Application of High Performance Training Strategies to Enhance Occupational Readiness in Law Enforcement Cadets

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APPLICATION OF HIGH PERFORMANCE TRAINING STRATEGIES TO ENHANCE OCCUPATIONAL READINESS IN LAW ENFORCEMENT CADETS

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

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ABSTRACT OF DISSERTATION

APPLICATION OF HIGH PERFORMANCE TRAINING STRATEGIES TO ENHANCE OCCUPATIONAL READINESS IN LAW ENFORCEMENT CADETS

Law enforcement requires cadets to achieve a requisite level of physical fitness to prepare for occupational demands. However, there is limited research on the effectiveness of academy exercise programs to optimize physical fitness and occupational physical ability through high performance training strategies more typically utilized in elite athletic populations. Furthermore, there is a paucity of research identifying physical fitness correlates of occupational performance. Collectively, this information will provide academies and practitioners with critical information to develop evidence-based training programs. Therefore, the purposes of this study were to: Aim 1) Examine the effectiveness of integrating autoregulatory progressive resistance exercise (APRE) and high intensity interval training (HIIT) to improve upper body strength, aerobic and anaerobic capacity, and occupational physical ability compared to the academy’s standard training program; Aim 2) Examine the relationship between physical fitness attributes and occupational physical ability test (OPAT) outcomes; Aim 3) Examine the utility of implementing session rating of perceived exertion (sRPE) to monitor cadets’ internal training loads and their relationship with injury risk. Two law enforcement academy classes were non-randomly stratified into a standard strength and conditioning program group (control; n=32) and an experimental group (n=31) that utilized APRE and HIIT training methodologies. Both groups self-reported sRPE for each resistance training, endurance training, and defensive tactics session. The training programs were 17-weeks in duration and included the following fitness and occupational assessments upon entrance, midpoint and exit of the academy: one repetition maximum (1-RM) bench press, sit-up and push-up repetitions, 300 m shuttle and 1.5 mile run time, and OPAT time. Paired samples t-tests, mixed factor repeated measures ANOVA, hierarchal linear model growth models, correlation, multiple linear regression and a regression tree analyses were used in the statistical analyses. Statistical significance was set at p<0.05. Aim 1: Both groups demonstrated significant improvements in all fitness outcomes except the OPAT from entrance to exit tests (p<.05). Despite the improved fitness outcomes, the OPAT time decreased in both groups from entrance to midpoint, but significantly increased at exit (p<.05), potentially indicating cadets completed the exit OPAT with submaximal effort. Furthermore, the experimental
group experienced greater improvements in push-up performance compared to the control group (p<0.001). Although the improvements were similar between groups for the remaining fitness assessments, the experimental group reported lower sRPE values (p<0.01), suggesting similar improvements in fitness outcomes at a lower internal load. Aim 2: 81% of the variance in OPAT time was explained by body mass, 300 m run time, 1-RM bench press and push-up repetitions, suggesting that the academy is using appropriate fitness tests to develop occupational readiness in cadets. Aim 3: sRPE-derived parameters were able to distinguish trends in internal training loads from various exercise modalities that reflect appropriateness of training stimuli and risk of injury. Collectively, this study demonstrated that high performance training methodologies are feasible to implement in a law enforcement academy training program and provide practical alternatives to enhance occupational readiness.

KEYWORDS: Law Enforcement, Cadets, Autoregulatory Training, Occupational Readiness, Perceived Exertion, Fitness

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APPLICATION OF HIGH PERFORMANCE TRAINING STRATEGIES TO ENHANCE OCCUPATIONAL READINESS IN LAW ENFORCEMENT CADETS

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CHAPTER 1. INTRODUCTION

Law enforcement is largely a sedentary occupation (2,10,125) interspersed with infrequent high intensity occupational tasks (2,125) including pursuing, apprehending and restraining subjects, hand combat, forcible entry, maneuvering through obstacles, and rescuing individuals (129,130). Despite the infrequent occurrence of intense physical demands, it is critical that officers achieve and maintain adequate physical fitness to perform these tasks. Research indicates that diverse physical fitness attributes are related to the performance of occupational tasks in incumbent law enforcement officers including cardiorespiratory fitness (6,39,43,62,72,119,130,156), body composition (39,43,119,148), muscular strength (4,39,62,148), power (43,62,72,119,130), and endurance (4,43,119). Despite this research among incumbent officers, additional research is warranted to define these relationships among academy cadets. To that end, law enforcement officers participate in training academies as cadets to enhance occupational readiness. There are approximately 664 state and local law enforcement academies in the United States, which produce about 45,000 new recruits per year (128).

There is variability in the exercise training programs and physical assessments utilized by training academies. This variability is due, in part, to the fact that there are no federal physical fitness and occupational physical ability standards for law enforcement officers. Furthermore, this variability makes it difficult to ascertain the efficacy of academy training programs to enhance occupational readiness and to develop an evidence-based approach to cadet preparation on a more global level. Regardless, limited research has demonstrated that academy training programs are generally effective at improving various physical fitness parameters in law enforcement cadets (37,42,100,117,171).
Additionally, there is evidence of diminishing physiological returns during the later phases of academy training programs \((42,100)\). Thus, it is critical to evaluate alternative individualized and periodized training strategies to optimize occupational readiness, fitness and decrease risk of injury throughout the course of the academy.

Several high performance training methodologies, more commonly used with elite athletic populations, may be incorporated in an academy training program to optimize occupational readiness. For instance, individualized high intensity interval training (HIIT) programs have been found to be a valid and reliable method for improving a variety of athletic qualities \((22)\), including aerobic performance improvement \((117)\) and reduced risk of injury in tactical populations \((115)\). However, the utility for this scaled metabolic conditioning program is largely unknown in a law enforcement population. In addition, Autoregulatory Progressive Resistance Exercise (APRE) is a resistance training strategy that modifies the training stimulus on a set-by-set basis to account for differences in physiological readiness to perform and adapt to stress on a given day \((162)\). APRE has been found to improve upper body strength over a brief training period in American football players \((98)\), however its effectiveness in a law enforcement population is unknown. Finally, session rating of perceived exertion (sRPE) is an inexpensive, valid and reliable method of monitoring internal training loads in a variety of athletic populations \((58–61)\). Although there is lack of published research regarding the use of sRPE for cadets in a law enforcement academy, it may be utilized as a method to quantify training stress during the academy to guide in the manipulation of training parameters and reduce risk of injury.
Given the importance of optimizing the occupational readiness of 45,000 U.S. law enforcement cadets each year, it is critical to identify best practices to guide practitioners in the development of safe and effective training programs. Therefore, the purpose of this study was to evaluate the feasibility and efficacy of implementing high performance training methodologies into a law enforcement academy physical training program to improve physical fitness and occupational physical ability. Specific aims were as follows:

Aim #1: To examine the effectiveness of integrating APRE and HIIT to improve 1-RM bench press, 300 m run, 1.5 mi run, and occupational physical ability test (OPAT) outcomes compared to the academy’s standard training program.

Hypothesis #1a: It was hypothesized that a periodized APRE program would increase 1-RM bench press in cadets compared to a standard academy resistance training program.

Hypothesis #1b: It was hypothesized that a periodized, scaled HIIT program would decrease 300 m run and 1.5 mile run times compared to a standard academy training program.

Hypothesis #1c: It was hypothesized that a combined APRE and HIIT training program would decrease OPAT time compared to a standard academy training program.
Aim #2: To examine the cross-sectional relationship between physical fitness assessment outcomes and occupational physical ability test (OPAT) completion times.

Hypothesis #2: It was hypothesized that fitness tests (1-RM bench press; sit-ups, 300 m run, push-ups and 1.5 mile run) utilized in the academy training program would be correlated to OPAT completion time.

Aim #3: To descriptively profile session rating of perceived exertion (sRPE) outcomes during an academy training program to monitor training load parameters and assess risk of injury in cadets.

Hypothesis #3: It was hypothesized that daily collection of sRPE would provide a subjective measure of training loads for resistance training, aerobic training, defensive tactics training, and overall training load.
1.1 Assumptions and Delimitations

Assumptions

Assumptions of this study include the following:

1. Participants gave maximal effort during physical fitness assessments;
2. Participants in the experimental group gave maximal effort during the APRE and HIIT training programs;
3. Participants recorded sRPE honestly physical and defensive tactics training;
4. Instructions were followed for all training programs and tests.

Delimitations

The study was delimited to the following:

1. Research personnel were limited in ability to modify certain aspects of the Academy’s training program due to state regulations;
2. The time of day for which physical training was performed varied;
3. The academy cadet cohort represents a variety of law enforcement agencies, some of which have additional fitness requirements compared to standard law enforcement training.
1.2 Abbreviations

LEOs  Law Enforcement Officers
CVD  Cardiovascular Disease
RPE  Rating of Perceived Exertion
OPAT  Occupational Physical Ability Test
30-15 IFT  30-15 Intermittent Fitness Test
sRPE  Session RPE
GAS  General Adaptation Syndrome
SFRA  Stimulus-Fatigue-Recovery-Adaptation
HIIT  High Intensity Interval Training
PRE  Progressive Resistance Exercise
DARPE  Daily Adjustable Progressive Resistance Exercise
APRE  Autoregulatory Progressive Resistance Exercise
POPAT  Police Officers Physical Ability Test
VO_{2\max}  Maximal Oxygen Consumption
A-VO_{2\text{diff}}  Arteriovenous Oxygen Difference
HR  Heart Rate
PARE  Physical Abilities Requirement Evaluation
SWC  Smallest Worthwhile Change
V_{IFT}  Terminal Velocity upon Completion of 30-15 IFT
RoG  Rate of Growth
I.S.  Initial status (baseline performance)
ACWR  Acute To Chronic Workload Ratio
A:C  Acute To Chronic Ratio
A.U.  Arbitrary Units
1-RM  One-repetition maximum
CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

The purpose of the literature review was to explore several high performance methodologies and their potential application to law enforcement cadets. The first section explores the key concepts of adaptation, stress, periodization, followed by an expansive review of the following high performance training methodologies: scaled resistance training through Autoregulatory Progressive Resistance Exercise (APRE), session rating of perceived exertion (sRPE) for monitoring training load, the use of high intensity interval training (HIIT) via the 30-15 intermittent fitness test (30-15 IFT) to improve aerobic and anaerobic performance and the use of an occupational ability test to reflect the physical demands identified within the law enforcement profession.

2.1.1 Adaptation, Stress and Periodization

This section provides an overview of the foundational concepts of adaptation and stress and their application to exercise training. In 1878, physiologist Claude Bernard proposed that animals have a complex internal environment, termed “milieu interne”, which was maintained at a constant level to tolerate changes in the external environment (32). This concept was further expanded upon by Walter Cannon, who suggested that maintenance of an organism’s internal environment is a result of complex coordinated physiological reactions that are specific to each organism. He termed this concept “homeostasis” (32). In his 1928 paper, the “Organization for Physiological Homeostasis”, Walter Cannon described the etymology of homeostasis, “homeo” meaning like or similar and “stasis” meaning condition (32). Homeostasis refers the stability or steady state of an organism’s internal environment. When the external environment changes, complex
physiological processes occur to maintain the organisms’ steady state. Ultimately, the concepts of Bernard and Cannon led to work of Hans Selye and his description of the General Adaption Syndrome (141).

The General Adaptation Syndrome (GAS) was first described by Hans Selye in his 1936 publication “A Syndrome Produced by Diverse Nocuous Agents” (141). In his paper, he described a common response phenomenon experienced by rats that were subjected to a variety of “acute nonspecific nocuous agents” (141) such as surgical injury, excessive muscular exercise or intoxication of various drugs. The first phase of this syndrome was considered the “general alarm reaction”, or alarm phase (141,142), which occurs 6-48 hours after exposure to a damaging agent and is represented as a systemic response of the organism which includes a reduction in organ size, increases in edema formation and loss of muscle tone (142). The second phase, the stage of resistance (142), begins 48 hours after exposure to the damaging agent and is represented by a variety of hormonal responses to correct the acute injury. Interestingly, the organism can develop a resistance to the acute injury, therefore allowing it to adapt to changes in its surroundings (142). As a result of the adaptation, the organism will reverse the responses of the general alarm reaction stage. Conversely, if the organism experiences this damaging agent for a period of one to three months (141), the organism could lose its resistance, allowing the systemic response of the damaging agent to proliferate, and can ultimately lead to the organism succumbing to the agent.

Selye postulated that this syndrome can be considered a “general adaptation syndrome” because the syndrome observed as a general response to a variety of agents of which he observed through experimentation. Although Selye did not specifically define
stress, he did suggest that “anything that causes stress endangers life, unless it is met by adequate adaptive response” (142) and furthermore “anything that endangers life causes stress and adaptive responses” (142). Selye suggests that this process of resistance and adaption is a complex systemic event which is a requirement for life (142). Through the works of Bernard, Cannon, and Selye, we understand that human physiology has processes that allows for adaptation and survival in diverse environments.

Stress is an ambiguous term often associated with both positive and negative connotations. In physiology, stress is used to describe a disruption or potential disturbance in homeostasis in which a variety of compensatory mechanisms are activated to protect the organism (68). In the original homeostasis concept, an organism is at homeostasis when in a “normal state” and deviations from this state would be directly corrected by negative-feedback loops specific to the compromised system (150). However, Sterling and Eyer (150) suggested that previous research has not shown a singular normal state for any physiological parameter in an organism, but rather one that fluctuates over time. An example was given where blood pressure fluctuated greatly throughout a 24-hour period and several activities, such as sleep, physical activity, and behavioral state, can also influence it. Moreover, there are complex combinations of physiological activity in response to a stressor, which involve many organ and body systems. Sterling and Eyer proposed that in order for an organism to maintain stability (homeostasis), it must “vary all of the parameters of its internal milieu and match them appropriately to environmental demands” (150). This concept was named allostasis which means “stability through change” (150).
There are several important facets in the concept of allostasis. First, the response to stressors are highly individualized. The two factors which determine this are a person’s perception and interpretation of a situation and the condition of their body (103). Next, for adaptation to occur, there needs to be a “resetting” of homeostatic regulators in response to a stressor, to create a new set point and improve the organism’s chance of survival to that condition (68). Finally, allostatic load represents the negative consequences of chronic exposure of a stressor by an organism, reducing its ability to adapt, which can ultimately lead the organism into a disease state (103).

Stress and adaptation are crucial aspects of periodization, a systematic training plan designed to manage adaptation and fatigue from exercise to optimize athletic performance (120,159). In general, periodization can be viewed as a template which allows strength and conditioning specialists to design and implement a detailed exercise plan which combines multiple methodologies and modalities to best prepare athletes for competitions in their respective sport. A periodized training program is structured into several nested phases of various time lengths and is used to manage training volume and intensity (159). The largest phase, the macrocycle, represents a year or multiyear training plan (74), while mesocycles and microcycles (2-6 week and 1-2 week phases, respectively) can be referred to as blocks of training that manage appropriate training stimuli and adequate recovery periods to optimize adaptations (74,120,173). Moreover, general and specific preparation phases can be used to reflect progressive changes in training volume and intensity to allow an athlete to reach peak performance for their competition (159).

The concept of periodization was originally modeled after Selye’s GAS (35,74,159). The alarm phase represents the overall response from an exercise training
session, whereas the resistance phase represents the individuals return to homeostasis or adaptation from the training stress (i.e. supercompensation). The exhaustion phase occurs as a result of excessive stress and lack of recovery, placing the individual in an overstrained, potentially injurious state. This model suggests that the body will respond in a similar manner regardless of the type of stressor experienced, therefore, the extent and duration of adaptation is determined by the magnitude and duration of training (35,159). This concept was further developed into the Stimulus-Fatigue-Recovery-Adaptation (SFRA) theory. The SFRA theory suggests that the extent of stimulus determines the amount of fatigue experienced by the individual (74,159). For adaptation to occur, there must be sufficient, but not necessarily complete, recovery from the training stimuli. Moreover, if the individual is not exposed to adequate training stimuli, they may experience a decrease in performance known as detraining or involution (74,159).

There are several limitations of the GAS and SFRA theories which include the premise that fitness and fatigue share a causal relationship (159) and that there is no difference between the effect of a training stressor on different physiological responses (i.e., neuromuscular vs. metabolic) (159). As a result, the Fitness-Fatigue Theory was developed and is currently the prevailing theory of training adaptations. This theory suggests that fatigue and fitness are concurrent effects of any training stimuli which can be summed to represent the individual’s state of preparedness (74,120,159). For positive adaptation to occur, there needs to be a balance of fatigue recovery strategies and appropriate training stimuli for elevated preparedness (74). In contrast, low training stimuli or excessive fatigue could lead to a decrease in preparedness and represent a detraining effect (74). Furthermore, the Fitness-Fatigue theory suggests that different training stimuli
can produce unique training responses known as residual training effects (35,74). Ultimately, optimizing physical performance is determined by manipulating the structure of the periodized training plan to achieve positive residual training effects and reduce fatigue.

Research investigating the use of periodized training plans in law enforcement cadets is very limited. Cocke et al. (37) evaluated a group of cadets that underwent a periodized training plan compared to four randomized training groups (RTGs) who utilized a workout-of-the-day style training during a 6-month police academy training program. The investigators found that the RTGs experienced greater overall improvement in all physical fitness outcomes compared to the periodized training group, however there were several limitations that may have affected these results such as small sample size in the periodized group, inconsistent results between the RTGs, and importantly, training intensity and volume were not equated between the groups (37). In contrast, a study by Vantarakis and coworkers (161) reported that a two month periodized training program significantly improved musculoskeletal fitness compared to the control group in Naval Cadets (161). In addition to the potential fitness benefits of periodized programs, these programs have also been found to reduce injury risk compared with non-periodized training interventions (37,42).

In summation, stress and adaptation are important concepts which enhance the understanding of how an organism adapts to its environment. Periodization is a structured, progressive training method that manipulates training volume, intensity, and specificity parameters to reduce fatigue and promote optimal training adaptations. There are several theories that have been used as a model for periodization, with the Fitness-Fatigue Theory
being the most prevalent. With regards to law enforcement cadets, periodization has been shown to improve physical fitness and potentially reduce risk of injury.

2.2 High Performance Methodologies

In a recent investigation by Martinez and Abel (100), the authors retrospectively evaluated 146 law enforcement cadets’ physical fitness outcomes during a 23-week program and noted significant improvements in all physical fitness outcomes. However, there were greater relative improvements in all fitness outcomes during the first half of the academy training program compared to the second half, indicating initial physiological adaptation and potentially a lack of sophistication in the training program design. Moreover, the magnitude of improvements -mile run, 300 m shuttle run, and 1-RM bench press were considerably less than the push-up and sit-up outcomes. This indicates that the training emphasis was placed on muscular endurance, but not necessarily aerobic endurance, anaerobic power, and muscular strength, qualities needed to perform critical occupational tasks. In athletics, the science of physical preparation and performance evolved to include new methodologies that allow for an individualized approach applied to group training (113). Utilization of many of these methods for occupational physical performance in law enforcement cadets has not yet been explored.

The following sections contains a detailed discussion of the history and application of each high performance training methodology. Furthermore, physiological adaptations to strength and endurance training are also be examined. Specific focus was given to literature pertaining the use of these methods in law enforcement cadets.
2.3 Autoregulatory Progressive Resistance Training

2.3.1 Progressive Resistance Exercise

In the 1940s, during World War II, Thomas Delorme was a surgeon at the Gardenier Hospital in Chicago where he observed a large backlog of patients, primarily due to extensive rehabilitation procedures which could last 6-9 months (158). He observed the need for a time efficient rehabilitation procedures to free hospital beds to accommodate incoming injured soldiers (158). Delorme had the idea of using strength training as a method to restore muscular function from injury, influenced by his personal experience using strength training during childhood to overcome rheumatic fever (158). The research he published became seminal works which developed into many of the concepts found in programming resistance training today.

