1} greater cfPWV suggests that the obese LEOs have an increased risk of 28% for all cardiovascular events, 30% for cardiovascular mortality, and a 30% increase in all-cause mortality (74). Increases in arterial stiffness in obese/overweight populations has been attributed to a variety of different factors related to adipokine levels within the body (58, 71, 79). Adiponectin is produced by adipose tissue and possesses anti-inflammatory, antiproliferative, antiatherogenic, and insulin-sensitizing mechanisms (58). Adiponectin has the ability to provide the body with some protective effects, but low levels have been found in obese and hypertensive patients (58). With limited adiponectin, nitric oxide synthesis expression decreases, which decreases the protective effects of nitric oxide and thus decreases the vessel's ability to vasodilate. Low levels of adiponectin have been associated with increased arterial stiffness, however the extent of the exact mechanisms are still being investigated (58).

Another adipokine affected by obesity is leptin. Obese individuals have elevated leptin levels in the plasma, which are known to increase aldosterone, sodium retention volume expression, and increased blood pressure (58). High levels of leptin also contributes to production of vascular smooth muscle cell proliferation, endothelial oxidative stress, and reactive oxidative species formation (58). There has been an established positive correlation between leptin levels and arterial stiffness (58). Even though these adipokines may provide a mechanism for increased arterial stiffness, this study did not directly measure these biomarkers and can only speculate as to why there was a significant difference between the three body composition groups.

Hypertension has been established as a correlate of arterial stiffness. Previous research in LEOs, while utilizing the previous American Heart Association (AHA) standards, has demonstrated that the prevalence of hypertension ranges from 15-39%, (40, 80). The present study's sample was within this range utilizing the previous AHA standards, as 29% of the subjects were classified as hypertensive (7). However under the new AHA standards 71% of the subjects would be classified as hypertensive, which is more than double. Table 4-2 shows subjects' average systolic blood pressure (129.8 mmHg) would be classified as elevated and borderline stage-1 hypertension according to the new AHA standards. The sample's average diastolic pressure (83.8 mmHg), would also classify subjects as stage-1 hypertension, utilizing the new AHA standards. For all LEOs, the group average cfPWV (6.72 ± 1.36 $m \cdot s^{-1}$) is within normative range for the group average age and sex (37.1 yr, male, cfPWV = 6.50 ± 1.35 $m \cdot s^{-1}$), established by the European Society of Cardiology. However compared to non-hypertensive LEOs in the present study, the hypertensive cohort's cfPWV was 1.4 $m \cdot s^{-1}$higher (Table 4-9) with the previous AHA standards and 1.0 $m \cdot s^{-1}$higher (Table 4-10) with the new standards, which places these hypertensive groups at a higher risk for CVD risk compared to their non-hypertensive peers. Hypertension has a strong link to arterial stiffening, so much so that a few researchers question which occurs first (40). It has been noted that acute rises in blood pressure can cause acute/chronic increases in arterial stiffness in subjects (12). These sustained rises in blood pressure may accelerate structural changes within the vasculature walls, because hypertensive individuals have elevated stiffness compared to age-matched controls (12). The fracturing and remolding of connective tissue proteins like elastin and collagen are examples of structural changes within the vascular wall (especially in the ascending aorta) that occur over time due to the increased blood pressure. Even though arterial stiffness has been linked with hypertension, Blacher et al. demonstrated that atherosclerosis alterations, such as arterial wall thickening, calcium build up, and plaque formation, can increase cfPWV independent of age and blood pressure (10). This would indicate that measuring arterial stiffness in conjuncture with brachial blood pressures would provide health practitioners with a better understanding of the CVD risk of their patients involved in law enforcement.

This investigation evaluated several different multiple regression analyses predicting arterial stiffness as measured by cfPWV, and concluded that Model A from Table 4-8 is the strongest. Model A utilizes age, relative body fat, and brachial diastolic blood pressure to explain 54% (adj. R^2) of the variance in cfPWV values in this population. The variables of age, body fat, and hypertension have been associated with increases in arterial stiffness in diverse populations (29, 30, 36). This regression model also provides a simple and practical formula to estimate cfPWV, as a doctor can collect these measures during a yearly physical exam. These simple measures and a normative value table could identify an at-risk LEO earlier, which could lead to primary care interventions to protect LEOs rather than tertiary treatments.