In his 1945 paper titled “Restoration of Muscle Power by Heavy Resistance Exercise”, Delorme evaluated the utilization of resistance training for strength development based on 300 clinical observations. First, Delorme argued that endurance training performed for high repetitions and low resistance was not appropriate for power development (i.e., hypertrophy and strength) in atrophied muscle (46,47). Subsequently, high resistance with low loads was determined to be more appropriate for power development (46,47). Inadvertently, Delorme also discussed the importance of what we now know as “specificity”, by stating that endurance training and heavy resistance training are appropriate to develop those specific goals, however, they are incapable of producing each other’s results (46). In Delorme’s training intervention, he used a repetition maximum system to determine weekly training loads, coined the 10 repetition maximum (10-RM). Additionally, a one repetition maximum was performed to use as a reference for quadriceps
power (46) and represented maximal volitional effort (49). The initial 10-RM and 1-RM tests were performed once per week with the remaining session utilizing the 10-RM workload. Lastly, each session had a volume of 70-100 repetitions, where the weight was progressively increased until around 80 repetitions, which would represent the 10-RM load. Ultimately, the results of this investigation showed that heavy resistance training was an effective method of restoring muscular power. It was also suggested that this power adaptation could be maintained by performing resistance training exercises one to two times per week for 15-20 minutes (46).

In 1948, Delorme and Watkins published the “Technics of Progressive Resistance Exercise” which made some notable modifications to Delorme’s previous work. First, describing exercises as “heavy resistance exercises” was changed because heavy is a misnomer which insinuates only to the portion of the exercises are performed maximally. Instead, the authors adopted “progressive resistance exercise” (PRE) as it correctly describes the progressive increases in training load each set. The next modification was in regard to the amount of volume used. Initially, 70-100 repetitions was suggested for strength development (46,48). The authors found that fewer repetitions (20-30) allowed for greater training loads to enhance hypertrophy, in a shorter period of time (48). This refined PRE protocol was utilized to improve knee function in soldiers who experienced femoral fractures during active duty (49). The results found that the exercise group experienced significant improvements in knee range of motion and strength in a short period of time (49). These investigations would be the first of many evaluating the efficacy of PRE.
2.3.2 DAPRE and APRE

A derivative of PRE was created in 1979 when Kenneth Knight created the Daily Adjustable Progressive Resistive Exercise (DAPRE) program to allow patients in rehabilitation to consistently perform resistance exercises maximally (87). The purpose of creating the DAPRE method stemmed from Knight’s criticism of previous work done by Delorme (46) in which it was suggested that an individual’s 10RM should be tested each week in order to program appropriate resistance for that week. Knight proposed that Delorme’s PRE method does not provide appropriate individualized increases in training load to allow for progressive increases in strength (87). The DARPE program consists of four sets of exercises at a variety of loads. The first two sets require the patient to train at a load of half and three-quarters of the final working load, respectively. The next set is then performed for a maximum number of repetitions. Next, the lifter uses a table of scaled loads to adjust the working weight for the fourth set. This process is then repeated for the fourth set with the final weight adjustment serving as the new working weight for the next training session. Several published investigations have found DAPRE to be an effective protocol to improve quadriceps strength (3,88,170).

Although DAPRE was created for use in knee rehabilitation (87), a variation of DARPE known as the Autoregulatory Progressive Resistance Exercise (APRE) protocol, was developed by Mel Siff with a focus of improving power, hypertrophy and strength in athletes (162). Autoregulation is a form of periodization which individualizes an athlete’s training by modifying volume or intensity parameters based on their performance during that training session (98). The APRE protocol uses the same four set format as the DARPE protocol, however, it utilizes three different repetition maximum values for each targeted
training goal: 3-RM for power, 6-RM for strength and hypertrophy and 10-RM for endurance and hypertrophy (162). Additionally, each variant has a specific load adjustment table to allow for daily progression and subsequent programming (162).

There is very limited published research evaluating the efficacy and benefits of APRE. In an investigation by Mann and colleagues (98), the authors compared APRE with traditional linear periodization in collegiate American football players to improve back squat and bench press strength. After a six-week intervention, the APRE group experienced significantly greater improvements in bench press and squat strength compared to the linear periodization group. While periodization strategizes have been suggested to improve occupational readiness (37,42), there are no investigations utilizing APRE on law enforcement cadets. The results by Mann et al. demonstrate its potential usefulness for improving upper body strength over a short period of time, which could benefit cadets within the time constraints of the training academy.

In summary, the seminal work on PRE by Delorme (46–49) created the basis for much of the resistance training programming concepts we use today. Further refinement of the PRE led to development of the DARPE protocol that Knight used for patients undergoing knee rehabilitation (87). Mel Siff (162) then adapted the DARPE protocol for use in healthy populations and renamed it APRE. Although there are very few investigations on the efficacy and benefits of APRE, Mann et al. (98) found that it was effective at improving upper body strength in a short period of time in collegiate football athletes. No research regarding the use of APRE has been conducted in the law enforcement population, however, it may be an effective tool for improving strength in law enforcement cadets during their basic academy training.
2.3.3 Physiological Adaptations to Resistance Training

This portion of the review will briefly address the primary adaptations of resistance training. The complex structure of muscle facilitates force production and subsequently, body movement. Muscle exists in a hierarchal structure consisting of muscle fascicles, muscular fibers, myofibrils and sarcomeres. The sarcomere is the basic contractile unit of muscle and contains several myofilaments essential for muscular contractions which includes actin, myosin and titin (57,74). The prevalent theory for concentric contraction is known as the cross bridge cycling theory. Excitation of a muscle fiber results in a downstream of processes that ultimately allow calcium release from the sarcoplasmic reticulum into the sarcomeres (20). Calcium, in addition to the hydrolysis of ATP, allows for actin and myosin interaction which results in a power stroke and subsequent overlap of actin and myosin, shortening the length of the sarcomeres (20). Finer, Simmons and Spudlch (57) observed that during isometric conditions, 3-4 piconewtons of force is produced by a single myosin.

Some of force generating capabilities of muscle have been associated to its cross sectional area (CSA) which directly relates to a combination of sarcomeres in series and in parallel (168). When sarcomeres are increased in series, it creates longer muscle fiber lengths, produces more force, increases contractile velocity, muscular power, and range of motion (28,168). Eccentric resistance exercise has been found to increase sarcomeres in series (168). In contrast, sarcomeres in parallel are generally associated with direct increases in muscular CSA (168), known as muscular hypertrophy. It has been observed that protein synthesis mechanisms begin approximately four hours after a resistance training stimulus (63,168). Muscular hypertrophy is associated with increases in the
contractile machinery which subsequently allow a muscle to produce more force (168). Another muscular adaptation associated with hypertrophy (via sarcomeres in parallel) is the increased pennation angle of the muscle (168). Pennation angle refer to orientation of muscle fibers in relation to the muscle’s points of origin and insertion (74). It has been observed that muscular hypertrophy increases pennation angles (86), however, it is also associated with reduced muscular force production per CSA (85). As a result, when developing maximal muscular force production, hypertrophy-focused training methodologies should be incorporated cautiously (85).

An additional factor that influences muscular force production are muscle fiber types, also known as myosin isoforms. There are three commonly expressed isoforms in humans, type I, type IIa and type IIx. Type I are represented as smaller fibers that do not produce large amounts of force and are fatigue resistant. In contrast, type IIx fibers are larger, produce more force and are fatigable. Type IIa fibers exhibit a combination of type I and IIx fibers, where they produce more force than type I and are more fatigue resistance compared to type IIx. There is evidence that resistance training can lead to hypertrophy in all three fiber types, with type I fibers experiencing the smallest growth and type IIx/IIa experiencing the largest (51,149). Additionally, resistance training has shown to cause fiber type transitions type IIx to type IIa (149). Lastly, genetic disposition of fiber types could influence athletic performances where type IIa/IIx is preferable for success in power event and type I fibers are preferable to endurance events (74,121).

Another important aspect essential to muscle function and adaptation is the contribution of the nervous system. For muscle action to occur, an action potential propagates from central nervous system to a specialized interface between the motor
neuron and muscle called the neuromuscular junction (74). Here, the action potential depolarizes the terminal axon which releases the neurotransmitter acetylcholine which binds to its receptors on the post-synaptic endplate on the muscle fiber (20). When sufficient acetylcholine has been bound, the muscle fiber depolarizes, allowing muscular contraction to occur. This system, which includes motor neuron and all the muscle fibers it innervates, is called the motor unit.

Resistance training has been shown to induce positive adaptations in several aspects of motor unit function. Motor unit recruitment is guided by the Hennemen’s size principle (78) where smaller motor units are first recruited and as more force is required, larger motor units are recruited for the task (20). In relation to the specific muscle fiber types, the order of recruitment is as follows: I—Ia—Ix (135). Resistance trained individuals are able to achieve greater motor unit activation compared to their untrained counterparts (135). Other observed adaptations are increased motor unit synchronization, which has been shown to increase co-activation of additional muscles (143) and increased motor unit firing rates (i.e., rate coding), both of which increase force production (53). Adaptations to the neural components of muscular activity have been found to account for strength improvements in the first 4-6 weeks of resistance training, whereas muscular hypertrophy is responsible for strength improvements after 6 weeks of training (63).

2.4 Perceived Exertion

2.4.1 Rating of Perceived Exertion

In physical performance, perception cues can be a primary source of information which allows us to regulate the work intensity of a given task (13). These cues can manifest
as a variety of feelings of exertion and/or fatigue which include muscle pain, shortness of breath and increased heart rate (13). Ultimately, what we perceive exertion is a systemic collection of physiological signals and responses which include feedback from the muscles, joints, respiratory and central nervous systems subjectively experienced through a physical activities (14).

Gunnar A. V. Borg pioneered perception research with the goal of determining how to measure perception of physical stress. Specifically, he focused on psychophysics, a scientific field which investigates how “the intensity of the perception grows with physical intensity” (13). The direct relationship between human perception and physical intensity is not easily defined. In a hypothetical example by Borg (14), they conducted an experiment where an individual drove at 50 mi·hr⁻¹ and was then asked to drive at what they perceived to be half as fast. When the person slows down to what they perceive 50% of 50 mi·hr⁻¹, however, the objective measure of the car’s speed was 35 mi·hr⁻¹. This suggests that human perception of intensity cannot be directly compared with a concurrent objective measure of intensity, however the relationship could be defined using other mathematical techniques.

Early perception research utilized ratio scaling and power functions to measure perceived intensities (13,14,16). Ratio-scaling utilizes a numbered system which featured an absolute zero and the subsequent values were equidistant (14). Power functions were used to describe perception variety found with physical intensity (13,16). A common equation developed to describe variations in both perceptual and physical intensity is as follows: \( R=\text{arc}(S-b)^c \), where “\( R \)” is the response in intensity, “\( a \)” and “\( b \)” are constants representing absolute zero, “\( S \)” is the intensity of the stimulus, “\( c \)” is a measure constant.
and “n” is the exponent (13,14,16). A variety of exponents have been found to represent response intensities with 1.6 being a common value representing handgrip strength (14,151), cycling (15), and running (15). A major drawback of ratio-scales and power functions is the difficulty in comparing results as the values equated are relative to the subject and has no direct comparison to the results of another individual.

To overcome the challenges for allowing inter-individual comparisons (14), Borg developed a rank-order category scale with verbal/descriptive anchors that represented subjective intensity (14). Although the scale’s values would not directly represent objective values of any given activity (14), it could be utilized in for variety of applications. In 1962, Borg developed the scale that would become synonymous with measures of perception, known as the Ratings of Perceived Exertion (RPE) Scale (12–14). The RPE scale had a total of fifteen values with verbal anchors attached to a majority of the values. The lowest value “6” was associated with “No exertion at all”, whereas “20” was associated with “Maximal Exertion” (16).

One problem that Borg experienced validating the RPE scale was determining a physiological variable in which its value increases with increased intensity (13). Borg found that absolute heart rate (HR) was highly correlated with RPE (r=.85) as work intensity increased from low to high on the cycle ergometer (13). Another important facet of this RPE scale was that it also provided an expedited way to subjectively determine heart rate by multiplying the RPE value by 10 (13). For example, an RPE of “10” would represent a heart rate of approximately 100 b·min⁻¹. Although the original RPE scale was developed and validated for healthy middle-aged men on a cycle ergometer (12,13), it has been tested for use with other modalities (i.e., walking, running, isometric muscular work,
arm ergometry and resistance training (13) as well as become a model for development of future perception scales.

In considering other physiological variables that could be used with RPE, it was found that any variables that conform with linear increases with exercise intensity could be utilized (i.e., heart rate, oxygen consumption (13)). Moreover, variables such as blood lactate, experience a curvilinear increase with exercise intensity (114) and are not represented appropriately by the RPE scale. When Borg investigated the use of the RPE scale with blood lactate, he found that the blood lactate variables increased approximately three times more per unit at the higher values of 16 and 17 than at the lower RPE values (12,114). This would prompt Borg to develop a new eleven point category-ratio (CR-10) psychophysical scale that could be used with non-linear physiological responses (114).

Similar to Borg’s RPE scale, the CR-10 contains an absolute zero and values with verbal anchors, however, the scale would range from 0 to 10 instead of 6-20 and would represent an positively accelerated function (i.e., the slope increases as the value increases) (114). To test the reliability and validity of this new scale, he performed an experiment to determine the relationship between his new RPE scale and heart rate, blood and muscle lactate (114). Ten subjects performed an incremental cycle ergometer test, starting at no load and increasing 50W every four minutes until voluntary exhaustion occurred. During the last thirty seconds of each stage, heart rate, RPE, blood lactate (through a fingertip sample) and muscle lactate (through muscle biopsy) was taken. The results showed that blood and muscle lactate increased with increased power output (r = 0.9973 and r = 0.9989 respectively) when expressed as a quadratic function of power output. Borg concluded that the CR-10 scale paralleled blood and muscle lactate values with increased physical
intensity and therefore could represent lactate response in exercise (114). In subsequent investigations by Borg et al., they found strong correlations between perceived exertion versus measures of blood lactate and heart rate (15,17,18) and aches and pains of the legs (17,18) during cycle ergometry (15,18) and arm ergometer exercise (17).

2.4.2 Session RPE

A variation of the CR-10 scale, known as session RPE (sRPE), was initially developed as method to measure training load. Foster et al. (61) utilized a training impulse calculation to determine the effect of training load on running performance and physiological indices such as blood lactate. The training impulse calculation was developed by Banister et al. (61) by which training intensity, measured through continuous heart rate monitoring, is multiplied by training duration and equates to the impulse score. Although heart rate was generally utilized as a measure of training intensity for cardiovascular exercise, Foster and coworkers (61) determined that collecting heart rate information for their large sample of subjects would be difficult. Subsequently, the authors chose RPE for their measure of intensity for two reasons.

First, as previously addressed, the original RPE scale was developed and had a positive correlation (r = 0.85) with heart rate (12,13). Additionally, the CR-10 RPE was validated to represent increases in heart rate (15,18) and blood lactate (15,17,18,114) in cardiovascular exercise. Secondly, through pilot testing, Foster et al. (61) determined that the newly termed sRPE had a relationship with time spent at different blood lactate zones (<2.5 mmol·dL\(^{-1}\), 2.5-4 mmol·dL\(^{-1}\), and >4.0 mmol·dL\(^{-1}\), respectively) during thirty minutes of steady state running exercise. The authors ultimately concluded that sRPE could
be used to control training intensity based on its observed relationships with heart rate, blood lactate and exercise intensity (61).

To implement sRPE, the authors asked the subjects “How was your workout?” based on the modified CR-10 RPE scale, thirty minutes after the completion of the training session (60,61,79). It was noted that waiting thirty minutes post training prevented the final intensity (whether high or low) experienced by the subject, to not skew their perception of intensity for the entirety of the training session (60). The sRPE could then be multiplied by the duration of the training session to determine training load. Although the Foster et al. (61) study did not discuss sRPE further than its implementation in their experiment, its potential as a way of measuring training load became apparent and would be soon be further investigated. One such study by Foster et al. (59) examined if there was a qualitative relationship between athletic performance in running, cycling and speed skating and sRPE training load. After six weeks of training utilizing sRPE to monitor training load with self-selected increases in training intensity, there was an 11% increase in weekly training load with a subsequent decrease of an average of 2.2% in time trial performance (59). Based on these results, the authors’ concluded that training load via sRPE could be a viable alternative to measure athletic performance.

Session RPE has also been investigated to monitor overtraining syndrome in athletes. Carl Foster (58) evaluated the relationship between the incidence of minor illness and various sRPE-derived metrics including training load, monotony and strain. Training monotony represents the variability of training loads within a week and is calculated as the average daily training load divided by the standard deviation of the average training load (58,104). If the daily training load is consistently high each day of a given week, there
would be high training monotony. In contrast, alternating high and low daily training loads will produce lower training monotony scores. Training strain refers to potential negative adaptations from training as a result of excess training volume or intensity (58,104) and is calculated as the product of a weekly training load and training monotony. Specifically, the investigation had twenty-five competitive athletes record sRPE, training duration, and any incidence of illness recorded during each training session for a period ranging from six months to three years. The results showed that 84% of illness could be explained by a training load greater that an individualized training threshold (58). Similarly, 77% and 89% of illnesses could be attributed to an increase in training monotony or training strain, respectively. Foster concluded that calculations derived from sRPE could potentially be a valid method of representing factors related to overtraining in athletes. An example of a strategy to prevent overtraining through training load, monotony and strain is to alternate the intensity of the training days (i.e., hard vs. easy) to allow for a balanced load management approach (40,58). While these metrics have been utilized in sports such as rugby (40,166), tennis (69), cycling (45) and cross country skiing (152), there is no research regarding its use in tactical populations.

A secondary aim of the Foster (58) investigation was to determine the general validity of sRPE with heart rate training zone scores. The heart rate training zone method, developed by Sally Edwards (58) multiplies the duration a person exercises at specific heart rate zone (in fractional minutes) by an associated value (1-5) used to represent the intensity of that specific zone. For example, a heart rate zone which represented 50-60 b·min\(^{-1}\) had a value of 1 while a heart rate zone of 60-70 b·min\(^{-1}\) had a value of 2. The cumulative sum of all the heart rate zone scores of a given training session represented that session’s
training intensity (58). Foster (58) compared sRPE training loads concurrently with the heart rate training zone scores and found a correlations ranging from \(r = 0.75 - r = 0.90\) for the seven subjects tested. Foster concluded that sRPE could be a valid method to quantify a training session without the use of external devices.

To further expand on the utility of sRPE, Foster et al. (60) evaluated its use as a potential method to monitor high intensity training as a majority of the previous investigations utilized steady state cardiovascular training (58,59,61). The authors found that sRPE can provide a subjective estimate of training load with non-steady state activities such as high intensity training and team sport (60). Additionally, it has a positive correlation with heart rate zone scores, however the measures were not interchangeable (60). Moreover, while sRPE does not provide specific, objective information of training intensity or load, it is an easy method to utilize and does not require “the knowledge of maximum exercise responses (e.g., \(HR_{peak}\)) to anchor the monitoring method” ((60); p114).

In 2006, more than a decade since the creation of sRPE, Herman et al. intensity (79) evaluated its validity and reliability to monitor exercise training. Session RPE was found to have respectable test-retest reliability (\(r = 0.78\)) and validity against several objective measures of exercise intensity such as \(%VO_{2peak}\) (\(r^2 = 0.76\)), \(%HR_{peak}\) (\(r^2 = 0.74\)) and \(%HR_{reserve}\) (\(r^2 = 0.71\)) (79). In addition, it was observed that sRPE had weaker relationships at high exercise intensities compared with an objective measure of exercise intensity (79). Overall, Herman et al. (79) concluded that sRPE demonstrated adequate test-retest reliability on repeated performances as well its validity in measuring exercise intensity. Although the authors experienced inaccuracies of the sRPE at higher exercise intensity (where sRPE was maximum but the objective measures of exercise were not), it was
discussed that similar occurrences can be observed in other internal load monitoring methods (i.e., heart rate monitor-based) and remains to be a fundamental problem experienced when monitoring exercise intensity (79).