There are several limitations to this study. One major limitation of this study was the voluntary nature of subject recruitment. Many of the officers who were presumed to be in poorer health, likely declined to participate in the study. In fact, many officers who declined to participate stated that they knew they were fat and out of shape, and did not want to find out about their poor health from the investigators. This limitation occurs frequently in research and likely produces a bias in the population's estimate of health outcome variables. This sentiment is why further testing of LEOs must be completed in conjuncture with administrative support, to truly understand the health disparities that are present in this population. A second limitation of this study was the inability to collect valid sleep measures, as sleep logs were inaccurate and are needed to produce reliable actigraphy sleep data. A third limitation was the use of a cross-sectional designed study to assess longitudinal outcomes, however a cross-section study can still provide important insights for future studies. A final limitation of this study was the use of currently employed LEOs. These officers are deemed fit for duty, while many officers retire early, because they cannot fulfill the requirements of being a law enforcement officer. This leads to a bias known as the healthy worker effect, which must be investigated in future studies with the law enforcement population.

CHAPTER V: SUMMARY AND CONCLUSION

In summary the first purpose of this investigation was to descriptively compare arterial stiffness between LEOs and the general population. The primary findings of this investigation demonstrated that LEOs have significantly lower levels of arterial stiffness earlier in their career, which may be a sign of the healthy worker effect due to the screening process and cadet training requirements prior to full-time employment as a LEO. Whereas, later in their careers LEOs had significantly higher arterial stiffness as compared to the general population. The apparent disproportional increase in arterial stiffness across the career-span suggests that the occupation of law enforcement may contribute to the accelerated arterial stiffness, as measured by cfPWV.

The second purpose was to identify lifestyle, occupational, and demographic predictors of arterial stiffness in LEOs. The results from this investigation confirmed that age and obesity are primary factors in determining arterial stiffness in a cohort of LEOs. The other hypothesized variables results showed that time spent on third shift, perceived stress and moderate-to-vigorous physical activity were not predictors of arterial stiffness in LEOs. Time on third shift and moderate-to-vigorous physical activity did have an interaction effect, which will need to be further evaluated in future studies. Also years in law enforcement provided strong predictive power of arterial stiffness, which is a novel contributor to arterial stiffness. Occupational longevity as a predictor of arterial stiffness may help inform prospective employees which career choices are at greater risk for CVD, however this relationship will also need further evaluation.

Arterial stiffness as measured by cfPWV might be an important tool to diagnosis CVD risk among LEOs, since many traditional risk factors appear to be absent until post-retirement (80). Increased arterial stiffness (cfPWV) has been linked to sudden cardiac events independent of traditional CVD risk factors. If direct measurement is unavailable, using a regression model with age, relative body fat, and diastolic blood pressure could provide a reasonable estimation of arterial stiffness among LEOs. This information would be valuable for practitioners and patients by providing an earlier detection of CVD risk and thus identifying candidates for appropriate interventions. This would also provide a benefit to the government and taxpayers through reducing health care costs through using primary or secondary care instead of relying on tertiary care.

In conclusion, older LEOs as well as LEOs who present traditional risk factors such as hypertension and obesity are at greater risk of increased arterial stiffness. This investigation highlights the need for weight and blood pressure management for CVD risk reduction of an at risk population. The investigation also highlights that age, relative body fat, and diastolic blood pressure are the best predictors of arterial stiffness in this cohort of LEOs.

APPENDIX

Personal/Work History Questionnaire

Personal History Questionnaire

Subject #:______

Age: ______________

Ethnicity/race: ______________

Gender: ______________

Years in Law Enforcement: ________________

Current Rank (yrs./months at this rank): _______________________________

Previous Ranks (yrs./months):____

____

Current shift (how long have you been on this shift): _____________________

Yrs./months on First shift: ______________________

Yrs./months on Second shift: ____________________

Yrs./months on Third shift: _____________________

Do you tend to maintain your sleep schedule on your off duty days/nights or do you change? Please explain:____

____

____

____

Do you use any stimulants to stay awake during your shift? (energy drink, caffeinated drinks, etc.), if so what and roughly how often (per shift) and (per week)

____

____

____

____

Any time spent in military/ROTC (please specify):______________________________

Any time spent deployed (please specify): _____________________________________

____

Are you:	Married/Living with a partner
(circle one please)	Single
	Separated/Divorced/Widowed

How many dependents live with you (specify ages please)? ________________________

Do you sleep in the same bed as anyone, if so how many and how often?