Although Foster (60) suggested that sRPE could be utilized to measure anaerobic performance, there were no specific data regarding the relationship of sRPE with resistance exercise. Day et al. (44) investigated the reliability of sRPE to measure intensity of resistance training and found that there was a correlation of \( r = 0.88 \) between the two variables (44). In a subsequent study by Sweet et al. (153), the authors found higher values of sRPE were related to higher percentages of 1-RM, despite changes in total work performed. Furthermore, Egan et al. (52) demonstrated that the resistance training mode could also influence the RPE rating independent of the load used. The authors’ investigation compared super slow training (consisting of a 10 second eccentric and 10 second concentric motion for each repetition) at 55\%\ 1-RM with a traditional resistance training at 80\%\ 1-RM. Both training modes utilized 6 sets of 6 repetitions, and found that super slow training experienced higher sRPE values (52).

Singh et al. (145) experienced similar results where strength and hypertrophy protocols produced higher sRPE values compared to power training. It was suggested that the differences in perception of intensity may be due to lack of fatigue from the power protocol. Evidence of this mechanism was suggested by Linnamo et al. (90) who found that explosive exercise utilizes the neuromuscular system for performance and does not produce significant fatigue. Another factor that may influence sRPE values with resistance training is training volume. Pritchett et al. (122) found that there was higher RPE values reported at the lower intensity resistance training when greater volume (more total work)
was performed. Additionally, the authors observed a positive correlation between total work and sRPE where total work explained 85% of the variance in session RPE ($r^2 = 0.85$, $p = 0.029$) (122). Hiscock, Dawson and Peeling (80) conducted a comprehensive investigation regarding the influence of resistance training parameters on sRPE. The authors found that if volume (measured as tonnage) and rest between sets remained the same, training intensity would be a principle determinant of sRPE (80). In contrast, when performing exercise to volitional fatigue, sRPE should be similar regardless of the training intensity and the rest periods observed. Lastly, the authors found that measuring sRPE 15 minutes after completion of an exercise protocol was not significantly different from session RPE measured after 30 minutes, suggesting that measurements at that either time point is adequate (80).

2.4.3 Acute to Chronic Workload Ratio

Recently, there has been an increase in research evaluating training load monitoring applications. One such method known as the acute to chronic workload ratio (ACWR), is based on Bannister’s pioneering research on modelling human performance (30,71). ACWR utilizes either rolling averages or exponentially weighted moving-averages (71) of acute (current workload and potential fatigue experienced by an individual (82) and chronic (i.e., fitness of the individual) (82) training loads to create a dynamic index of athletic preparedness (71,96). Training load measurements can be classified into two groups, internal and external training load. Internal training loads reflect physiological and psychological stressors experienced in training or competition and typical measurements include heart rate and session RPE (19,71). In contrast, external training loads reflect various measures of work performed in training or competition and typical measurements
include power output and GPS data (19,71). Another important aspect of ACWR is the time period used for its calculation. Most commonly a seven to twenty-eight day acute to chronic ratio has been utilized in research, however many different ratios have been explored (71).

The current state of research utilizing ACWR is in refinement of its application as well as evaluating its association to potential injury sustained in team sports (71). For the purpose of this review, publications that focused on using sRPE for ACWR measurements were assessed. Gabbett (64) found that higher training loads were associated with greater non-contact, soft tissue injury rates in rugby players. In addition, Hulin et al. (82) found that when the acute workload was lower than or similar to the chronic workload (acute to chronic ratio (A:C) <0.99), there was a 4% likelihood of injury the following week in fast cricket bowlers. Furthermore, if A:C >1.5 the risk of injury was 2-4 times greater in the subsequent week (82).

Interestingly, the authors also observed a decreased injury risk in players who produced high workloads over a chronic period of time (82), indicative of a protective effect against injury in individuals with a higher training status. In a 2016 study, Hulin et al. (82) evaluated the use of ACWR to predict injury in rugby players and found that an A:C>2.11 presented the greatest risk of time-loss injuries in the current week (16.7%) and subsequent week (11.8%). Moreover, very high chronic workloads and a 2-week ACWR average presented the greatest risk of injury (83). In a clinical analysis, Blanch and Gabbett (9) assessed sRPE-based ACWR data from the sports of cricket, rugby and Australian football. They found that an A:C of 0.8-1.3 was associated with a reduced likelihood of
injury whereas an A:C of >1.5 was associated with a significant increase in risk of injury (9,65).

Interestingly, each sport appears to have different ACWR ranges associated with injury. Malone et al. (96) found that elite soccer players who had in-season A:C >1.0 - <1.25 had a significantly lower risk of injury when compared to players who had an A:C of <0.85. Similarly, Malone et al. (97) found that in-season Gaelic football players with an A:C >1.35-1.5 had a lower risk of injury compared to players with an A:C <1.0. Moreover, players with an A:C >2.0 had significantly higher risk of injury (65,97). As previously mentioned, there are different ACWR ratios that can be used for analysis. McCall et al. (102) found than A:C ratios of 1:3 and 1:4 were associated with non-contact injury (p<0.05) in soccer players. Furthermore, when using a 7 to 28 day ratio, an A:C 0.97-1.38 was associated with greater risk of injury compared to an A:C <0.97. Similarly, when using a 7 day to 21 day ratio, an A:C >1.47 was associated with a greater risk of injury when compared to an A:C <0.97. While it has been suggested that utilizing both internal and external load measures will allow for superior training load monitoring (71), it is not always feasible. Although a low-cost method such as sRPE is valid, reliable, and easy to implement, it has several limitations. It requires an honest assessment of effort from players and this method is unable to differentiate between long-low intensity and short-high intensity workouts (102).

In summary, sRPE appears to be a valid and reliable method for monitoring resistance (44,52,79,80,122,145) and cardiovascular (58–61) training loads. Additionally, there is evidence that sRPE could be utilized to detect overtraining syndrome through the use of training loads, monotony and strain (58,104). Furthermore, sRPE-based ACWR has
found to be associated with risk of injury in team sports \((9,64,71,82,83,96,97,102)\). There are several limitations that have been described by the authors investigating the use of sRPE. First, sRPE does not directly relate to the specific intensity utilized in training \((52,60,145)\). Next, sRPE may not accurately represent high intensity activity especially when simultaneously compared to an objective measure of the activity \((79)\). Lastly, although sRPE can be utilized with resistance training, volume \((80,122)\), intensity \((80,122)\) and mode of exercise \((52,145)\) can influence sRPE values and should be taken into consideration when utilizing sRPE in programming.

While there are no known investigations utilizing session RPE to monitor training loads in law enforcement populations, Canino et al. \((31)\) found sRPE to be an alternative method to measure aerobic performance during soldiering tasks in the U.S. Army. Although the physical training programs in law enforcement academies vary greatly in the United States, utilizing session RPE to monitor training loads may be beneficial to quantify both physical and defensive tactics training and allow for improved programming for increased performance outcomes and injury prevention.

### 2.5 30-15 Intermittent Fitness Test for High Intensity Interval Training

The 30-15 Intermittent Fitness Test (30-15 IFT) was designed by Martin Buchheit \((23)\) to elicit physiological responses and sport specific demands commonly found in team sports. These qualities include aerobic performance, acceleration, deceleration, change of direction ability, anaerobic power development and recovery ability between exercise bouts \((23,24)\). The protocol consists of 30 s shuttle runs followed by 15 s of active recovery, and can be performed over a distances of 28 m or 40 m, on a 400 m track or in an ice rink
The shuttle runs occur at increasing speeds which are guided by an audio file. Upon completion of the 30-15 IFT, the athletes receive a $V_{IFT}$ score which represents the velocity at the completion of the test. The $V_{IFT}$ is then used to create individualized run-based high-intensity interval training programs.

The use of velocity to as a measure of physical fitness is an important concept within the development of the 30-15 IFT. While VO$_{2\text{max}}$ is widely accepted as a measure of cardiovascular fitness, it does not fully represent performances of intermittent activities. Velocities at which VO$_{2\text{max}}$ is achieved is considered critical speed and can be used to measure maximal aerobic capacity. Furthermore, end-test velocity, the velocity achieved at the end of a graded exercise protocol, can be considered a “composite velocity”, which represents both aerobic and anaerobic contributions to test performance, and can occur after VO$_{2\text{max}}$ was achieved. In regard to the 30-15 IFT, the $V_{IFT}$ represents the end-test velocity. Correlational data between $V_{IFT}$ and the following variables appear to support Buchhiet’s rationale of the 30-15 IFT measuring a variety of athletic qualities: VO$_{2\text{max}}$ ($r = 0.68$), 10 m sprint ($r = 0.63$), countermovement jump height ($r = 0.65$), inter-effort heart rate recovery ($r = 0.47$), and performance on repeated sprint test ($r = 0.88$).

There have been several studies regarding the validity and reliability of the 30-15 IFT within different populations. Buchheit et al. (26) found that the 30-15 IFT $V_{IFT}$ was significantly correlated with VO$_{2\text{peak}}$ and VCO$_{2\text{peak}}$ from a continuous incremental exercise test ($r = 0.76$, $p = 0.001$ and $r = 0.77$, $p = 0.001$, respectively) in male team sports players (basketball, soccer or handball). A Bland-Altman analysis of VO$_{2\text{peak}}$ and HR$_{\text{peak}}$ between the two modes of testing found adequate levels of agreement, despite a large amount of
variability (26). Additionally, the 30-15 IFT yielded greater values for peak breathing frequency, minute ventilation, carbon dioxide production and blood lactate compared to the continuous test (26). The authors suggested that the discontinuous nature of the protocol along with the acceleration, deceleration and change of direction motions required to complete the protocol, elicited higher ventilatory patterns (26).

Bruce and Moule (21) observed a significant relationship between the $V_{IFT}$ obtained from the 30-15 IFT and a similar shuttle protocol, the Yo-Yo Intermittent Recovery Test in sub-elite female Netball athletes (21). Additionally, the 30-15 IFT $V_{IFT}$ demonstrated adequate test-retest reliability ($ICC = 0.84, p < 0.001$; (21). Covic et al. (41) examined the validity, reliability and utility of the 30-15 IFT in female soccer players. The authors observed significant correlations between $VO_{2max}$ ($r = 0.67, p = 0.013$), $HR_{peak}$ ($r = 0.77, p = 0.02$) and end running velocity ($r = 0.67, p = 0.013$) between the 30-15 IFT and a continuous lab-based graded exercise test (41). Moreover, Covic et al. (41) noted adequate test-retest outcomes ($ICC = .91-.94$) for $V_{IFT}$, $HR_{peak}$, and $VO_{2max}$, from the 30-15 IFT. $VO_{2max}$ was estimated in this investigation using an equation developed by Buchheit utilizing $V_{IFT}$ data. Lastly, a smallest worthwhile change value of 1 stage of the $V_{IFT}$ was observed. The smallest worthwhile change (SWC) determines the minimal threshold of change needed to observe a “true” change in performance (160). Several investigations evaluated the reliability and usefulness (determined by SWC) in a variety of team sports. A stage of the $V_{IFT}$ represents a change in speed of 0.5 km·hr$^{-1}$ (22,23) and is used to represent SWC in 30-15 IFT investigations. Valladares-Rodriguez et al. found $V_{IFT}$ and $HR_{peak}$ observed from the 30-15 IFT was reliable in male ($ICC = 0.92, 0.91$) and female ($ICC = 0.91, 0.91$) professional futsal players, respectively (160). The authors also found
that male futsal athletes have a SWC of at least 2 stages while female futsal athletes need a SWC of 1 stage for performance improvement (160). Thomas et al. (155) found the $V_{IFT}$ to have a test-retest reliability of ICC=0.80 and a SWC of two stages in male semi profession soccer players. Finally, Scott et al. (140) reported acceptable levels of $V_{IFT}$ reliability (ICC=0.83-0.94) and a SWC of 1 stage in rugby athletes.

Research utilizing the 30-15 IFT in populations outside of team sports, such as law enforcement, is very limited. As stated earlier, one of the concepts of the 30-15IFT is that the resultant $V_{IFT}$ represents a variety of physical attributes (23), some of which also reflect attributes needed in police officers (129). For example, the 300 m shuttle run is one of the Cooper Fitness Tests that can be used to evaluate anaerobic power in law enforcement cadets (154). Subsequently, a study by Scott et al. (139) found that 67% of the variance in $V_{IFT}$ can be explained by the 300m sprint performance and repeated sprint ability. It can be inferred that the 30-15 IFT could have some potential application in the law enforcement profession.

The potential utility of the 30-15 IFT for implementation with police recruits has been evaluated by several authors. Orr et al. (115) found that the 30-5 IFT can predict injury in law enforcement cadets. Specifically, if a cadet achieved a score of below 16 on the $V_{IFT}$, they would more likely sustain an injury during training in the academy. One instance of the using the 30-15 IFT for programming in police recruits was reported by Orr, Ford and Sterli (117). The authors programmed an ability-based training (ABT) intervention (using $V_{IFT}$-derived shuttle runs) that was completed once a week over a 10-week period. Subsequently, this investigation found no significant differences in aerobic fitness improvements between using the ABT compared with a general running program,
however, there were lower running volume and reported injuries in the ABT group (117). Overall, these results suggest the potential utility of the 30-15 IFT for testing and programming in police recruits.

In summary, the 30-15 IFT appears to be a valid and reliable method for measuring a variety of cardiovascular and physical attributes (23). When using the resultant V_{IFT}, one can program individualized interval based shuttle run programs and can generally expect significant changes in performance with a change of 1 stage (140,160). Furthermore, there is evidence that the 30-15 IFT can be utilized with tactical populations for performance enhancement (117) and potentially reduce risk of injury (115).

2.5.1 Physiological Adaptations to Endurance Training

This section will briefly review the primary cardiovascular adaptations to endurance training. The cardiovascular and respiratory systems represent a complex network of organ systems working in concert to supply nutrients and remove waste products throughout the body (74). There are several important variables which reflect the status of the cardiovascular system. The most prevalent indicator of cardiovascular function is maximum oxygen consumption, VO_{2max} (L·min^{-1}), which can be normalized by body mass (kg) to allow for inter-individual comparisons. VO_{2max} is calculated by multiplying cardiac output by the arteriovenous oxygen difference (A-VO_{2diff}) (89). The A-VO_{2diff} represents the sum of oxygen that transported by blood to and consumed by tissue (89). Cardiac output represents the amount of blood is ejected through the heart per minute (56). Furthermore, cardiac output is derived by multiplying heart rate by stroke volume. Stroke volume represents the amount of blood ejected during each beat and
represents the difference between the volume of blood in the left ventricle at the end of the filling phase (diastole) and the end of ejection (systole) (89).

Endurance training has been shown to affect all of the described variables. There is a positive relationship between heart rate and cardiac output to match the metabolic demands of exercise (77). The primary goal of endurance training is to maximize the amount of oxygen that can be efficiently utilized by the body. Endurance training elicits increases in maximal oxygen consumption through significant increases in cardiac output, and to a lesser extent, increases in $A \cdot VO_2^{\text{diff}}$ (77,106). In fact, endurance training produce a range of increases in cardiac output from 5-20 L·min$^{-1}$ in young males and females to 25-40 L·min$^{-1}$ in elite athletes (77). Moreover, as maximal heart rate is generally unaffected by endurance training (106), a larger exercise-induced diastolic blood volume results in a significant increase in stroke volume (77).

There are several structural and muscular adaptations that also occur from endurance training. The heart undergoes hypertrophy which increases the heart chamber size, accommodating the 20-50% increase in blood volume (77). Furthermore, there is an increase in heart wall thickness in all four heart chambers, allowing for enhanced contractility (167). With regards to skeletal muscle and in contrast to resistance training, there is evidence that endurance training results in a preferential increase in type I muscle fibers, significant decrease in type IIx fibers and an minimal increase of type IIa fibers (11,81). Lastly, endurance training has been found to induce mitochondrial biogenesis (172), increasing the mitochondrial content of skeletal muscle fibers (81) and subsequently, the oxidative capacity for energy metabolism (11,81).
The 30-15 IFT represents a form of aerobic training known as high intensity interval training (HIIT). HIIT involves performing an activity in intervals with set work-to-rest ratios at generally high intensities whereas endurance training is commonly performed for long, continuous durations. A meta-analysis comparing the effects of HIIT and continuous endurance training found that both modalities elicit improvements in VO$_2$max (76,105), with HIIT experiencing greater overall gains (105). Additionally, HIIT has also been found to elicit positive adaptations to anaerobic power (67,174) and athletic performances (67,112).

2.6 Occupational Physical Ability Test

Understanding the occupational demands of LEOs is a key component for a needs analysis determination of the types of physical training and assessments that are appropriate for this population (129). Although general physical fitness parameters are typically assessed (e.g., push-up, sit-ups, etc.) these assessments typically represent the athleticism of the recruits (66). In contrast, occupational physical ability tests (OPATs) represent simulated scenarios that may be experienced in the field and can subsequently evaluate a recruit’s occupational readiness (66,130). Although the legality of using OPAT performances for hiring LEOs will not be discussed in this review, it is an important factor which affects development and utilization of OPATs. As such, OPATs must be objective assessments that reflect occupational physical demands observed in the line-of-duty and use minimal nondiscriminatory standards (164).

Although there is a wide variety of OPATs utilized in the law enforcement academies, a few specific examples will be described here. The POPAT (Police Officers
Physical Abilities Test) has been thoroughly investigated and subsequently modified since its creation in 1985 (130). It consists of an obstacle run, push/pull apparatus and an agility course that represent three different commonly experienced scenarios: lift and carry, pursuit and arrest (130). The scoring of POPAT is based on the time of completion with a passing cut off time of 4 minutes and 15 seconds (130). One significant drawback of the test, however, came in regards to gender differences of the cohort where only 16% of the women and 68% of the men had successfully completed the test (130). The authors suggested that lack of experiences with OPATs as well as a sedentary lifestyle may have contributed to the results. A modified version of the POPAT, the Physical Abilities Requirement Evaluation (PARE) was developed with the potential to “survive a Humans Rights challenge” (10,148). Through an independent evaluation of the portions of the POPAT that had an significant inverse impact on women’s performance, several portions of the test were removed or retimed (2). Additionally, an evaluation of officers completing the PARE test pre-training and after an 18-month training intervention found an increase in passing rate from 60% to 93% (2). Ultimately, the PARE has been considered a defensible physical ability test that can be used for law enforcement (2,10,164).

If an OPAT a portion of an academy training program used to hire law enforcement personnel, it is important to make sure the physical training performed reflects ways to improve OPAT outcomes. For example, Rhodes and Farenholtz (130) compared the POPAT total completion times to a variety of fitness tests and graded exercise tests and determined that 50% of the variance in POPAT completion times were explained by maximal aerobic power and anaerobic capacity. Similarly, Stanish et al. (148) found that 77% of the variance in PARE completion time could be explained by body fat percentage
and maximal aerobic power. Subsequently, Stanish et al. (148) also found that 79% of the variance in PARE times in males are attributed to agility, standing long jump and a bench press done at 70 lb whereas, 43% of the variance in women was explained by agility.