____

Personal History Questionnaire   Subject #:______

Are you involved in any task forces or special units (specify please)? ___________

____

Do you compete in organized sports, competitions, or events, if so please list and give a brief description of activity. : ____

____

____

What type(s) of exercise do you do (weight lifting, running, ect…) ______________

____

____

Education:

o Grade School o Jr. High School o High School

o College (2-4 years) o Graduate School o Degree ______________

Physical Activity Readiness Questionnaire

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	**1.**	**Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2.**	**Do you feel pain in your chest when you do physical activity?**
☐	☐	**3.**	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4.**	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5.**	**Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6.**	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7.**	**Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____

SIGNATURE ____ DATE ____________________

SIGNATURE OF PARENT ________________________________ WITNESS ____________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

Health History Questionnaire

AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire

Assess your health status by marking all *true* statements

History

You have had:

___ a heart attack
___ heart surgery
___ cardiac catheterization
___ coronary angioplasty (PTCA)
___ pacemaker/implantable cardiac
___ defibrillator/rhythm disturbance
___ heart valve disease
___ heart failure
___ heart transplantation
___ congenital heart disease

Symptoms

___ You experience chest discomfort with exertion.
___ You experience unreasonable breathlessness.
___ You experience dizziness, fainting, or blackouts.
___ You take heart medications.

If you marked any of these statements in this section, consult your physician or other appropriate health care provider before engaging in exercise. You may need to use a facility with a **medically qualified staff.**

Other health issues

___ You have diabetes.
___ You have asthma or other lung disease.
___ You have burning or cramping sensation in your lower legs when walking short distances.
___ You have musculoskeletal problems that limit your physical activity.
___ You have concerns about the safety of exercise.
___ You take prescription medication(s).
___ You are pregnant.

Cardiovascular risk factors

___ You are a man older than 45 years.
___ You are a woman older than 55 years, have had a hysterectomy, or are postmenopausal.
___ You smoke, or quit smoking within the previous 6 months.
___ Your blood pressure is >140/90 mm Hg.
___ You do not know your blood pressure.
___ You take blood pressure medication.
___ Your blood cholesterol level is > 200 mg/dL.
___ You do not know your cholesterol level.
___ You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister).
___ You are physically inactive (i.e., you get <30 minutes of physical activity on at least 3 days per week).
___ You are > 20 pounds overweight.

If you marked two or more of the statements in this section you should consult your physician or other appropriate health care provider before engaging in exercise. You might benefit from using a facility with a professionally qualified exercise staff to guide your exercise program.

___ None of the above

You should be able to exercise safely without consulting your physician or other appropriate health care provider in a self-guided program or almost any facility that meets your exercise program needs.

Operational Police Stress Questionnaire

Operational Police Stress Questionnaire

Below is a list of items that describe different aspects of being a police officer. After each item, please circle how much stress it has caused you over the past 6 months, using a 7-point scale (see below) that ranges from "No Stress At All" to "A Lot Of Stress":

No Stress At All			Moderate Stress			A Lot Of Stress
1	2	3	4	5	6	7

1. Shift work	1	2	3	4	5	6	7
2. Working alone at night	1	2	3	4	5	6	7
3. Over-time demands	1	2	3	4	5	6	7
4. Risk of being injured on the job	1	2	3	4	5	6	7
5. Work related activities on days off (e.g. court, community events)	1	2	3	4	5	6	7
6. Traumatic events (e.g. MVA, domestics, death, injury)	1	2	3	4	5	6	7
7. Managing your social life outside of work	1	2	3	4	5	6	7
8. Not enough time available to spend with friends and family	1	2	3	4	5	6	7
9. Paperwork	1	2	3	4	5	6	7
10. Eating healthy at work	1	2	3	4	5	6	7
11. Finding time to stay in good physical condition	1	2	3	4	5	6	7
12. Fatigue (e.g. shift work, over-time)	1	2	3	4	5	6	7
13. Occupation-related health issues (e.g. back pain)	1	2	3	4	5	6	7
14. Lack of understanding from family and friends about your work	1	2	3	4	5	6	7
15. Making friends outside the job	1	2	3	4	5	6	7
16. Upholding a "higher image" in public	1	2	3	4	5	6	7
17. Negative comments from the public	1	2	3	4	5	6	7
18. Limitations to your social life (e.g. who your friends are, where you socialize)	1	2	3	4	5	6	7
19. Feeling like you are always on the job	1	2	3	4	5	6	7
20. Friends / family feel the effects of the stigma associated with your job	1	2	3	4	5	6	7

Organizational Police Stress Questionnaire

Below is a list of items that describe different aspects of being a police officer. After each item, please circle how much stress it has caused you over the past 6 months, using a 7-point scale (see below) that ranges from "No Stress At All" to "A Lot Of Stress":

No Stress At All			Moderate Stress			A Lot Of Stress
1	2	3	4	5	6	7

1. Dealing with co-workers	1	2	3	4	5	6	7
2. The feeling that different rules apply to different people (e.g. favouritism)	1	2	3	4	5	6	7
3. Feeling like you always have to prove yourself to the organization	1	2	3	4	5	6	7
4. Excessive administrative duties	1	2	3	4	5	6	7
5. Constant changes in policy / legislation	1	2	3	4	5	6	7
6. Staff shortages	1	2	3	4	5	6	7
7. Bureaucratic red tape	1	2	3	4	5	6	7
8. Too much computer work	1	2	3	4	5	6	7
9. Lack of training on new equipment	1	2	3	4	5	6	7
10. Perceived pressure to volunteer free time	1	2	3	4	5	6	7
11. Dealing with supervisors	1	2	3	4	5	6	7
12. Inconsistent leadership style	1	2	3	4	5	6	7
13. Lack of resources	1	2	3	4	5	6	7
14. Unequal sharing of work responsibilities	1	2	3	4	5	6	7
15. If you are sick or injured your co-workers seem to look down on you	1	2	3	4	5	6	7
16. Leaders over-emphasise the negatives (e.g. supervisor evaluations, public complaints)	1	2	3	4	5	6	7
17. Internal investigations	1	2	3	4	5	6	7
18. Dealing the court system	1	2	3	4	5	6	7
19. The need to be accountable for doing your job	1	2	3	4	5	6	7
20. Inadequate equipment	1	2	3	4	5	6	7

Chronotype Questionnaire

Horne-Östberg Morningness-Eveningness Questionnaire

(Horne, J., & Östberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness
in human circadian rhythms. *International Journal of Chronobiology, 4*, 97-100.)

For each question, please select the answer that best describes you by circling the point value that best indicates how you have felt in recent weeks.

1`. *Approximately* what time would you get up if you were entirely free to plan your day?

5:00 AM – 6:30 AM = 5
6:30 AM – 7:45 AM = 4
7:45 AM – 9:45 AM = 3
9:45 AM – 11:00 AM = 2
11:00 AM – 12:00 noon = 1

2. *Approximately what time would you go to bed if you were entirely free to plan your evening?*

8:00 PM – 9:00 PM = 5
9:00 PM – 10:15 PM = 4
10:15 PM – 12:30 AM = 3
12:30 AM – 1:45 AM = 2
1:45 AM – 3:00 AM = 1

3. If you usually have to get up at a specific time in the morning, how much do you depend on an alarm clock?

Not at all = 4
Slightly = 3
Somewhat = 2
Very much = 1

4. How easily do you find it to get up in the morning (when you are not awakened unexpect-edly)?

Very difficult = 1
Somewhat difficult = 2
Fairly easy = 3
Very easy = 4

5. How alert do you feel during the first half hour after you wake up in the morning?

Not at all alert = 1
Slightly alert = 2
Fairly alert = 3
Very alert = 4

6. How hungry do you feel during the first half hour after you wake up?

Not at all hungry = 1
Slightly Hungry = 2
Fairly hungry = 3
Very hungry = 4

7. During the first half hour after you wake up in the morning how do you feel?

Very tired = 1
Fairly tired = 2
Fairly refreshed = 3
Very refreshed = 4

8. If you had no commitments the next day, what time would you go to bed compared to your usual bedtime?

Seldom or never later = 4
Less than 1 hour later = 3
1 – 2 hours later = 2
More than 2 hours later = 1

9. You have decided to do physical exercise. A friend suggests that you do this for one hour twice a week, and the best time for him is between 7:00 and 8:00 AM. Bearing in mind nothing but your own internal "clock," how do you think you would perform?