Similar investigations using OPATs created for specific law enforcement populations have also been assessed. Beck et al. (6) evaluated the fitness characteristics needed to successfully complete an Officer Physical Ability Test in campus law enforcement officers. The authors found that agility and aerobic endurance were significantly correlated with the OPAT times while a variety of other physical fitness parameters were associated with specific components of the OPAT (6). Furthermore, officer age was significantly correlated to both physical fitness and OPAT completion time, suggesting the importance of maintaining fitness across the career span (6). Dawes et al. (43) evaluated the relationship between several physical fitness tests and a physical ability test designed for active duty highway patrol officers. With regards to general fitness categories, the authors found that anaerobic power, aerobic and muscular fitness were significant predictors of OPAT performance (43). Moreover, the specific physical fitness tests that had an impact on OPAT scores were the vertical jump, sit-up, push-up and 20 m multistage fitness test (43).

In summary, physical ability tests are simulated job tasks that can be used to determine law enforcement recruits’ occupational readiness (129). In developing these tests, it is crucial that they represent an objective measurement of actual jobs tasks and have minimal non-discriminatory standards (164). A variety of OPATs have been designed for law enforcement, including the POPAT and PARE (2,130). It has been shown that reasonable physical fitness is needed to pass these tests, and improving overall physical
fitness can increase performance times (2). Furthermore, OPATs should represent a variety of physical abilities (2,6,34,43,130,156) which could be developed through an academy training program. Overall, implementing OPATs in basic training academies could provide an effective, objective measure of occupational readiness in recruits. Moreover, it can be used as a tool to evaluate and improve physical fitness training programs to better prepare recruits for the physical demands of law enforcement.

2.7 Summary

Law enforcement represents a diverse tactical population (129) whose occupational demands involve long periods of sedentary activity interspersed with high intensity activity (2,125). Police academies typically incorporate physical fitness training programs to train law enforcement cadets to be physically capable of completing critical job tasks. Currently in the United States, there are no universal standards regarding which evaluations should be used to determine physical preparedness, however, any test utilized for hiring or has punitive consequences must adhere to federal legislation regarding nondiscriminatory practices. Published literature regarding the effectiveness of a police academy training program to improve cadet physical fitness is scarce. An investigation by Martinez and Abel (100) evaluated the effectiveness of a 23-week police academy program and determined that new methodologies to develop aerobic endurance, anaerobic power, and muscular strength qualities were needed. Thus, the purpose of this literature review was to explore several high performance methodologies that could be implemented in police academies to enhance occupational readiness. First, APRE has been found to improve upper body strength over a brief training period (98) in American football players, but its applicability to law enforcement is unknown. Next, sRPE is an inexpensive, valid and
reliable method of monitoring training loads (58–61) which could be utilized to quantify overall training stress during the academy. Third, the 30-15 IFT is valid and reliable method for improving a variety of athletic qualities (22) via high intensity interval training and has been shown to improve aerobic performance (117) and reduce risk of injury in tactical populations (115). Lastly, OPATs are designed to reflect scenarios commonly experienced by incumbent officers (66,130) and can be utilized to evaluate a cadet's occupational readiness for job tasks (129).
CHAPTER 3. METHODOLOGY

3.1 Experimental Design

The purpose of this research project was to develop an evidence-based training program, implementing innovative high-performance methodologies to improve occupational fitness and performance outcomes in law enforcement cadets. Specifically, there are three specific aims targeted. First, the study examined the effectiveness of integrating APRE and HIIT to improve upper body strength, aerobic endurance and anaerobic capacity, and occupational physical ability compared to the academy’s standard training program. The second aim was to determine the cross-sectional relationship between physical fitness assessment outcomes versus OPAT completion times. Finally, the third aim was to descriptively profile sRPE outcomes during an academy training program to monitor training load parameters and assess risk of injury in cadets.

This investigation utilized a longitudinal quasi-experimental design inclusive of a standard care control group and a high performance training group, representing two consecutive academy classes from a state law enforcement training academy. Group assignment was not randomized. The 20-week Law Enforcement Academy program consisted of a 17-week physical training period with physical fitness, occupational performance and anthropometric assessments in both groups occurring at entrance, mid-point, and exit of the academy. Both groups collected daily sRPE for each training modality. The control group completed an unaltered academy training program. Alternatively, the experimental group completed a scaled HIIT program and APRE program during the academy. Table 3.1 provides an overview of the academy’s schedule.
Table 3.1. Law enforcement academy training program timeline.

<table>
<thead>
<tr>
<th>Academy week</th>
<th>Training week</th>
<th>Fitness assessment</th>
<th>OPAT</th>
<th>APRE*</th>
<th>30-15 IFT*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Entrance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Familiarization</td>
<td></td>
<td>30-15 IFT</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>OPAT</td>
<td>Program 1</td>
<td></td>
<td>30-15 IFT</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
<td>Program 1</td>
<td></td>
</tr>
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<td>4</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>8</td>
<td>Midpoint</td>
<td>OPAT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td></td>
<td></td>
<td>Program 2</td>
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<td></td>
</tr>
<tr>
<td>17</td>
<td>16</td>
<td>OPAT</td>
<td></td>
<td>30-15 IFT</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>17</td>
<td>Exit Test</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>19</td>
<td>18</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>20</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Experimental group only

3.2 Subjects

A convenience sample of 63 cadets participated in this study. Table 3.2 describes the demographic and anthropometric outcomes for the cadets.
Table 3.2. Subjects’ demographic and physical characteristics stratified by cohort and sex.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>% of cohort</th>
<th>Age (yr)</th>
<th>Body mass (kg)</th>
<th>Height (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>27</td>
<td>84.4%</td>
<td>27.4 ± 5.4</td>
<td>97.4 ± 17.1</td>
<td>181.3 ± 7.5</td>
</tr>
<tr>
<td>Female</td>
<td>5</td>
<td>15.6%</td>
<td>26.2 ± 3.1</td>
<td>69.1 ± 10.8</td>
<td>166.6 ± 7.7</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>100%</td>
<td>27.2 ± 5.1</td>
<td>93.0 ± 19.2</td>
<td>179.0 ± 9.2</td>
</tr>
<tr>
<td><strong>Experimental</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>27</td>
<td>87.1%</td>
<td>28.9 ± 8.1</td>
<td>92.7 ± 17.1</td>
<td>181.0 ± 6.4</td>
</tr>
<tr>
<td>Female</td>
<td>4</td>
<td>12.9%</td>
<td>24.5 ± 1.3</td>
<td>60.4 ± 8.2</td>
<td>163.2 ± 5.2</td>
</tr>
<tr>
<td>Total</td>
<td>31</td>
<td>100%</td>
<td>28.4 ± 7.7</td>
<td>88.5 ± 20.3</td>
<td>178.7 ± 8.7</td>
</tr>
</tbody>
</table>

3.3 Procedures

**Physical Fitness Tests and Anthropometrics**

Standard care practices of the academy included a fitness battery administered by the academy training staff which consisted of five physical fitness tests: one repetition (1RM) bench press, number of sit-ups completed in one minute, 300 m run, number of push-ups completed in 2 min, and 1.5 mile run. The following section outlines the test procedures administered during each of the fitness evaluations (50). Prior to the start of the fitness assessment, subjects’ body mass were measured on a stadiometer (Healthometer 499KL, Sunbeam, Boca Raton, FL) and standing height was self-reported to the instructor.

**1-RM Bench Press**

Each cadet was allowed three minutes to warm-up. Each test lift was spotted by two instructors with locking collars applied to the barbell for each set. A 7.62 cm thick sponge was fixed to the center of a standard barbell. During the entrance exam, the cadet utilized a load on the first set equal to or less than 55.3% of a resistance load-to-body mass (RL/BM) ratio. During the exit exam, the threshold was increased to less than 73% for the
first set and equal 73% for the second set. For each lift, the cadet was positioned with their eyes directly under the bar, both hands clasped around the bar, and feet flat on floor. The cadet lowered the barbell until the sponge touched their chest and pressed the barbell back to the starting position. If there was any violation of the protocol, including bouncing the barbell off of the chest, the lift was stopped and the recruit was notified of violation. The cadets were allowed a maximum of three minutes rest between attempts. During the entrance exam, the cadet increased the load lifted until the participant reached ≥73% RL/BM or failed on two consecutive attempts. During the exit exam, the test was terminated after a failed attempt occurred. Previous research has reported high test-retest reliability (ICC: 0.95-0.99) for this test (131,144).

**Sit-up Test**

The cadets were provided a 5-minute recovery period prior to performing the sit-up test. The sit-up test requires the cadet to perform a maximum number of repetitions in one-minute. The cadet lied supine on the floor, with feet flat and placed approximately hip width apart, and secured by another cadet. The cadet flexed their knees to 90 degrees and interlaced the fingers with hands placed behind the head. When performing the sit-up repetition, the elbows must cross the vertical plane of the knees during the upward movement phase, the shoulder blades must touch the floor during the downward movement phase, and the buttocks must remain in contact with the floor throughout the duration of the repetition. The cadet was allowed to rest in the “upward” position of the repetition, but not allowed to touch the ground or knees with their hands. The test was terminated when the cadet stopped or time expired. The academy required a minimum of 13 and 18 completed repetitions during the entrance and exit exams, respectively. Previous research
have found high test-retest reliability (ICC = 0.93) in similar evaluations of trunk muscular endurance (5).

300 Meter Run

The cadets were provided a 15-minute recovery period prior to performing the 300 m run. Cadets were encouraged to stretch prior to the test. Cadets completed a 300 m run on a 1/8th mile indoor track as fast as possible. The Academy required a maximum completion time of 68 s during the entrance exam and 65 s during the exit exam. Previous research have found high test-retest reliability (ICC = 0.98) in similar evaluations of anaerobic power (165).

Push-up Test

The cadets were provided with a 15-minute recovery period prior to performing the push-up test. Cadets performed as many push-up repetitions as possible in two minutes for the push-up test. There is a two minute time limit during the entrance exam, however, there is no time limit during the exit exam. The push-up position was defined as hands placed shoulder width apart, feet placed hip width apart, and body in a plank position. The cadet initiated the test in the upward position with the arms extended. The cadet lowered their body until the upper arms were parallel to the ground, then returned to the start position by extending the arms. Cadets were allowed to rest in the upward position, as long as the elevated plank position was maintained. The repetition did not count if the protocol instruction was violated. The academy required a minimum of 14 and 25 completed repetitions during the entrance and exit tests, respectively. Similar push-up protocols have higher reported reliability (ICC = 0.93-0.98) (5,111,133).
1.5 mile Run

The cadets were provided with a 30-minute recovery period prior to performing the push-up test. Cadets were encouraged to stretch prior to the start of the test. Cadets completed 12 laps on a 2.41 km (.125 mi) indoor track as fast as possible. The academy requires a minimum completion time of 17:56 and 16:15 minutes for the entrance and exit exams, respectively. All times were converted to fractional minutes for analysis. High test-retest reliability (ICC = 0.95) were reported in timed distance runs in different populations (27).

3.4 Daily Session RPE

Session RPE has been found to have a high test-retest reliability (ICC=0.78) (79) and valid for monitoring resistance training (44,52,79,80,122,145), aerobic training (58–61) and combat skills training (147). Session RPE was evaluated each day (excluding weekends) from the academy training program. At least thirty minutes after the completion of a training session, the cadets complete an online survey (Table 3.3) to rate the perceived intensity using the Borg CR-10 RPE Scale (114) and listed the exercise duration of resistance training, aerobic training, defensive tactics and overall (global) workout. Cadet submissions were populated onto a spreadsheet for analysis. Session RPE was calculated as reported RPE intensity multiplied by exercise duration (representing training load), for each respective training type. Raw data were cleaned by removing duplicates and cadets who separated from the training academy prior to completion of the academy training (Figure 4.5). Similar to existing literature (102,136), when values were partially reported, the daily average of the value was entered. All cadet responses were averaged into single
daily cohort values for each respective training type and used for subsequent analysis. Reponses rates were calculated as the number of cadets who responded divided by the total amount of cadets in each respective group.

Table 3.3. Daily session rating of perceived exertion (sRPE) online survey form.

How would you rate today’s workout?

<table>
<thead>
<tr>
<th>Rating</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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</thead>
<tbody>
<tr>
<td>Descriptor</td>
<td>Rest</td>
<td>Very, Very Easy</td>
<td>Easy</td>
<td>Moderate</td>
<td>Some what hard</td>
<td>Hard</td>
<td>*</td>
<td>Very Hard</td>
<td>*</td>
<td>*</td>
<td>Maximal</td>
</tr>
</tbody>
</table>

*Required

3.5 30-15 Intermittent Fitness Test and High Intensity Interval Program

The 30-15 IFT protocol consists of a 30 s shuttle run followed by 15 s of active recovery (24). The 30-15 IFT has a high test-retest reliability (ICC = 0.84) (21) and is a valid measure of indices of aerobic (22,23,26) and anaerobic fitness (22). Using a prerecorded audio file consisting of auditory tones, the cadets were required to run back and forth between two sets of lines 28 m apart (Figure 3.1). The velocity of the first 30 s stage was set at 8 km·hr⁻¹ with the speed increasing 0.5 km·hr⁻¹ for each subsequent stage.
There was a 2 m “safe zone” placed at each of the primary lines (Figure 3.1, Lines A, B, & C) which, in conjunction with the tones, allowed the cadets to monitor their running pace. During the 15 s recovery period, the cadets were instructed to walk forward to the nearest line to begin the next stage. Cadets were instructed to complete as many stages as possible. Termination of the protocol occurred when the cadet was no longer able to maintain the required running velocity or unable to reach the 2 meter safe zone in time with the audio signal, three consecutive times. The velocity from the last successfully completed stage determined the cadet’s $V_{IFT}$ (velocity of the Intermittent Fitness Test).

![Figure 3.1. Diagram of the 28 and 40m layouts of the 30-15 Intermittent Fitness Test. Adapted from Buchheit (2019) (25).](image)

Table 3.4 outlines the 12-week shuttle run program completed once per week during the training academy. The results of the entrance and midpoint 30-15 IFT were used to program phase 1 (training weeks 3-8) and phase 2 (training weeks 10-15), respectively. A spreadsheet was created with each cadet’s $V_{IFT}$ results to calculate individualized shuttle
run distances, and thus velocities, for each shuttle intensity, and rounded to the nearest fifth meter. Thus, the shuttle run velocities were individually set based on the fitness level of each cadet, such that the relative intensity was similar for each cadet, but the absolute running velocity varied. Each set of workout intervals was two minutes in duration. Upon completion of the two minute interval, the cadet was provided with two minutes of recovery while another cadet started their interval. Two 40 meter course layouts with cones at five meter intervals were applied to the academy’s running track for the shuttle runs.

Table 3.4. 30-15 Intermittent fitness test and shuttle run program parameters.

<table>
<thead>
<tr>
<th>Training Week</th>
<th>Test</th>
<th>Work (s)</th>
<th>Rest (s)</th>
<th>Intensity (% V_{IFT})</th>
<th># of intervals</th>
<th>Sets</th>
<th>Inter-set Recovery duration (min)</th>
<th>Total work duration (min)</th>
<th>Total exercise duration (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>30-15</td>
<td>20</td>
<td>20</td>
<td>90</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>14-16</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>20</td>
<td>92</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>14-16</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>15</td>
<td>95</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>14-16</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>15</td>
<td>98</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>14-16</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>10</td>
<td>101</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>12-14</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>10</td>
<td>104</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>12-14</td>
</tr>
<tr>
<td>8</td>
<td>30-15</td>
<td>20</td>
<td>20</td>
<td>92</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>12-14</td>
</tr>
<tr>
<td>9</td>
<td>20</td>
<td>20</td>
<td>95</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>12-14</td>
</tr>
<tr>
<td>10</td>
<td>15</td>
<td>15</td>
<td>98</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>12-14</td>
</tr>
<tr>
<td>11</td>
<td>15</td>
<td>15</td>
<td>101</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>12-14</td>
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<tr>
<td>12</td>
<td>10</td>
<td>10</td>
<td>104</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>10-12</td>
</tr>
<tr>
<td>13</td>
<td>10</td>
<td>10</td>
<td>107</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>10-12</td>
</tr>
<tr>
<td>14</td>
<td>30-15</td>
<td>20</td>
<td>20</td>
<td>92</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>12-14</td>
</tr>
</tbody>
</table>

Active running distances were calculated by first converting the running speed in km·h⁻¹ to m·s⁻¹, and then multiplying the converted running velocity by the active running interval time. The result is the total straight distance covered. The straight distance was then divided by the course distance (i.e., 28 meters) to determine the number of turns to be completed. A correctional factor was applied for the number of turns performed per repetition. Specifically, 0.7 s was subtracted from the active running time (118). Finally, the corrected
time was multiplied by the running velocity (m·s$^{-1}$) to calculate the final active running distance.

3.6 Autoregulatory Progressive Resistance Training

The APRE protocol was selected based on its success with American Football players (98). The APRE protocol utilized the entrance and midpoint 1RM bench press assessment results for subsequent programming. The APRE portion of the program only utilized the bench press exercise to demonstrate a proof-of-concept. Specifically, the 10-RM (repetition maximum), 6-RM and 3-RM APRE protocols outlined by Siff (162) (Table 3.5) were utilized for exercise programming and each of the protocols followed the same progressive parameter scheme. The first two sets of the bench press within a training session were performed at submaximal intensities. The third set consisted of the cadet performing repetitions to fatigue with the specified RM load. Utilizing the table provided, the cadet then adjusted their load for the last set based on the number of repetitions performed in set 3. Set 4 was then completed for maximum repetitions of the new load. Similar to set 3, the cadet utilized the table to determine the starting RM load for the next bench press resistance training session. The cadets had a two minute rest period between each of the work sets. Table 3.6 outlines the 14-week linear periodized APRE program for the experimental group. When the protocol changed within the program, the final RM workload of the last workout was used to estimate their 1-RM, which was converted to the new protocol’s estimated RM. The “Estimating 1-RM and Training loads” (74); p 455-56) was used for RM conversions.
Table 3.5. 3-, 6-, and 10 repetition maximum (RM) autoregulatory progressive resistance exercise protocol.

<table>
<thead>
<tr>
<th>Set</th>
<th>3RM Routine</th>
<th>Set</th>
<th>6RM Routine</th>
<th>Set</th>
<th>10RM Routine</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Warm up</td>
<td>0</td>
<td>Warm up</td>
<td>0</td>
<td>Warm up</td>
</tr>
<tr>
<td>1</td>
<td>6 reps @ 50% of 3RM</td>
<td>1</td>
<td>10 reps @ 50% of 6RM</td>
<td>1</td>
<td>12 reps @ 50% of 10RM</td>
</tr>
<tr>
<td>2</td>
<td>3 reps @ 75% of 3RM</td>
<td>2</td>
<td>6 reps @ 75% of 6RM</td>
<td>2</td>
<td>10 reps @ 75% of 10RM</td>
</tr>
<tr>
<td>3</td>
<td>Reps to failure @ 3RM</td>
<td>3</td>
<td>Reps to failure @ 6RM</td>
<td>3</td>
<td>Reps to failure @ 10RM</td>
</tr>
<tr>
<td>4</td>
<td>Adjusted reps to failure</td>
<td>4</td>
<td>Adjusted reps to failure</td>
<td>4</td>
<td>Adjusted reps to failure</td>
</tr>
</tbody>
</table>

Repetition-Load Adjustment Table

<table>
<thead>
<tr>
<th>Repetitions Completed</th>
<th>Weight Change</th>
<th>Repetitions Completed</th>
<th>Weight Change</th>
<th>Repetitions Completed</th>
<th>Weight Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>-5 - 10lb</td>
<td>0-2</td>
<td>-5 - 10lb</td>
<td>4 - 6</td>
<td>-5 - 10lb</td>
</tr>
<tr>
<td>3-4</td>
<td>No change</td>
<td>3-4</td>
<td>-0 - 5lb</td>
<td>7 - 8</td>
<td>0 - 5lb</td>
</tr>
<tr>
<td>5-6</td>
<td>+5 - 10lb</td>
<td>5-7</td>
<td>Leave same</td>
<td>9 - 11</td>
<td>Leave same</td>
</tr>
<tr>
<td>7+</td>
<td>+10 - 20lb</td>
<td>8-12</td>
<td>+5 - 10lb</td>
<td>12 - 16</td>
<td>+5 - 10lb</td>
</tr>
</tbody>
</table>

Table 3.6. 14-week periodized autoregulatory progressive resistance exercise (APRE) bench press program.

<table>
<thead>
<tr>
<th>Training Week</th>
<th>Protocol</th>
<th>Training Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-4</td>
<td>10RM</td>
<td>Hypertrophy</td>
</tr>
<tr>
<td>5-6</td>
<td>6RM</td>
<td>Strength/Hypertrophy</td>
</tr>
<tr>
<td>7-8</td>
<td>3RM</td>
<td>Strength/Power</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Midpoint Fitness Assessment</td>
</tr>
<tr>
<td>10-11</td>
<td>10RM</td>
<td>Hypertrophy</td>
</tr>
<tr>
<td>12-14</td>
<td>6RM</td>
<td>Strength/Hypertrophy</td>
</tr>
<tr>
<td>15-16</td>
<td>3RM</td>
<td>Strength/Power</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exit Fitness Assessment</td>
</tr>
</tbody>
</table>

3.7 Occupational Physical Ability Test

For this investigation, the experimental OPAT utilized was developed based on a modified POPAT taken from a law enforcement agency from the southeastern United States as well as feedback from the training staff of the training academy. Figure 3.2 represents the layout of the OPAT course on a running track. Course completion procedures were as follows: The cadet began seated on a 0.46 m box, located 1.52 m from
cone A. The cadet ran around cone B and returned to cone A. This was then repeated one time for a total run distance of about 48.8 m. When the cadet approached cone A, they ran around the left side of cone A towards cone C. At cone C, the cadet ran towards the obstacle course. The cadet performed a 1.22 m long jump, 12.19 m from Cone C. The cadet then scaled and descended a 1.22 m barrier. Next, the Cadet performed a 0.61 m crawl under a barrier. Next, the cadet ran around cone D towards cone E. The cadet ran towards the left side of cone E, straddled a 31.75 kg bag and performed 3 complete lateral rolls. The cadet performed 10 push-ups and then performed 3 bag straddle rolls. The cadet then stood up and ran behind cone E towards cone C. The cadet repeated the obstacle course, running towards cone D. The cadet ran around cone D towards cone E. The cadet then made a left turn around cone E and ran towards the step box. The cadet performed 12 step-ups on a 0.31 m box. For each step-up, both feet had to touch the step. The count went “one, two” step down, step down, “three, four”, step down, step down”. Upon completion of the step-ups, the cadet ran from point G towards cone F, 15.24 m away. The cadet then ran around cone F towards point G. When the cadet reached point G, they completed 12 more step-ups. Once completed the cadet moved towards the victim drag station. When the cadet touched the mannequin, a split time representing the chase and apprehend portion of the test was recorded. The cadet then positioned themselves behind the 41 kg mannequin equipped with a 11 kg weighted vest (52 kg total), grabbed the mannequin by the wrist and dragged it 15.24 m (from cones H to I). Final completion time was recorded when the mannequin’s feet passed cone I. The victim drag time was calculated as completion time minus chase and apprehension time. All times were converted to fractional minutes for analysis.
Figure 3.2. Schematic of occupational physical ability test.

3.8 Statistical Analysis

Data were reported as mean ± standard deviation. Normality of data was assessed using Shapiro-Wilks tests.

Aim #1: Based on the results of an a priori power analysis (effect size ($f$) = 0.25, power = 0.8, alpha = 0.05), 28 subjects were required to identify a significant interaction effect of group on fitness and OPAT outcomes. The relative change in fitness outcomes
across the time points was calculated relative to the baseline value: (% Difference = posttest value − entrance value) / entrance value) x 100). 3 x 2 (time vs. group) mixed factor repeated measures ANOVA were used to evaluate the effects of the training interventions over time on performance outcomes in cadets. If the assumption of sphericity was violated, the Greenhouse-Geisser adjusted values were reported. Independent t-tests were used for post-hoc analysis to identify differences between groups at the three time points and a Bonferroni adjustment (i.e., $p \leq 0.017$) was applied to control for inflation of Type I error. Cohen’s $f$ effect sizes were defined as 0.1, 0.25, and 0.40 (small, medium, large, respectively) (38). Furthermore, partial eta squared ($\eta^2_p$) effect sizes are defined as 0.01, 0.06 and 0.14 (small, medium, large, respectively) (132).

In addition to traditional statistical methods, hierarchal linear modeling (HLM) techniques were also used. The assumption of sphericity (i.e., the assumed variance between each repeated measure is equal) (163), must be met to utilize repeated measures ANOVA statistics. If violated, one must use correction factors (e.g., Greenhouse Geisser) in order to interpret the results. In contrast, HLM models do not operate under the assumption of sphericity (124) and therefore can be utilized as an alternative method in analyzing repeated measures data that violate sphericity, such as the data included this study. HLM is an extension of traditional regression analysis techniques (84) where grouped data (84,126) (i.e., multiple time points per person) are organized into a hierarchical structure allowing variables estimated in one level to become outcome variables in a subsequent level (126). Furthermore, it allows for simultaneous evaluation of relationships for within and between subject factors (169). HLM is commonly employed in health-related (84,169) research.
Two-level HLM growth models utilizing the entire cohort were used in the current analysis. Simple growth models were first completed for each dependent variable (i.e., 1-RM bench press, sit-ups, 300 m run, push-ups, 1.5 mile run and OPAT completion time) which served as the 1st level of their respective HLM analysis. This level provides average value and variance information for the initial status (I.S.; representing average baseline fitness performance) and rate of growth (RoG; representing the average change in performance between each time point) for each variable (94). The level-two model introduced several between-subject variables to develop more complex growth models (94). If any of the between subject variables for I.S. and/or RoG were statistically significant, the proportion of variance explained by the final model ($R^2$) was calculated (126,169). The between subject factors assessed in this investigation were: age, sex (male vs. female), group (control vs. experimental) and specialty (non-specialty vs. specialty group). The specialty group represents cadets whom typically undergo additional training for the municipality they represent (i.e., Fish and Wildlife).

Additional information typically found in HLM outputs includes true parameter variance (i.e., variance in I.S and RoG measurements adjusted for measurement and sampling error (94)) and observed parameter variance (i.e., parameter variance plus sampling error variance (126,127)). Furthermore, the ratio of true parameter variance and observed parameter variance is known as the Reliability of Estimates which reflects the level of variation found in I.S. and RoG parameters among subjects (94,127). Finally, correlations between I.S and RoG reflect the type of growth pattern observed with dependent variable. Two common growth patterns observed are (29) are fan-open (increased growth over time) and fan-closed (reduced growth over time).
Aim #2: A regression tree analysis was performed to explore the potential predictors of OPAT performance. Furthermore, stepwise multiple linear regression analysis was performed to determine predictors of OPAT entrance performance. Bivariate correlations were used to determine the relationship between entrance OPAT performance times and physical fitness assessment parameters.

Aim #3: Independent t-tests were used to compare the reported intensity, duration and sRPE values between the groups. Global sRPE values were used to calculate training load (weekly sum of daily training loads), training monotony (training load divided by weekly training load standard deviation) and training strain (summed weekly training load divided by training monotony) (104). Furthermore, a 7:21 A:C ratio (102) was calculated using a rolling 7-day average of global sRPE values divided by a rolling 21-day average of global sRPE. Dates of injury incidences and event classifications (physical training assessments, defensive tactic assessments, academic tests, & officer skills tests) were collected for each group.

The following criteria were used to interpret all correlation coefficients: negligible (r = 0 - 0.1), weak (r = 0.10 - 0.39), moderate (r = 0.40 - 0.69), strong (r = 0.70 - 0.89) and very strong (r = 0.90 - 1.0) (137). Significance was set to p < 0.05 for all analysis unless otherwise specified. Microsoft Excel, SPSS Software Program (version 26.0; SPSS, Inc., Chicago, IL) and HLM 8 for Windows (Scientific Software International, Inc, Skokie, IL) were used to organize and analyze the data.
CHAPTER 4. RESULTS AND DISCUSSION

4.1 Results

4.1.1 Aim #1

Figure 4.1a-f presents the results of the physical fitness and OPAT assessments during the academy training program. Regarding the entire cohort, there was a significant main effect of group on push-up performance ($F(2,118)=6.658$, $p=0.001$, $\eta^2=0.10$, power 0.91; Figure 4.1d). Specifically, the experimental group completed more push-ups than the control group at entrance and exit exams. Among all cadets and fitness assessments there were main effects for time such that all physical assessments significantly improved throughout the training program. Specifically, there were improvements in the 1-RM bench press ($F(1.74,106.2)=47.6$ $p<0.001$, $\eta^2=0.44$, observed power =1.0; Figure 4.1a), sit-ups completed ($F(2,122)=462.6$ $p<0.001$, $\eta^2=0.51$, observed power =1.0; Figure 4.1b), 300 m run time ($F(2,118)=47.4$ $p<0.001$, $\eta^2=0.45$, observed power =1.0; Figure 4.1c) and 1.5 mile run time ($F(1.5, 86.9)=115.1$ $p<0.001$, $\eta^2=0.66$, observed power=1; Figure 4.1e) In contrast, there was a significant increase in OPAT completion time ($F(1.4, 80.6)=32.1$ $p<0.001$, $\eta^2=0.36$, observed power =1.0; Figure 4.1e) between the entrance and exit assessments. Figure 4.2 presents the average relative change in performance for all assessments between the control and experimental groups. Overall, push-ups had the greatest average relative improvement whereas the smallest relative improvement occurred in the OPAT. Sit-up, 300 m run, push-up, 1.5 mile run and OPAT assessments had greater relative improvement between the first half of the training program (entrance vs. mid-point) compared with last half (mid-point vs. exit).
Figure 4.1a-f. Comparison of physical fitness and occupational physical ability test (OPAT) outcomes between control and experimental groups at three time points (entrance, mid-point, and exit) during a police academy training program. Values represent mean ± SD.

The OPAT completion times in both groups experienced similar relative improvement to push-ups in the first half of the training program, however, the second half of the training program led to a regression of OPAT performance. The control group
experienced higher relative improvements during the first half of the training program in all assessments compared to the experimental group (p < .05). Similarly, the control group had greater improvements in the second half of the training program in all tests except push-ups and 1.5 mile run compared to the experimental group. Moreover, the control group experienced an increase in their 1.5 mile run time during the second half of the training program (p=0.163).

Figure 4.2. Average relative improvement in physical fitness outcomes between control and experimental groups. Entrance (ent), Mid-point (mid), Exit (ext). ¹ Significant difference (p<0.01) from ent-mid. ² Significant difference (p<0.01) from mid-ext. ³ Significant difference (p<0.01) from ent-ext. a Significant difference (p<0.05) from ent-mid. b Significant difference (p<0.01) from ent-ext.

Table 4.1 presents the results of the HLM growth models for the physical fitness assessments of entire cohort. For the bench press performance, real growth was observed (p<0.001), as there was a correlation of -0.34 between initial status and RoG, suggesting a fan-closed growth pattern. On average, the cadets increased their bench press performance by 4.7 ± 1.5 kg during each training phase, for an average total increase of 9.4 kg during the academy training program. There were significant differences noted in RoG (p<0.001),
however, the differences were not explained by age, sex, group or specialty. Sex was a factor that affected initial bench press performance (p=0.001), such that male cadets lifted, on average, 53.8 kg more than female cadets, while holding all other variables constant. Approximately 38.3% of the variance in baseline bench press performance can be explained by this model.

For the sit-up performance, real growth was observed (p<0.001) as there was a correlation of -0.74 between initial status and RoG suggesting a fan-closed growth pattern. On average, the cadets increased their average sit-up performance by 2.8 ± 1.03 repetitions during each training phase for an average increase of 5.6 repetitions during the academy training program. There were no significant differences found in RoG (p=0.091). None of the between-subject factors explained the variation in baseline bench press performance.

For the 300 m run performance, there was a correlation of -0.15 between initial status and RoG suggesting a fan-closed growth pattern. Real growth was observed (p<0.001). On average, the cadets decreased their 300 m performance time by 1.4 ± 1.8 s for a total average decrease of 2.8 s during the academy training program. There were no significant differences in RoG. Between-subject factors of sex and specialty were found to affect initial 300 m performance such that female cadets completed the 300 m run, on average, 6.3 s slower compared to male cadets (p<0.001) and cadets in the specialty group completed the 300 m run, on average, 3.3 seconds faster than the non-specialty group (p=0.036), holding all other variables constant. Approximately 21.2% of the variance in baseline 300 m run time can be explained by the final model.
Table 4.1. Hierarchical linear growth models for the fitness assessments of the entire cohort.

<table>
<thead>
<tr>
<th>n=63</th>
<th>Bench Press (kg)</th>
<th>Sit Ups (reps)</th>
<th>300m Run (s)</th>
<th>Push Ups (reps)</th>
<th>1.5 Mile run (min)</th>
<th>OPAT (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Unconditional Model</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>HLM Results Describing Variation In Initial Fitness Performance And Rate Of Growth In Law Enforcement Cadets</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Average Within-Student Model</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Fixed Effects</strong></td>
<td><strong>I.S.</strong></td>
<td><strong>RoG</strong></td>
<td><strong>I.S.</strong></td>
<td><strong>RoG</strong></td>
<td><strong>I.S.</strong></td>
</tr>
<tr>
<td>Effect</td>
<td>92.4</td>
<td>4.7</td>
<td>38.8</td>
<td>2.8</td>
<td>53.8</td>
<td>-1.38</td>
</tr>
<tr>
<td>SE</td>
<td>3.7</td>
<td>0.57</td>
<td>0.88</td>
<td>0.29</td>
<td>0.63</td>
<td>0.16</td>
</tr>
</tbody>
</table>

|      | **Observed Parameter Variance** |                  |            |                |                  |            |
|      | **Estimate** | **Estimate** | **Estimate** | **Estimate** | **Estimate** | **Estimate** |
| I.S. | 843.1 | 49.2 | 25.2 | 196.1 | 3.1 | 0.06 |
| RoG | 20.8 | 5.35 | 1.5 | 26.7 | 4.1 | 0.4 |

|      | **True Parameter Variance** |                  |            |                |                  |            |
|      | **Est.** | **X^2** | **Est.** | **X^2** | **Est.** | **X^2** | **Est.** | **X^2** | **Est.** | **X^2** |
| I.S. | 826.2 | 3009.3 | 42.8 | 431.1 | 22.4 | 574.1 | 147.1 | 248.1 | 2.7 | 432.5 | 0.04 | 214.6 |
| RoG | 10.2^c | 122.4 | 1.07^m | 77.3 | 0.006^m | 56.02 | 2.4^m | 66.0 | 0.7^m | 62.4 | 0.02^m | 61.6 |

|      | **Reliability Estimates** |                  |            |                |                  |            |
|      | **r** | **-0.34** | **-0.74** | **-0.15** | **-0.84** | **-0.99** | **-0.98** |

|      | **Conditional Model** |                  |            |                |                  |            |
|      | **HLM Results Explaining Variation Of Initial Fitness Performance Status Of Law Enforcement Cadets.** |                  |            |                |                  |            |
|      | **Averages Within-Student Models** |                  |            |                |                  |            |
|      | **Fixed Effects** | **Effect** | **SE** | **Effect** | **SE** | **Effect** | **SE** | **Effect** | **SE** | **Effect** | **SE** | **Effect** | **SE** |
| Sex | 53.8^c | 3.8 | - | - | -6.3^c | 1.5 | 12.3^c | 3.3 | - | - | -0.13^a | 0.06 |
| Group | - | - | - | - | - | - | - | - | -3.3^a | 1.5 | 8.1^a | 3.4 | - | - |
| Specialty | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

|      | **Correlation Between Initial Status and Rate of Growth** |                  |            |                |                  |            |
|      | **r^2** | **0.38** | **0.21** | **0.20** | **0.07** | **0.08** |

SE: Standard Error
I.S.: Initial Status, RoG: Rate of Growth
Mean I.S. and RoG P<0.001 for all tests.
N^aNot statistically significant, ^bP<0.05, ^cP<0.01, ^dP<0.001

For the push-up test, there was a correlation of -0.84 between initial status and RoG suggesting a fan-closed growth pattern. Real growth was observed (p<0.001). On average, the cadets increased the number of push-ups performed by 6.9 ± 1.5 repetitions each training phase for a total average increase of 13.8 repetitions during the academy training program. There were no significant differences in RoG (p=0.34). Between-subject factors of sex and specialty sub-discipline were found to affect baseline push-up performance.
Specifically, male cadets performed, on average, 12.3 repetitions more than female cadets (p<0.001) and cadets in the specialty group performed, on average, 8.1 repetitions more than the non-specialty group (p=0.02), holding all other variables constant. Approximately 19.8% of the variance in baseline push-up performance was accounted for by the final model.

For the 1.5 mile run test, there was a correlation of -0.99 between initial status and RoG suggesting a fan-closed growth pattern. Real growth was observed (p<0.001). On average, the cadets decreased their 1.5 mile run time by 0.75 ± 0.23 minutes during each training phase for a total average decrease of 1.5 min during the academy training program. There were no significant differences in RoG (p=0.463). The between-subject factor of Group affected baseline 1.5 mile run performance such that the experimental group completed the run, on average, 0.81 min faster than the control group (p=0.014), holding all other variables constant. Approximately 6.5% of the variance in baseline 1.5 mile run performance was accounted for by the final model.

For the OPAT performance, there was a correlation of -0.98 between initial status and RoG suggesting a fan-closed growth pattern. There was real growth (p<0.001). On average, the cadets increased their OPAT completion time by approximately 0.05 ± 0.02 minutes during each training phase, for a total average increase of 0.1 min during the academy training program. There were no significant differences in RoG (p>0.5). Sex was a between-subject factor that affected baseline OPAT performance (p=0.042). Specifically, female cadets completed the OPAT 0.13 minutes slower than male cadets, holding all other variables constant. Approximately 8.1% if the variance in baseline OPAT performance is accounted for by the final model.
Figures 4.3a-d present the average weekly training load (sRPE) for each mode of training between both classes. The experimental group reported a significantly smaller sRPE values compared to the control group for all types of training throughout the length of the academy training program.
Figure 4.3a-d. Average weekly training load for resistance training (RT), aerobic training (AT), defensive tactics (DT) and overall workout (Global) between control and experimental groups. Values represent mean ± SD. *Significant difference (p<0.05) from experiment.
4.1.2 Aim #2

Figure 4.4 presents the results of a regression tree analysis of initial OPAT performance. In this analysis, there were six terminal nodes that are described in descending order from best to worst entrance OPAT performance. The cadets who performed the best (n=14, mean 1.68 ± 0.11 mins) on the initial OPAT test had 300 m run times less than or equal to 50.5 s. All subjects in this node were male (age = 28.8 yrs, height = 176.9 cm, and weight = 81.3 kg). The next group (n=10, had mean initial OPAT = 1.92 ± 0.1 mins) had 300 m run times greater than 57.5 s. All subjects in this group were male (age = 25.9 yrs, height = 182.6 cm, and weight = 87.8 kg).