Would be in good form = 4
Would be in reasonable form = 3
Would find it difficult = 2
Would find it very difficult = 1

10. At *approximately* what time in the evening do you feel tired, and, as a result, in need of sleep?

8:00 PM – 9:00 PM = 5
9:00 PM – 10:15 PM = 4
10:15 PM – 12:45 AM = 3
12:45 AM – 2:00 AM = 2
2:00 AM – 3:00 AM = 1

11. You want to be at your peak performance for a test that you know is going to be mentally exhausting and will last two hours. You are entirely free to plan your day. Considering only your "internal clock," which one of the four testing times would you choose?

8:00 AM – 10:00 AM = 6

11:00 AM – 1:00 PM = 4
3:00 PM – 5:00 PM = 2
7:00 PM – 9:00 PM = 0

12. If you got into bed at 11:00 PM, how tired would you be?

Not at all tired = 0
A little tired = 2
Fairly tired = 3
Very tired = 5

13. For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which one of the following are you most likely to do?

Will wake up at usual time, but will not fall back asleep = 4
Will wake up at usual time and doze thereafter = 3
Will wake up at usual time, but will fall asleep again = 2
Will not wake up until later than usual = 1

14. One night you have to remain awake between 4:00 AM and 6:00 AM in order to carry out a night watch. You have no time commitments the next day. Which one of the alternatives would suit you best?

Would not go to bed until the watch is over = 1
Would take a nap before and sleep after = 2
Would take a good sleep before and nap after = 3
Would sleep only before the watch = 4

15. You have two hours of hard physical work. You are entirely free to plan your day. Considering only your internal “clock,” which of the following times would you choose?

8:00 AM – 10:00 AM = 4
11:00 AM – 1:00 PM = 3
3:00 PM – 5:00 PM = 2
7:00 PM – 9:00 PM = 1

16. You have decided to do physical exercise. A friend suggests you do this for one hour twice a week. The best time for her is between 10:00 PM and 11:00 PM. Bearing in mind only your internal “clock,” how well do you think you would perform?

Would be in good form = 1
Would be in reasonable form = 2
Would find it difficult = 3
Would find it very difficult = 4

17. Suppose you can choose your own work hours. Assume that you work a five hour day (including breaks), your job is interesting, and you are paid based on your performance. At *approximately* what time would you choose to begin?

5 hours starting between 4:00 AM and 8:00 AM = 5
5 hours starting between 8:00 and 9:00 AM = 4
5 hours starting between 9:00 AM and 2:00 PM = 3
5 hours starting between 2:00 PM and 5:00 PM = 2
5 hours starting between 5:00 PM and 4:00 AM = 1

18. At *approximately* what time of day do you usually feel your best?

5:00 AM – 8:00 AM = 5
8:00 AM – 10:00 AM = 4
10:00 AM – 5:00 PM = 3
5:00 PM – 10:00 PM = 2
10:00 PM – 5:00 AM = 1

19. On hears about "morning types" and "evening types." Which one of these types do you consider your self to be?

Definitely a morning type = 6
Rather more a morning type than an evening type = 4
Rather more an evening type than a morning type = 2
Definitely an evening type = 1

Total Score =

70 86 = definite morning type
59 - 69 = moderate morning type
42 - 58 = neither type
31 - 41 = moderate evening type
16 - 30 = definite evening type

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VITA

The author, Jason Michael Keeler, was born in Indianapolis, IN and raised in Fishers, Indiana. He attended Indiana University from 2007-2011, and received a Bachelor of Science in Exercise Science. He earned a Masters of Science in Exercise Physiology at the University of Kentucky in the Fall of 2014.