Figure 4.4. Regression tree analysis of initial occupational physical ability test (OPAT) performance.
The next group (n=10, mean initial OPAT = 1.98 ± 0.1 mins) had 300 m run times less than or equal to 57.5 s and performed greater than 30.5 push-ups. There were 9 male and 1 female subject in this group (mean age = 25.9 yrs, mean height = 182.6 cm, and mean weight = 87.8 kg). The next group (n=9, mean initial OPAT = 2.1 ± 0.1 mins) had 300 m run times less than or equal to 57.5 s and less than or equal to 30.5 push-ups. There were 6 male and 3 female subjects in this group (mean age = 27.6 yrs, mean height = 177.2 cm, and mean weight = 88.9 kg). The next group (n=8, mean initial OPAT = 2.14 ± 0.1 mins) on the initial OPAT test had 300 m run times greater than 57.5 s and greater than 30.5 push-ups. There were 6 male and 2 female subjects in this group (mean age = 27 yrs, mean height = 179.4 cm, and mean weight = 96.3 kg). Finally, the last node represents the worst performers (n=9, mean initial OPAT= 2.35 ± 0.14 mins), had 300 m run completion times greater than 57.5 seconds and performed less than or equal to 29 push-ups. There were 6 male and 3 female subjects in this group (mean age = 29.6 yrs, mean height = 179.5 cm, and mean weight = 99.4 kg).

Table 4.2 presents the results of a stepwise multiple linear regression analysis of initial OPAT performance. The final model determining initial OPAT performance time included the 300 m run completion time (p < 0.001), body mass (p = 0.005), 1-RM bench press (p = 0.044) and push-ups (p = 0.058).
Table 4.2. Stepwise multiple linear regression models predicting entrance occupational physical ability test (OPAT) completion times with physical fitness assessments in 60 law enforcement cadets.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-0.127 NS</td>
<td>0.684</td>
<td>0.565*</td>
<td>0.5*</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.256)</td>
<td>(0.255)</td>
<td>(0.25)</td>
</tr>
<tr>
<td>300 m run (s)</td>
<td>0.39</td>
<td>0.28</td>
<td>0.27</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.004)</td>
</tr>
<tr>
<td>Push-Ups (Repetitions)</td>
<td>-0.006</td>
<td>-0.005</td>
<td>-0.003 NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.002)</td>
<td></td>
</tr>
<tr>
<td>Body Weight (kg)</td>
<td></td>
<td></td>
<td>0.002*</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>1-RM Bench Press (kg)</td>
<td>-0.002*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.001)</td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.71</td>
<td>0.77</td>
<td>0.79</td>
<td>0.81</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.70</td>
<td>0.76</td>
<td>0.78</td>
<td>0.79</td>
</tr>
<tr>
<td>SEE</td>
<td>0.132</td>
<td>0.117</td>
<td>0.114</td>
<td>0.111</td>
</tr>
</tbody>
</table>

All values significant p ≤ 0.01 unless noted otherwise. NS: Not statistically significant. *p ≤ 0.05. (standard error). 1-RM Bench press: one repetition maximum bench press performance.

The equation predicting initial OPAT performance is as follows:

\[
\text{OPAT performance (fractional min)} = 0.5 + (0.027 \times 300 \text{ m run (s)}) - (0.003 \times \text{maximum number of completed push-ups}) + (0.004 \times \text{body mass (kg)}) - (0.002 \times \text{1-RM bench press (kg)})
\]

\[
\text{SEE} = 0.1105
\]

Table 4.3 presents average time of completion of the two scenarios represented in the OPAT, (chase and appended and victim drag) at three time evaluation periods.
Table 4.3. Entrance, mid-point and exit mean completion times (minutes) of the chase and apprehend and victim drag scenario found within the occupational physical ability test.

<table>
<thead>
<tr>
<th></th>
<th>Entrance</th>
<th>Mid-point</th>
<th>Exit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chase and Apprehension</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Group</td>
<td>1.80 ± 0.22</td>
<td>1.73 ± 0.21</td>
<td>1.89 ± 0.20</td>
</tr>
<tr>
<td>Experimental Group</td>
<td>1.71 ± 0.21</td>
<td>1.67 ± 0.20</td>
<td>1.87 ± 0.21</td>
</tr>
<tr>
<td><strong>Victim Drag</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Group</td>
<td>0.24 ± 0.05</td>
<td>0.23 ± 0.04</td>
<td>0.24 ± 0.05</td>
</tr>
<tr>
<td>Experimental Group</td>
<td>0.24 ± 0.07</td>
<td>0.22 ± 0.05</td>
<td>0.22 ± 0.05</td>
</tr>
</tbody>
</table>

Table 4.4 presents the bivariate correlation analysis of initial OPAT performance, bodyweight and fitness assessments. There were several significant correlations between fitness assessments and OPAT time at the entrance assessment. There was a weak positive correlation with body mass, a moderate negative correlation with sit-ups and a moderate positive correlation with victim drag. Furthermore, there is a strong negative correlation with push-ups, a strong positive correlation with 1.5 mile and 300 m runs and very strong correlation with the chase and apprehend scenario.
Table 4.4. Bivariate correlation matrices of occupation physical ability test (OPAT) performance versus demographic, anthropometric and fitness assessment outcomes in 63 law enforcement cadets.

<table>
<thead>
<tr>
<th></th>
<th>Age (yr)</th>
<th>Body mass (kg)</th>
<th>Height (cm)</th>
<th>1-RM bench press (kg)</th>
<th>Sit-ups (reps)</th>
<th>300 m run (s)</th>
<th>Push-ups (reps)</th>
<th>1.5 mile run (min)</th>
<th>OPAT (min)</th>
<th>Chase and apprehend (mins)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass (kg)</td>
<td>-0.03</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>0.12</td>
<td>0.73**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-RM bench press (kg)</td>
<td>-0.02</td>
<td>0.67**</td>
<td>0.47**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sit-ups (reps)</td>
<td>-0.09</td>
<td>-0.16</td>
<td>-0.05</td>
<td>0.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300 m run (s)</td>
<td>-0.06</td>
<td>0.20</td>
<td>-0.07</td>
<td>-0.25*</td>
<td>-.58**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Push-ups (reps)</td>
<td>0.12</td>
<td>-0.21</td>
<td>-0.06</td>
<td>0.39**</td>
<td>0.61**</td>
<td>-.68**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.5 mile run (min)</td>
<td>-0.05</td>
<td>0.32**</td>
<td>0.07</td>
<td>-0.07</td>
<td>-.52**</td>
<td>0.74**</td>
<td>-0.68**</td>
<td>0.71**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPAT (time)</td>
<td>0.003</td>
<td>0.33*</td>
<td>0.11</td>
<td>-0.25</td>
<td>-.62**</td>
<td>0.84**</td>
<td>-0.76**</td>
<td>0.71**</td>
<td>0.70**</td>
<td>0.97**</td>
</tr>
<tr>
<td>Chase and apprehend (min)</td>
<td>0.04</td>
<td>0.48**</td>
<td>0.23</td>
<td>-0.10</td>
<td>-0.60**</td>
<td>0.81**</td>
<td>-0.73**</td>
<td>0.70**</td>
<td>0.97**</td>
<td></td>
</tr>
<tr>
<td>Victim drag (min)</td>
<td>-0.14</td>
<td>-0.44**</td>
<td>-0.42**</td>
<td>-0.67**</td>
<td>-0.34**</td>
<td>0.46**</td>
<td>-0.44**</td>
<td>0.32**</td>
<td>0.52**</td>
<td>0.31*</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
4.1.3 Aim #3

Figure 4.5 presents a flow chart of total individual responses for session-RPE that were adjusted for duplicates and cadets that did not finish the academy training program. Figure 4.6 presents the average phase training loads for each type of training between both classes. Table 4.5 presents the average self-reported RPE and duration values for resistance, aerobic defensive tactics and overall session trainings. Training phase 1 represents the training period between the entrance and mid-point assessments whereas training phase 2 represents the training period between mid-point and exit assessments.

Figure 4.5. Flowchart illustration the screening process for inclusion of session rating of perceived exertion (sRPE) data for analysis.
Figure 4.6. Comparison of average phase training loads (session RPE; sRPE) for resistance training (RT), aerobic training (AT), defensive tactics (DT), and overall workout (Global) between control and experimental groups. Values represent mean ± SD. *p < 0.001, **p < 0.01.

Table 4.6 presents the weekly average response rate percentages for each type of training. Although there were no significant differences between groups in response rates for aerobic training (p = 0.13) and defensive tactics (p = 0.74), the experimental group had significantly fewer resistance training (p = 0.029) and global session (p<0.001) responses compared to the control group.
Table 4.5. Average self-reported resistance training (RT), aerobic training (AT), defensive tactics (DT) and session rating of perceived exertion (RPE) and duration between the control and experimental groups during a 20 week police academy training program.

<table>
<thead>
<tr>
<th>Group</th>
<th>Training Phase 1</th>
<th></th>
<th>Training Phase 2</th>
<th></th>
<th>Overall</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Experimental*</td>
<td>Control</td>
<td>Experimental*</td>
<td>Control</td>
<td>Experimental*</td>
</tr>
<tr>
<td>Average RT RPE</td>
<td>7.0 ± 0.7</td>
<td>4.5 ± 0.8</td>
<td>7.3 ± 1.1</td>
<td>4.6 ± 1.1</td>
<td>7.1 ± 0.9</td>
<td>4.7 ± 0.9</td>
</tr>
<tr>
<td>Avg RT Duration (min)</td>
<td>48.7 ± 8.7</td>
<td>34.9 ± 10.5</td>
<td>53.4* ± 11.3</td>
<td>43.2** ± 14.3</td>
<td>51.0 ± 10.3</td>
<td>38.4 ± 12.8</td>
</tr>
<tr>
<td>N (days) reported</td>
<td>38</td>
<td>40</td>
<td>36</td>
<td>29</td>
<td>74</td>
<td>69</td>
</tr>
<tr>
<td>Average AT RPE</td>
<td>7.0 ± 0.6</td>
<td>4.8 ± 0.9</td>
<td>7.3 ± 0.9</td>
<td>4.2* ± 1.3</td>
<td>7.1 ± 0.7</td>
<td>4.6 ± 1.1</td>
</tr>
<tr>
<td>Avg AT Duration (min)</td>
<td>36.1 ± 11.2</td>
<td>26.3 ± 8.3</td>
<td>34.4 ± 10.5</td>
<td>28.2b ± 9.7</td>
<td>35.3 ± 10.8</td>
<td>27.0 ± 8.9</td>
</tr>
<tr>
<td>N (days) reported</td>
<td>38</td>
<td>40</td>
<td>37</td>
<td>27</td>
<td>75</td>
<td>67</td>
</tr>
<tr>
<td>Average DT RPE</td>
<td>7.8 ± 1.0</td>
<td>5.1 ± 1.3</td>
<td>7.6 ± 1.7</td>
<td>4.5 ± 1.3</td>
<td>7.7 ± 1.3</td>
<td>4.8 ± 1.3</td>
</tr>
<tr>
<td>Avg DT duration (min)</td>
<td>56.4 ± 18.7</td>
<td>66.3b ± 11.9</td>
<td>71.7** ± 4.8</td>
<td>59.8b ± 22.0</td>
<td>62.2 ± 16.7</td>
<td>63.2** ± 17.6</td>
</tr>
<tr>
<td>N (days) reported</td>
<td>38</td>
<td>22</td>
<td>23</td>
<td>20</td>
<td>61</td>
<td>42</td>
</tr>
<tr>
<td>Average Session RPE</td>
<td>7.1 ± 0.6</td>
<td>5.1 ± 0.7</td>
<td>6.9 ± 0.8</td>
<td>4.6* ± 0.9</td>
<td>7.0 ± 0.7</td>
<td>4.9 ± 0.8</td>
</tr>
<tr>
<td>Avg Session Duration (min)</td>
<td>63.3 ± 17.7</td>
<td>60.2** ± 16.9</td>
<td>67.7 ± 12.0</td>
<td>67.4** ± 13.9</td>
<td>65.5 ± 15.0</td>
<td>63.7** ± 15.9</td>
</tr>
<tr>
<td>N (days) reported</td>
<td>38</td>
<td>40</td>
<td>40</td>
<td>38</td>
<td>78</td>
<td>78</td>
</tr>
</tbody>
</table>

Training phase 1 represents the training period between the entrance and mid-point assessments.
Training phase 2 represents the training period between mid-point and exit assessments.

*Significant difference (p<0.05) from phase 1.
**Significant difference (p<0.001) from phase 1.

a Significant difference (P<0.001) from control group unless otherwise noted.
b Significant difference from control group (p>0.05).
ns No significant difference between groups.
Table 4.6. Average weekly response percentage rates for resistance training (RT), aerobic training (AT), defensive tactics training (DT) and overall session (sRPE) for the control and experimental groups.

<table>
<thead>
<tr>
<th>Training Week</th>
<th>RT</th>
<th>AT</th>
<th>DT</th>
<th>sRPE</th>
<th>RT</th>
<th>AT</th>
<th>DT</th>
<th>sRPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>66.1 ± 20.6</td>
<td>88.7 ± 6.8</td>
<td>48.4 ± 54.7</td>
<td>98.4 ± 2.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>51.6 ± 30.5</td>
<td>76.8 ± 18.9</td>
<td>37.4 ± 41.7</td>
<td>85.8 ± 12.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>34.8 ± 28.5</td>
<td>54.2 ± 23.6</td>
<td>41.1 ± 34.8</td>
<td>63.9 ± 27.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>49.7 ± 26.1</td>
<td>58.1 ± 24.5</td>
<td>48.4 ± 39.9</td>
<td>79.4 ± 8.7</td>
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</tr>
<tr>
<td>5</td>
<td>51.0 ± 28.3</td>
<td>72.9 ± 9.3</td>
<td>9.7 ± 0.0</td>
<td>76.1 ± 10.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>36.1 ± 18.2</td>
<td>51.0 ± 21.1</td>
<td>0.0 ± 0.0</td>
<td>52.9 ± 21.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>37.4 ± 23.6</td>
<td>58.1 ± 16.5</td>
<td>39.8 ± 33.1</td>
<td>64.5 ± 11.6</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>8</td>
<td>34.8 ± 26.2</td>
<td>48.4 ± 19.8</td>
<td>45.2 ± 31.9</td>
<td>56.8 ± 20.4</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>9</td>
<td>21.9 ± 22.7</td>
<td>29.7 ± 26.3</td>
<td>72.6 ± 2.3</td>
<td>45.2 ± 34.1</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>10</td>
<td>28.2 ± 18.9</td>
<td>28.2 ± 9.5</td>
<td>14.0 ± 1.9</td>
<td>31.0 ± 23.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>33.1 ± 29.0</td>
<td>36.3 ± 34.8</td>
<td>35.5 ± 27.1</td>
<td>54.1 ± 20.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>22.6 ± 11.2</td>
<td>22.6 ± 17.1</td>
<td>0.0 ± 0.0</td>
<td>25.8 ± 16.8</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>13</td>
<td>38.7 ± 22.6</td>
<td>33.3 ± 8.1</td>
<td>23.2 ± 21.6</td>
<td>46.5 ± 14.0</td>
<td></td>
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</tr>
<tr>
<td>14</td>
<td>23.7 ± 19.7</td>
<td>32.3 ± 18.3</td>
<td>27.4 ± 25.1</td>
<td>33.1 ± 19.1</td>
<td></td>
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<tr>
<td>15</td>
<td>14.5 ± 11.4</td>
<td>8.1 ± 2.3</td>
<td>11.3 ± 2.3</td>
<td>12.9 ± 5.6</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>16</td>
<td>5.4 ± 1.9</td>
<td>5.4 ± 3.7</td>
<td>9.7 ± 0.0</td>
<td>9.7 ± 3.2</td>
<td></td>
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</tr>
<tr>
<td>17</td>
<td>7.5 ± 1.9</td>
<td>8.6 ± 1.9</td>
<td>8.1 ± 2.3</td>
<td>8.4 ± 1.8</td>
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Average 41.9 ± 26.5 49.7 ± 24.8 35.0 ± 26.5 70.1 ± 7.5 32.8* ± 20.1 44.4 ± 28.7 27.7 ± 18.7 49.7** ± 14.9

Values reported as mean (%) ± SD. Phase 1: weeks 1-9. Phase 2: weeks 9-17. a Significant difference from control group (p<0.05) at phase 1. b Significant difference from control group (p<0.001) at phase 2. c Significant difference from control group (p<0.05) at phase 2. * Significant difference from control group (p<0.05). ** Significant difference from control group (p<0.001).
Figure 4.7a-b presents the training load, monotony, and strain for both groups during the academy training program. Training monotony (>1.0) and strain were high in control and experimental groups throughout the entirety of the training program (Figure 4.4a-b). Of note, there were high monotony values for the weeks in which injuries occurred in the control group (week 2: 1.38, week 4: 1.43, week 9: 1.34, & week 13: 1.44) and the experimental group (week 8: 1.42, week 14: 1.20, & week 16: 0.78).

Figures 4.8 and 4.9 represent the acute:chronic (A:C) ratio trends for the control and experimental groups, respectively. Overall the experimental group produced lower overall acute and chronic training loads compared to the control group. This could be attributed to lesser RPE and duration values (Table 4.5) reported for the experimental group in all training modes. Furthermore, the overall A:C ratios for notable activities (ie., injuries, academic tests, police skill tests, defensive tactics and physical fitness assessments) ranged from 0.72-3.0 A.U. in the control group and 0.12-1.85 A.U. in the experimental group. For injuries that occurred during the academy training program, the control group had an A:C range of 0.87-1.59 A.U., whereas in the experimental group had an A:C of 0.88 – 1.19 A.U. The A:C of days in which an academic test occurred were 1.1-1.61 and 0.4-1.16 in the control and experimental group, respectively. In the weeks which injuries occurred, in the control group, there were greater average aerobic, resistance and global sRPE values reported when compared to their respective training academy mean (RT sRPE:389 A.U. vs. 367; AT sRPE: 322 A.U. vs. 270 A.U.; Global sRPE: 525 A.U. vs. 460 A.U.)
Figure 4.7a-b. Training load, monotony and strain for the control and experimental groups during a 17-week police academy physical training program.
The same trend was noted/identified in the experimental group (RT sRPE: 263 A.U. vs. 182 A.U.; AT sRPE: 218 A.U. vs. 141 A.U.; and Global sRPE: 342 A.U vs. 307 A.U.) Officer skill tests produced an A:C range of 0.72-1.76 and 0.84-1.85, in the control and experimental groups, respectively. Defensive tactics assessments produced an A:C range of 0.83-2.51 and 0.52-1.08, in the control and experimental groups, respectively. Moreover, 83% and 85% (control and experimental group, respectively) of officer skill and defensive tactics training combined produced consistently low A:C values (0.52-1.09). Physical fitness assessments produced an A:C range of 1.1-3.0 and 0.12-1.19 in the control and experimental groups, respectively.

Many outliers (A:C <0.52 A.U. and >1.40 A.U.) within the data set can be attributed to insufficient data points collected to accurately calculate the A:C ratio or holiday vacations where recording of RPE data was not completed. In the control group, these outliers occurred during the following assessments: academic test (week 4: 1.61 A.U.), officer skills test (week 4 1.77 A.U), defensive tactics assessment (week 17: 2.51 A.U.), and physical fitness assessments (week 17: 2.51 and week 18: 3.0 A.U.). Lastly, in the experimental group, these outliers occurred during the following assessments: academic test (week 12: 0.4 A.U.), defensive tactics assessment (week 12: 0.52 A.U.) officer skills test (week 10: 1.42 A.U. and week 12: 1.85 A.U.) and physical fitness assessment (week 9: 0.12 A.U.).
Figure 4.8. Acute load, Chronic load, 7:21 day acute to chronic ratio and instances of notable activities (i.e., injuries, academic tests, police skill tests, defensive tactics and physical fitness assessments) for the control group during the 17-week training academy.
Figure 4.9. Acute load, Chronic load, 7:21 day acute to chronic ratio and instances of notable activities (i.e., injuries, academic tests, police skill tests, defensive tactics and physical fitness assessments) for the experimental group during the 17-week training academy.
4.2 Discussion

4.2.1 Aim #1

The purpose of Aim 1 was to evaluate the effectiveness of integrating APRE and HIIT to improve 1-RM bench press, 300 m run, 1.5 mi run, and occupational physical ability test (OPAT) outcomes. Despite the experimental group having greater mean 1-RM bench press performances at each evaluation point (entrance, mid-point, exit), there were no significant differences between the groups (Figure 4.1a). Moreover, both the control and experimental groups exhibited similar relative and absolute improvements during each half the training program suggesting that the APRE program produced similar improvements compared to the current academy training program, despite a decreased training load (Figure 4.3). No attempt was made to match volume and intensity between the control and experimental group training program because the volume and intensity of the APRE program is set each training day based on individual performance (98). Ultimately, this information could potentially explain the non-significant differences between the groups.

Although the improvements observed in this study are similar to the results of Mann et al. (98), who compared the used of APRE and linear periodized programs for increasing bench press performance in collegiate American Football athletes, Mann and colleagues (98) obtained these results in substantially less time (6 weeks vs. 17 weeks). A potential reason for this result is the difference in training frequency focused on improving bench press performance between the current investigation and Mann et al. (98) (1 vs. 3 days). This is supported by the research of Schoenfeld et al. (138) who observed greater training frequencies led to greater increases in bench press strength. Despite the differences
between the Mann et al. (98) investigation, the short term increases in bench press exhibited in this study suggest that autoregulatory progressive resistance exercise protocols could be utilized in police academy training programs to improve bench press performance in cadets.

Interestingly, the experimental group exhibited greater improvement in push-up performance (Figure 4.1d) compared to the control group. The post-hoc analysis revealed that these specific differences occurred at the entrance exam, indicating the experimental group started the academy with greater muscular endurance, and the exit exam, which may potentially reflect an indirect influence of the APRE bench press program. To that end, Gottschall et al. (70) noted similarities in muscle activation patterns of the push-up and bench press exercises for posterior deltoid, pectoralis major, latissimus dorsi, biceps brachii, triceps brachii and erector spinae muscles. Similarly, Tillaar (157) observed similar kinematic and muscle activation patterns between submaximal bench press exercise and weighted pushups. Thus, these results may suggest the interchangeability of these exercises to influence overall upper-body muscular fitness.

Lastly, the improvements observed in both bench press and push-up performance of the current investigation reflect similarly to previous investigations. Crawley et al. (42) observed significant increases push-up performance but not 1-RM bench press performance following a 16-week academy training program, suggesting the inclusion of periodization to increase performance outcomes. Cocke et al. (37) observed significant improvements in 1-RM bench and push-up performance in both randomized training and linear periodization groups during a 6-month police academy training program.
Collectively, the presented results support the use of structured training programs to improve upper body strength and endurance performance in law enforcement cadets.

In this investigation, a 12 week periodized HIIT program was administered based on the results of the 30-15 IFT, which was performed at entrance and midpoint in the academy. This ensured that as cadets’ fitness increased, the individualized HIIT program would provide appropriate stimulus for further aerobic and anaerobic adaptation. There were no significant differences between the control and experimental group for the 300 m run (Figure 4.1c) and 1.5 mile run (Figure 4.1e), despite the experimental group exhibiting greater mean scores in both tests. Both groups exhibited significant increases in the 300 m run performance in the first half of the training program as well as overall, but not during the second half of the training program. This result mirrored a previous investigation utilizing an academy exercise program (100). Furthermore, with regards to the 1.5 mile run, both groups experienced similar overall improvement at the end of the training academy. Unfortunately, objective training volume and intensity parameters were not available from the control group, which limits the ability to make comparisons between groups.

The current results suggest that utilizing the 30-15 IFT and subsequent individualized HIIT program could be a viable alternative to improving anaerobic power and aerobic endurance in law enforcement cadets. In a previous investigation by Orr et al. (115), the authors found that a $V_{IFT}$ score $\leq 16$ on the 30-15 IFT was associated with greater levels of injury in law enforcement cadets. In the present study, 42% of experimental group exceeded this $V_{IFT}$ threshold at the entrance exam and 47% at the exit exam. Despite these results, only 9% of the total experimental population experienced injuries compared to the
25% of the cohort in the Orr et al. (115) investigation, suggesting that further research is needed to strengthen the predictive power of $V_{IFT}$ to determine injury risk in law enforcement cadets.

These results were further supported by Orr and colleagues (117) who evaluated the impact of a 10-week, 30-15 IFT-derived ability-based program to improve aerobic endurance in law enforcement cadets. They found that while there was no significant difference in aerobic endurance between groups, but there was a decreased risk of injury observed in the intervention group (117). These results suggest a decrease risk of injury using metabolic conditioning programs compared to traditional long, slow distance running. Interestingly, in the current investigation, the intervention group experienced fewer injuries compared the control group (3 vs 5, respectively) throughout the academy training program. Although the exact running volumes performed by each group are unknown, sRPE was recorded throughout the training academy to subjectively account for training load.

Lastly, the effectiveness of the standard academy training program versus the APRE/30-15IFT program to improve OPAT performance was assessed in this investigation. There were no significant differences between groups in OPAT performance. Individually, the groups experienced a significant improvement in OPAT completion time (Fig. 4.1e, Fig. 4.2) between entrance and mid-point evaluation. Similar results regarding the effectiveness of academy physical training program to improve OPAT performance were found in a study by Rossomanno et al. (134). The authors (134) observed a significant reduction ($p < 0.01$) in physical ability test completion times following a 6-month fitness program in police officers. Interestingly, there was a significant decrease in test
performance 12- and 18-months after baseline measurements, attributed to poor exercise adherence between evaluations (134). Although the current study maintained consistent supervised training sessions through the training academy, a reduction in OPAT performance was observed in the second half of training. Since the OPAT was experimental and not required for completion of the academy training program, the cadets were instructed to complete the course with submaximal effort to prevent injury, and thus reflected decreased OPAT performance times. Regardless, the results of the current study as well as the investigation by Rossomanno et al. (134), promote the importance of maintaining physical fitness to stay occupationally fit as an incumbent LEO.

Session RPE provides a subjective measure of training load (58) and can be used to detect potential overtraining in athletes (58). Figures 4.3a-d represent the average weekly training load (sRPE) for different modes of training (resistance, aerobic, defensive tactics, and overall workout) for each group during the 17-week training academy. During the training academy, the intervention group reported a significantly lower training load compared to the control group all modes of training. When combined with the results of the fitness evaluations, it can be inferred that the intervention group experienced similar fitness gains compared to the control group at a lower physiological cost. Furthermore, the lower training load may, in part, explain the reduced number of injuries sustained by the intervention group (58). The inclusion of the APRE and 30-15 IFT may have influenced these results as they individualize/scale daily training loads based on the fitness level of each cadet and thus could prevent overtraining. In addition, these scaled training methodologies reduce the risk of overtraining a lesser trained cadet and undertraining a higher fit cadet.
For this investigation, HLM growth models were also utilized to assess the effectiveness of the intervention on evaluated fitness parameters. Using HLM analysis is not traditionally used in exercise science research, however it has been used in educational research for over 30 years (126). Moreover, HLM is a more robust regression analysis that has fewer assumptions compared to traditional repeated-measures ANOVA (84) and provides relevant information on the baseline performance of the cadets as well as the rate of growth in each of the fitness parameters. The first portion of Table 4.3 represents descriptive information of the I.S. and RoG for each of the fitness tests and the OPAT. The I.S. findings mirror the baseline parametric statistics for each fitness outcome. Additionally, the RoG provides the average relative change that occurs between each time point. These results may provide insight regarding the level of fitness improvement experienced by a particular training program. Future research may compare different cohorts using a variety of training programs to evaluate their effectiveness.

Another important portion if the HLM results is the correlation between initial status and rate of growth. Specifically, these results reflect the type of growth pattern occurring over time. All of the HLM analyses yielded negative correlations suggesting a fan-closed growth pattern (29) reflecting a smaller magnitude of improvement as cadet fitness increased. Furthermore, at the end of the training academy, differences in performance between the cadets have also decreased (i.e., decreased variance between cadets in fitness parameters). The magnitude of these correlations reflects how easy it is to detect these growth patterns within the data. Ultimately, these results reflect the principle of diminishing returns where the rate of adaptation diminishes through chronic exercise training (159).
The next section of Table 4.1 reflects the results of a 2-level HLM model. The second level introduces between-subject factors to evaluate its effects on I.S. and RoG. In this investigation, there were no significant differences in RoG for any evaluation except for the 1-RM bench press. This suggests that the entire cohort experienced similar RoG regardless of factors such as sex and group (control vs experimental). Although there were significant differences in RoG for the 1-RM bench press, thus none of the evaluated factors (sex, group, or specialty) explained any of the variation in 1-RM bench press RoG. Future investigations should evaluate additional between-subject factors (i.e., body mass and age) to explain variation in the RoG.

In contrast to RoG, there were significant factors that affected the I.S. of all fitness tests except sit-ups. Sex affected the I.S. of the bench press, 300 m run, 1.5 mi run and OPAT, reflecting superior performances by male cadets. Bishop et al. (1987) found that males were significantly stronger than females in bench press performance, with 97% of the variance in muscle strength attributed to muscle size (8). Similarly, Augustsson et al. found that women performed significantly fewer push-ups compared to males, suggesting that they have superior muscular endurance (5). Maud and Shultz (101) found that males produced higher absolute anaerobic capacity and power measures compared to females, although these differences became non-significant when the measured variables were adjusted for fat-free mass. Lastly, in a study by Rhodes and Farenholtz (130), only 16% of the female cadets passed the OPAT due to several components of the test requiring greater levels of upper body strength and endurance to complete in an acceptable time.

There was a significant effect of specialty (individuals with additional fitness requirements for the law enforcement agency represented) where that cohort had superior
300 m run and push-up results compared to the non-specialty group. This result supports previous research suggesting that pre-academy training programs can be effective to increase baseline fitness in cadets (42). Lastly, the provided $r^2$ values represent the amount of variance accounted for in the I.S. with these between-subject factors. The results of the present study observed 7-38% of the variance of I.S. accounted for by sex, group or specialty. Further investigation utilizing different between subject factors could further explain variation within baseline fitness performances in cadets as well as influence future training programming. Use of HLM growth models can be a superior method of repeated measure analysis between groups compared to traditional ANOVA statistics. Furthermore, future analysis in similar cohorts could provide greater insight into the effectiveness of training programs in reaching desired outcomes.

Despite the results evaluating specific effects of the experimental training program, each group experienced significant relative improvements in all fitness evaluations during the academy training (Figure 4.2). Improvements in overall fitness of law enforcement cadets as a result of a training academy physical training program has been previously reported. Wu et al. (171) reported significant increases in general fitness of law enforcement cadets following a 20-week cadet training program. Cocke et al. (37) observed overall fitness improvements utilizing two types of training programs, linear periodization and randomized training (i.e., workout-of-the-day style workouts), in police academy cadets during a 6-month training academy. Martinez and Abel (100) reported significant improvement in all fitness parameters following a 23-week academy training program. Furthermore, relative fitness improvements observed in the current investigation also reflected previous research. Crawley et al. (42) observed significant improvements in
several fitness parameters during the first half of a 16-week police academy training program) however, no significant improvement in the latter half with the authors citing lack of training periodization for these results. Although the length of the physical training program in the current study was similar to the study by Crawley et al. (1 hr·d⁻¹, 3d·wk⁻¹ for 17 weeks vs. 1 hr·d⁻¹, 3d·wk⁻¹ for 16 weeks (42), respectively), differences in training protocols utilized would explain the differences in the results. Overall these results suggest that APRE and 30-15IFT could be utilized as autoregulated and individualized training methods within police academy training programs.

There were several limitations in this investigation that may have influenced the observed results. First, the training protocols utilized in both groups were not matched for volume or intensity. While physical training days were standard for all academy classes (occurring three times per week for approximately 1 hour), different instructors were responsible for training a given class and had autonomy to modify the exercise session parameters and types. While the general goal of the physical training program for the cadets is to prepare them to successfully pass the exit evaluations, each instructor may utilize a variety of methodologies to reach this goal. In this investigation, we utilized the subjective measure of training load, session RPE, in attempt to monitor training loads between the groups. Second, the intervention programs for the experimental group occurred on the same day with the two remaining training days dedicated to standard training practices as dictated by the instructor. As a result, it is impossible to determine if observed improvements in fitness are solely a result of the experimental methodologies.

Third, the five fitness tests were evaluated on a proprietary scale developed by the Academy, in which cadets earned points based on the performance of each test. There are
benchmark scores that must be met at the entrance and exit exams to allow the cadets to start and complete the training academy, respectively. Specifically, the 1-RM bench press, sit-up, and push-up tests have cutoff points that does not necessitate the cadet to perform maximally to obtain maximum points. Additionally, instructors may prevent cadets from exerting maximal effort to help reduce risk of injury during the evaluations. Ultimately, this may mean that some of the test values may underestimate true maximal performance for each of these fitness outcomes. Lastly, we observed significant differences in push-up performance between both groups at the entrance and exit exam but not the mid-point assessments. A potential reason for this may be due to the mid-point assessments having no specific benchmarks to reach (unlike the entrance and exit exams) and are simply utilized to track cadet progress. As a result, the cadets may have displayed sub-optimal effort when completing these assessments.

There were three hypothesis for Aim 1 of this investigation. First, it was hypothesized that a periodized APRE program would produce greater 1-RM bench press strength in cadets compared to the standard academy training program. Although there were no significant differences in 1-RM bench press strength between the groups, the experimental group experienced similar fitness improvements with lower perceived effort. This reflects greater efficiency of an autoregulated training program compared to the standard academy training program, as well as reducing risk of injury during physical training. Second, it was hypothesized that a periodized metabolic conditioning program utilizing the 30-15 IFT and subsequent HIIT program would produce greater 300 m and 1.5 mile run performances compared to the standard academy training program. Although similar fitness improvements in the 300 m and 1.5 mile run performances were produced
in both groups, the results found no significant differences between experimental and control groups. Despite these results, average training loads in the experimental group were significantly lower than the control group, suggesting that the improvement in all fitness parameters were achieved with less physiological cost. (2,34,75,107,129). Third, there were no significant differences between groups in OPAT performance, however, each group experienced similar improvements as a result of the academy training programs. These results support the importance of consistent physical fitness training for maintaining occupational readiness in law enforcement officers. In conclusion, APRE and 30-15 IFT/HIIT protocols could be utilized to individualize training protocols, improve physical/occupational fitness and potentially reduce risk of injury sustained in law enforcement cadets.

4.2.2 Aim #2

The purpose of Aim #2 was to determine the relationship between physical fitness assessments (1-RM bench press; sit-ups, 300 m run, push-ups and 1.5 mile run) and OPAT completion time. This relationship is important in determining the effectiveness of the cadets’ physical training program in improving occupational readiness. A state-wide job task analysis was previously completed to ascertain which physical assessments represent the occupational physical demands of law enforcement and further create minimum standards required of each cadet to successfully perform upon completion of the training academy to become a LEO. The OPAT in this investigation reflected the physical demands of two common scenarios found in law enforcement: chase and apprehend (i.e., suspect pursuit and apprehension) (2,91,129,130) and victim drag
The first statistical technique used to determine this relationship was a regression tree analysis. A regression tree analysis is an exploratory method which splits a root node (representing the entire cohort) into smaller nodes (parent and child nodes, respectively) based on the greatest variation of the dependent variable that can be attributed to explanatory (independent) variables (95). In this analysis, the entrance OPAT completion time was the dependent variable while entrance body mass, bench press, sit-up, 300 m run, push-up and 1.5 mile run performance scores served as the independent variables. Figure 4.4 reflects the resultant regression tree analysis. Although numerous nodes were created, the two nodes of importance reflect the groups of cadets considered to be the highest and lowest performing groups. Specifically, the highest performing group represented 23.3% of the total cohort population and had the lowest mean OPAT completion times (1.68 ± 0.11 minutes). Cadets in this group completed the 300 m run in less than or equal to 50.5 s. In contrast, the worst performing group represented 15% of the total cohort population and had the highest mean OPAT completion times (2.35 ± 0.14 minutes). Cadets in this group had entrance 300 m run times greater than 57.5 seconds and performed less than or equal to 29 push-ups. The results of this analysis suggest that 300 m run completion time and push-up performance are important factors in OPAT performance. A potential explanation for these results may be reflective of the OPAT course design. The OPAT includes short distance runs that may reflect similar anaerobic demands produced in the 300m run, while push-ups were directly included in test. Furthermore, both of these physical attributes were present in the chase and apprehension portion of the test, which represents an approximately 88% of the total OPAT completion time. Additionally, both 300 m completion time and push-ups have strong correlations (Table 4.4) to OPAT
completion time. Although these results suggest the importance of anaerobic performance and upper-body muscular endurance in the completion of the experimental OPAT, additional analysis was completed to further explore the relationships in this aim.

A stepwise multiple regression analysis was performed to evaluate predictors of OPAT completion time. Although all four models presented in Table 4.2 had high r-squared values with OPAT performance, model D explained the greatest amount of variation ($r^2 = 0.81$). Within this model and subsequent equation, there were four predictors present (300 m run, push-ups, body mass, and 1-RM bench press) with all but push-ups completed reaching statistical significance. These results parallel those found in previous research. For example, Dawes et al. (43) found that approximately 69% of the variance in Physical Ability Test performance time was attribute to push-ups, sit-ups, vertical jump height, and 20 m multistage fitness test results. Their results support the relationship of cardiovascular fitness, muscular endurance and anaerobic power for successful occupational performance in highway patrol officers (43). Similarly, Stanish et al. (148) found that, 79% of the variance in PARE (Physical Ability Requirement Evaluation) performance time was attributed to muscular endurance, lower body power, and agility in Royal Canadian mounted Law enforcement cadet males, whereas in females cadets, 43% of the variance was attributed to agility alone. Discrepancy of the results between sexes were attributed to a small, homogenous sample size and the fighting component of the PARE may have been biased towards male stature and fitness characteristics (greater body mass, power and strength compared to females) (148).

Frio Marins et al. (62) evaluated fitness predictors of an OPAT in federal highway police, with and without personal protective gear. They found that without personal
protective gear, agility accounted for 45% of the variance in OPAT completion time. In contrast, with personal protective equipment (PPE), 81% of the variance in OPAT completion time was associated with aerobic fitness, upper body strength and agility. The authors suggested that the effects of PPE on officer performance should be considered when developing training programs to enhance occupational fitness (99), a result supported by previous literature (156). In the present study, the cadets wore standardized physical training clothing (i.e., shorts, t-shirt and sneakers) for all training sessions and evaluations. Future research should evaluate the effects of standard officer clothing (as a PPE condition) on occupational performance to determine if there is a discrepancy using this OPAT.

Lastly, Pihlainen et al. (119) produced a prediction equation that explained 66% of the variance in completion time of a military simulation test with loaded counter-movement vertical jumps, 3000 m run, skeletal muscle mass and push-ups as the significant predictors. The authors suggested that training specialists should incorporate lower body strength and power exercises to improve performance in combat situations. In the current study, the training academy did not require specific lower body strength requirements for completion of its program and as a result the physical training program incorporates workouts focused on directly improving performance on the standardized fitness evaluations. While there is evidence of utilizing 300 m to evaluate both anaerobic power and aerobic fitness (108, 146) with less injury risk to older cadets (108), increased emphasis on lower body strength and power exercises could potentially further increase physical readiness in cadets.

In the current study, 300 m run and 1.5 mile run were highly correlated, a relationship supported by the research of Sinnett et al. (146) who also found that 300 m run was highly correlated (r=0.79) with 10 km run suggesting that the 300 m run could be used
to evaluate both anaerobic and anaerobic performance (108). Similarly, sit-ups were found to have a significant correlation with push-ups. Esco et al. (54) reported a similar relationship ($r = 0.65$) between the variables which was suggested to be a result of similar muscular activation patterns in both exercises. Overall, the present study results are supported by previous research which observed a variety of demographic (age (6), anthropometric (height (119), body composition (43,119) and fitness characteristics (anaerobic power (43,62,119), muscular endurance (43,119), muscular strength (62), aerobic fitness (43,62,119), and agility (62) are associated with OPAT completion time and subsequently related to occupational physical performance in LEOs.

Interestingly, although significant in the regression analysis, 1-RM bench press performance was not significantly correlated to overall OPAT performance. Moreover, sit-up and 1.5 mile run performances were significantly correlated to OPAT completion time, however they were not significant predictors in the multiple regression or regression tree analysis. Evaluating the remaining correlations, specifically within each portion of the OPAT (chase and apprehension versus victim drag) as well between the fitness variables helped explained these relationships. Furthermore, Table 4.3 displays the completion times for each OPAT scenario (chase and apprehend and victim drag) at for each testing period, for each group.

As previously mentioned, the chase and apprehend portion of the OPAT accounts for an 88% of total OPAT completion time, suggesting that performance outcomes in this scenario significantly affects overall OPAT performance. Strong correlations were observed between the 300 m run and push-up performances versus the chase and apprehension completion time, reflecting the direct inclusion of these fitness attributes.
within the simulated scenario. Furthermore, there were significant correlations between OPAT completion time versus body mass, sit-ups and 1.5 mile run, suggesting that higher muscular and endurance as well as more favorable bodyweight could improve occupational fitness. Cesario et al. (34) observed similar correlations to an abbreviated version of the chase and apprehend scenario known as the 75-yard pursuit run (75PR) where push-ups, sit-ups and 2.4 km performances were related to 75PR completion times in law enforcement cadets. Lockie et al. (91) also found similar significant correlations between the apprehend portion of their Work Sample Test Battery and a variety of fitness attributes (push-ups, sit-ups, pull-ups, 201-m run and 2.4 km run) in law enforcement cadets. While differences between the various results are potentially the result of different assessments utilized, understanding the physical demands required to complete occupational tasks is important for developing effective training programs for cadets.

The victim drag had a moderate correlation to the overall OPAT reflecting the smaller influence victim drag has on overall completion time. Additionally, victim drag had a weak correlation with apprehend suggesting that the level of involvement of each fitness attribute were different in each scenario. Overall, there were different fitness attributes correlated with the victim drag compared to the apprehend scenario. Specifically, the strongest correlate of the victim drag was the 1-RM bench press, reflecting the importance of maximal upper body strength to complete the demands of this scenario (lifting and dragging a weighted object). The negative correlation between body mass and victim drag suggest that heavier cadets tended to complete this task faster. Collectively, it could be inferred that individuals with greater body mass tend to have a higher 1-RM bench press and subsequently faster victim drag completion time. This assertion is supported by
Caruso et al. (33) who observed significant correlations ($r = 0.78$) between body mass and maximal bench press performance in college-age men. Sit-ups, push-ups, 300 m run, and 1.5 mile run were significantly correlated with the victim drag. A review by Hauschild et al. (75) noted similar correlates between aerobic fitness and a casualty drag scenario ($r = 0.32$), however, they had contrasting findings for muscular endurance (0.16-0.33) reflecting potential differences in scenario completion requirements of various tactical populations (i.e., Military vs. Firefighter vs. Police). Moreno et al. (107) observed significant correlations with multiple indices of lower body power and body drag velocity ($r = 0.21-0.61$), suggesting the importance of lower body power in reducing task completion time of the victim drag. Lower body explosive power was not assessed in the present study. For the current study, the correlation of 300 m run and victim drag served a similar purpose showing the importance of anaerobic power for the victim drag task.

Future academy physical training programs should incorporate lower-body strength and power exercises to potentially further improve occupational fitness. This assertion supported by Lockie et al. (92) who found that strength measured through the hexagonal bar deadlift exercise was inversely associated with victim drag completion time.

Height was significantly correlated with the victim drag performance in this investigation. In general, this relationship was likely expressed due to the increased strength, body mass, and leverage of the taller cadets, who tended to be males. In this cohort, male cadets were an average of 16 cm taller than females. Furthermore, they performed the victim drag task significantly faster ($p < 0.002$) and possessed greater upper body strength ($p < 0.001$). As a result, the taller and stronger cadets were likely able to lift the mannequin higher off of the ground thus resulting in reduced friction between the
mannequin and the ground, potentially increasing the ability of the cadet to complete the victim drag task faster.

Lastly, age was not correlated to any performance outcome in the current study, a result of the limited age-range observed in this cohort (i.e., homogenous sample for age). Previous literature has found contrasting results regarding the effects of age and OPAT completion time. Frio Marins et al. (62) found no significant relationship between age and completion of an OPAT, regardless of PPE usage, in federal highway officers. In contrast, Beck et al. (6) found that age was significantly correlated with total OPAT completion time ($r = 0.57$) in campus law enforcement officers which may reflect the age-related physiological decrements in physical fitness. The status of the officer (i.e., cadet vs. incumbent) could be one possible reason for the discrepancy between results. Orr et al. (116) observed that incumbent officers experienced significant decrease in fitness performance compared to cadets, highlighting the need for continued structured physical training beyond the training academy. Unfortunately, inconsistencies between subject cohorts and methodologies in the current study and previous literature may explain much of the variation in the results. Ultimately, it is important for each cohort (cadet and incumbents) to participate in structured physical training programs to improve and maintain all fitness attributes to prevent age-related decreases in occupational performance (93).

For this investigation, it was hypothesized that the fitness evaluations utilized within the academy training program would be significantly correlated to OPAT completion time. The results of correlational and regression analysis have shown that, indeed fitness attributes are associated with all or part of the OPAT. Specifically, four of
the evaluations (sit-ups, 300 m run, push-ups and 1.5 mile run) were significantly correlated to overall OPAT completion time, while the apprehend and victim drag scenarios combined had significant relationships with all of the fitness test outcomes. Moreover, the prediction equation that was developed explained 81% of the variance in OPAT completion time was developed and composed of bodyweight, 300 m run, push-up, and 1RM bench press. Following a cross-validation, this equation could be used to monitor cadet progress of occupational physical ability. These results support the training academy’s usage of the current fitness evaluations as assessments of occupational performances.

There are several improvements that could be implemented to enhance the academy training program. First, previous research supports the use of lower-body strength and power exercises to improve occupational tasks such as the victim drag (92,107). Additionally, incorporating PPE when performing both fitness evaluations and the OPAT could further improve the understanding of the fitness attributes needed to successfully perform LEO job tasks (34). Although these results support future inclusion of the OPAT within the training academy, it should undergo a validation process. Although there are differences in the results of the previous literature which can be attributed to the inconsistency of fitness evaluations and occupational physical ability tests utilized, a wide range of fitness attributes were associated with the successful completion of occupational tasks. Utilizing an OPAT allows practitioners to better understand the fitness attributes required for successful occupational fitness performance.
4.2.3 Aim #3

Aim #3 of this study was to descriptively assess the utilization of session rating of perceived exertion (sRPE) to monitor training loads and potential injury risk in cadets. Although utilization of sRPE for monitoring training loads has been assessed in a variety of athletic populations (9,64,71,82,83,96,97,102), there is limited published evidence of its use in tactical populations. Previous literature has found sRPE to effective in monitoring resistance (44,52,79,80,122,145), aerobic (58–61) and combat skills (147), all components found within a police academy physical training program and thus providing proof-of-concept for use in this population. In the current investigation, perceived exercise intensity (measured using the CR-10 RPE scale) and duration of four training modes (resistance training, aerobic training, defensive tactics & overall daily training) were collected from the cadets via a web-based application.

In Aim 1, Figure 4.3a-d was presented to show the significant differences in training load responses between both groups, for all four training categories. The findings from this analysis indicates that the while the experimental group experienced similar fitness improvements compared to control group, they did so with less (overall) perceived effort. Specifically the sRPE was significantly lower for the experimental group for all types of training, throughout both training periods (Figure 4.6). Interestingly, in both groups, the defensive tactics portion of the training academy produced the highest reported training loads, followed by resistance and aerobic training. Defensive tactics are physically demanding (1) training sessions, which prepares cadets to defend themselves in violent encounters and may require more effort compared to traditional resistance and aerobic training.
To further explore differences between groups, Table 4.5 provides a descriptive analysis of the average reported intensity and duration parameters for each category of training, stratified by training phase. In both training phases, the experimental group reported significantly lower intensity and duration for aerobic, resistance and defensive tactics training. Similarly, the experimental group reported a significantly lower global training intensity, however, there were no differences in duration. Thus, the lower perceived intensity of the training modes in the experimental group produced lower training load values. These lower perceived intensity values may indicate that the absolute intensity of training program in the experimental group was less and/or the perception of effort (i.e., intensity) was less, potentially due to increased fitness status (73).

The training load measurement is itself varies greatly within previous literature, a result of different metrics utilized for assessment (i.e., session RPE vs. GPS calculated running distances) and the physical demands of the specific sport/occupation. sRPE-derived training load outcomes in the present study were lower than those reported in other elite level athletic populations. For example, while the current investigation observed weekly training loads between 650-2660 A.U in law enforcement cadets, Foster (58) observed training load ranges between 2000 – 5000 A.U. in Olympic Speed Skaters, whereas Comyns and Flanagan (40) observed average training loads between 1500-3500 A.U. in rugby athletes.

Similarly, the control group experienced higher range of training monotony (average daily training load divided by the standard deviation of the average training load (58,104)) compared to the experimental group (1.03-1.45 A.U. vs. 0.75-1.45 A.U, respectively). Previous research has found that higher training monotony scores reflect
less variation in daily training (40) and is associated with increased risk of overtraining (58). Training strain (weekly training load multiplied by training monotony (58,104)) reflects the overall training stress an individual is exposed to over the training week (40). While the control group had higher absolute training strain compared to the experimental group (as a result of higher average training load responses), the magnitude of the training strain (in relation to training load) was also greater than in the experimental group. This suggests that the control group was at a higher risk of injury (58), and indeed the control group sustained more injuries compared to the experimental group. Moreover, 63% of the injuries sustained by the entire cohort occurred when cadets experienced both high training monotony (~1.41 A.U.) and strain (~3410 A.U.). Esmaeili et al. (55) observed similar results in elite Australian Footballers in which the athletes were at a significantly greater risk of injury when they experienced high training monotony (>1.11 A.U.) and strain (>3,400 A.U.). Putlur et al. (123) observed that 55% and 64% of illnesses in female college students were attributed to sudden increases in training load and training strain, respectively. The current study supports previous research that associated high levels of training load, monotony and strain to higher risk of injury (104), illness (58,123) and decreased physical performance (58,123). Alternating intensities of training days (i.e., hard vs. easy) has been recommended to reduce both training monotony and strain, leading to a decreased risk of overtraining (58).

The last sRPE-derived metrics evaluated for its potential use in training load monitoring in law enforcement cadets were acute workload, chronic workload, and the acute-to-chronic-workload ratio (ACWR). The acute workload represents the current workload and potential fatigue (82) of the cadet, whereas the chronic workload represents
the fitness of the individual (82). The ACWR reflects the relationship between fitness and fatigue which has been associated with determining risk of injury (71). Although the ACWR is commonly calculated using a 7d-28d (1:4) rolling average (71), the 7:21d (1:3) rolling average was utilized in this study based on the results of McCall, Dupont and Ekstrand (102) who found that both 1:3 and 1:4 workload ratios provided similar relationships to injury risk in elite soccer players. Furthermore, shorter workload ratios allow training load monitoring in short-term training programs such as the police academy training program. In athletic populations, ACWR is generally assessed for injury risk throughout various periods of a team’s macrocycle (i.e., preseason, competition, post-season). In contrast, law enforcement cadets have short-term training programs designed to develop occupational readiness for their career. While cadets do not have to perform in the traditional sense of an athletic competition, they do have to successfully complete a multitude of physical assessments to become an incumbent officer.

Collectively, the observed A:C (Figures 4.8 & 4.9) for injuries incurred in the current investigation ranged from 0.87-1.59 A.U. and furthermore, these cadets reported higher training loads compared to phase mean. These results reflect those found in previous research conducted in athletic populations. Hulin et al. (65,82) observed that when an A:C >1.5 was observed, there was a 2-4-fold increased risk of injury the subsequent week in cricket bowlers. In contrast, when the acute workload was smaller than the chronic work (i.e., A:C < 0.99 A.U.), there was only a 4% chance of injury (65,82). Similarly, McCall, Dupont, and Ekstrand (102) observed an A:C of >1.42 produced the greatest likelihood of non-contact injury in elite European football athletes when compared to A:C 0.57-0.97. Furthermore, Hulin and colleagues (83) found that high chronic workloads, in
addition to A:C ≥ 1.54, were associated with a 29% risk of injury in Australian Rugby players, whereas a high chronic workload combined with moderate acute workloads were associated with a lesser risk of injury. These results suggest that a well-trained athlete may tolerate greater levels of training stress without injury (71,82). Although it is beyond the scope of the present study, we observed a large A:C range (0.12-3.0 A.U.) during all notable activities (i.e., academic tests, police skill tests, defensive tactics and physical fitness assessments) in cadets, however, it does not appear as if any particular event was associated with greater injuries.

There are several limitations affecting the calculation of the rolling averages for the current cohort. First, chronic workload could not be assessed until the first 21 days of training were recorded and therefore any injuries that occurred during this time period could not be associated with specific chronic loads. Second, cadets were given 1–2 weeks off for holiday breaks in which they were not required to assess their sRPE. For these dates, the primary investigator entered “0 sRPE” values for these time periods, which subsequently decreased both acute and chronic workload averages, and when cadets returned to the academy, experienced sharp increases in the acute workload parameter. While these factors may explain the outliers observed in the current investigation, it is still important to evaluate sudden spikes in acute workload as they have been associated with greater risk of injury (65). It has been observed that during preseason training, athletes are at a higher risk of injury (64,102,110) suggesting a need to gradually increase exercise intensity and volume to allow individuals to adapt to higher training loads (110). A similar suggestion could be applied to the cadets returning from holiday break wherein the training
intensity and volume gradually increases the subsequent week to reduce potential injury risk.

Overall, there are several limitations regarding the use of sRPE in the present study. First, the response rates for sRPE (Table 4.6) were inconsistent and reduced over the course of the academy training program. When specifically evaluating the overall workout sRPE, the control group maintained consistent responses (>55% response rate) until training week 13, whereas the experimental group had consistent results until week 8. This suggests that a small proportion of cadets influenced overall perception of training load which may not accurately reflect true training loads experienced by each group. In the current investigation, for responses were partially reported, the daily average of that value was recorded as recommended by the literature (102,136), however, if a cadet did not enter a response on a given day, no attempt was made to rectify the missing data. Furthermore, complete data for each individual cadet was not available and could have been helpful in further evaluation injury risk in cadets. Although the cadets were instructed to complete this form daily by the academy instructors, there was no direct oversight to make sure the responses were completed. Although this is a limitation of this study, it provides insight to difficulties of recorded sRPE within the structure of the existing training academy.

Another limitation of this study is the method of calculation used for the ACWR. In the current study we utilized rolling averages to calculate ACWR, however Williams and colleagues (166) have proposed the use of exponentially weighted moving averages (EWMA) to account for the deterioration of fitness and fatigue responses over time. Furthermore, Murray et al. (109) found that EWMA is more sensitive compared to traditional rolling averages ACWR in detecting increased risk of injury. Future
investigations utilizing EWMA with the current cohort may help determine which method is more appropriate for evaluating injury risk in law enforcement cadets.

Third, injuries were directly reported to the primary investigator by the training instructors, however, complete details (i.e., where the injury occurred; type of injury) were not all reported injuries, limiting further analysis of injury risk of this cohort. Fourth, the cadets were not able to consistently complete session RPE responses within the recommended 15-30 minutes (80) post-workout. Specifically, 71% of total cohort responses were recorded after 5:00 pm, potentially several hours after the training session. While this waiting period may result in bias responses (60), previous research has shown no significant difference in session RPE responses up to 24-hours post-exercise (36). Finally, the current study only utilized sRPE, an internal training load measure to subjectively assess cadet effort. Additional objective measurements (i.e., heart rate monitors, detailed training logs) would complement sRPE measurements (73) and allow for a more thorough load monitoring analysis.

In summary, Aim #3 sought to evaluate the use of sRPE to monitor training loads of cadets during a law enforcement academy training program. This study demonstrated that sRPE provides insight into the perceived training loads of cadets during each phase of the academy training program as well as for specific training modalities. Furthermore, there are numerous sRPE-derived metrics that provide information regarding training load changes and potentially information regarding risk of injury. The load monitoring outcomes of the present study also provides a basis for comparisons with other cadet classes using other training regimens. Future investigations should focus on methods to
increase subject compliance in recording measures as well as utilizing objective measurements to validate and complement training load monitoring in cadets.
In summary, the purpose of Aim 1 was to evaluate the effectiveness of APRE and HIIT to improve 1-RM bench press, 300 m run, 1.5 mi run, and OPAT outcomes compared to a law enforcement academy’s standard physical training program. Although there were no differences in 1-RM bench press, 300 m run and 1.5 mile run performances between the control and experimental groups, the experimental group achieved similar fitness improvements with lower perceived effort. This suggests that autoregulated and individualized training methodologies such as APRE and HIIT, provide sufficient stimulus for physical fitness adaptations at a lower internal load.

Similarly, there were no differences in OPAT performance in both groups, although each group experienced significant improvements in OPAT completion time during the academy. This reflects the importance of physical fitness in maintaining occupational readiness in law enforcement officers. Although traditional ANOVA analysis was utilized in this study, HLM growth models provided a more comprehensive analysis of the repeated measures data. There were no significant factors affecting the rate of growth of any fitness parameter, however, there were several factors (sex, group, and specialty) that affected the baseline performance of these parameters. Further investigation into the efficacy of HLM analysis to evaluate fitness training programs is warranted.

The purpose of Aim 2 was to determine the relationship between physical fitness assessments (1-RM bench press; sit-ups, 300 m run, push-ups and 1.5 mile run) and OPAT completion time. This investigation found that body mass, 300 m run, push-ups and 1-RM bench press are significant predictors of OPAT performance. Moreover, it was found that cardiorespiratory fitness, anaerobic power, muscular endurance and strength, body mass
and height were significantly correlated to OPAT performance, supporting the findings of existing literature (6,43,62,119). Furthermore, these results highlight the importance of understanding that occupational readiness in law enforcement requires proficiency in a multitude of biomotor abilities which should be developed through appropriate complimentary training methods.

Finally, the purpose of Aim 3 was to assess the utilization of sRPE to monitor training loads and potential injury risk in law enforcement cadets. Session RPE was found to be a useful method of evaluating training load responses of several training modalities such as resistance training, aerobic training and defensive tactics. Furthermore, utilization of several sRPE-derived metrics such as training monotony, training strain and ACWRs can provide significant insight of internal training load demands and potential risk of injury throughout the progression of the academy training program. It is recommended that future investigations incorporate additional measurements of external training load to further enhance physical fitness monitoring in cadets.

In conclusion, this study demonstrated the feasibility of implementing high performance training methodologies in a law enforcement academy training program to enhance occupational readiness and potentially reduce the risk of injury in law enforcement cadets. Furthermore, these inexpensive methods are highly accessible for immediate implementation in training academies and do not require specialized equipment or personnel for use.
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