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DEVELOPING AND TEST AND ECOLOGICALLY VALID FITNESS TEST
IN SUBURBAN SWAT OPERATORS

A THESIS APPROVED FOR THE
DEPARTMENT OF HEALTH AND EXERCISE SCIENCE

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Chapter 1: Introduction

At the beginning of the 1960's, the United States of America was faced with new challenges for law enforcement officers (LEOs) with the advent of increased terrorism on the domestic front and a need to combat the growing use and solicitation of controlled substances (7). Traditional policing had to evolve to accommodate the changing landscape of law enforcement, leading to the development of the modern day Special Weapons and Tactics (SWAT) teams. SWAT units operate in dangerous, high stress environments to resolve situations that traditional LEOs are not prepared to handle, or situations that are outside of their occupational responsibilities (7). These situations can include terrorist threats, ordinance disposal, riots, hostage rescue, active shooters, drug raids, and events where snipers are required. In consideration of these intensified job tasks demands, the occupational and tactical burdens of SWAT operators are greater than that of regular LEOs. Efficient, evidence-based physical training programs are essential to help prepare these individuals for the increased physical and psychological stressors. In a study by Pryor et al. (2012) the fitness characteristics of a typical suburban SWAT operator demonstrated that SWAT operators' key physical requirements for their occupational tasks include aerobic fitness, upper and lower extremity strength and endurance, power, flexibility, and core strength (14). These physical requirements may apply to the traditional LEO; however, the occupational task requirements are less. It is not current practice amongst most SWAT units to test these fitness components and in many cases the testing is infrequent, and not occupation specific.

The current physical fitness standard for the majority of SWAT teams across the nation is the Cooper fitness test. This test battery includes the following: 1) a 1.5 mile run 2) the maximum number of sit-ups in 120 seconds, 3) the maximum number of push-ups in 120 seconds, and 4) a 300-meter sprint (5). The results are broken up into gender and age groups and ranked by percentiles. This testing is still used predominately for convenience, as it does not take an extended period of time to complete and score, nor is it particularly taxing. This test has been validated with other aerobic capacity tests for the determination of VO_2max, and has remained the standard despite lacking evidence for its efficacy in evaluating SWAT operational performance capacity (5). The Cooper test does not closely simulate the physical demands an operator may face occupationally. This may especially be true since SWAT operators typically have up to 88 lbs. of ballistic protection and duty gear, in addition to their own body weight (14). Lastly, the movements performed by SWAT operators are often non-linear and multi-directional in nature requiring balance, agility, and power to maintain stability while carrying a loaded firearm in formation during the serving of a high-risk warrant or hostage removal (14).

Pryor et al. (2012) examined the 4 physical tasks faced by operators on the job. These tasks included donning and operating in full kit, operations within the perimeter and approach, tactical entry and maneuvers, and man down drills across the following fitness domains: aerobic capacity, extremity strength and endurance, power, flexibility, and body composition (14). Pryor et al. (2012) determined SWAT operators demonstrated moderate yet highly-varied aerobic capacity, inconsistent levels of flexibility, yet good extremity strength and moderate power. This may indicate an

unbalanced approach to training design and subsequent job task physical preparation. To increase the agreement with job task proficiency and the physical preparation needed to help ensure this proficiency, an ecologically valid and reliable assessment of the underlying constructs of SWAT-related job tasks is needed.

The Cooper fitness test may not adequately test all the required fitness elements, and may not be sensitive or specific enough to discern the variability in operational capacity present in this special population of tactical athletes. Since there is physical fitness testing that is inconsistent with the occupational requirements of a SWAT operator, it can be argued that the Cooper test is not specific or sensitive enough to show where an operator could be lacking physically. Do to the high stress and unique demands of the job, it is vital that the operator is prepared physically to meet the physiological demands of the job to carry out a successful mission. It is of dire importance that adequate physical preparation can mean the difference between life and death for these athletes. A physical fitness battery that simulates the occupational requirements of a SWAT operator could highlight areas that need improvement for fitness training. In a study by Davis et al. (2016), SWAT operators reported the physical tasks and exercise training they completed in relation to their SWAT readiness. The findings showed that power and strength were the most important traits to perform their jobs. Stamina/muscular endurance and cardiovascular/respiratory endurance were placed as the top two, most important focuses of training programs (8). In consideration of this need, a proposed test should cover all the elements listed in the study by Pryor et al. (2012) to adequately simulate occupational tasks. This led to the development of the SWAT Operator Readiness Test (SORT). This proposed battery includes 6 tests

designed to closely match the 5 required fitness elements mentioned previously, as well as, agility, dynamic flexibility, and both aerobic and anaerobic recovery capacity (14). This test included a timed lunge matrix to test hip flexibility, agility, and core strength with the weight of a full kit, a loaded, a weighted timed push-up test to determine upper body muscular endurance and a strength, a bodyweight isometric pull-up/hold test to test pulling endurance for holding a shield and holding an assailant in close quarters combat, a loaded paused squat to test lower body strength and endurance with the weight of a full kit, a 20m sled drag to simulate dragging a downed team member in full gear, and the Yo-Yo Intermittent Recovery Test Level 1 to simulate inconsistent aerobic events. The Yo-Yo Intermittent Recovery Test has been significantly correlated to time to exhaustion during a treadmill VO_2 test in athletic populations (10). The components chosen for this test battery, the fitness and occupational components from the Pryor (2012) study they relate to are in Table 1.

Table 1: Fitness and Occupational Components of the SORT Battery

Task	Physical Components	Test
Donning and operating in SWAT gear	1. Moderate/inconsistent aerobic fitness	Yo-Yo Test
Operations within the perimeter and approach	1. Moderate/inconsistent aerobic fitness 2. Good extremity strength	Yo-Yo Test Weighted Push-Ups, Squats, Isometric Hold, Lunge Matrix
Tactical entry and maneuvers	1. Moderate/inconsistent aerobic fitness 2. Fair power 3. Inconsistent flexibility	Yo-Yo Test Lunge Matrix
Man down drill	1. Moderate/inconsistent aerobic fitness 2. Inconsistent flexibility 3. Good extremity strength	Yo-Yo Test Lunge Matrix Sled Drag

We tested the SORT battery in a group (n = 24) of part-time SWAT operators and were able to identify weak areas requiring remediation/improvement during a pilot study. The battery was supported by the research participants as being "highly relatable" and "ecologically relevant" in intensity and movement to their typical job tasks. The hope for the SORT battery is to provide the following 1) a SWAT operator's current performance capacity 2) a physical assessment for talent identification purposes and 3) an assessment for training program construction and progression in greater specificity than the Cooper test.

Therefore, the purpose of this study was multifaceted: 1) to discern the test-retest reliability for a novel test battery aimed at assessing job task preparedness among SWAT operators 2) to provide validation support for the SORT battery by correlating it to a tactically authentic obstacle course used as qualification for SWAT teams, and lastly, 3) compare the Cooper test's agreement to the obstacle course, 4) compare reliability between the Cooper and SORT battery, 5) determine which portions of the SORT battery and Cooper test are the most reliable, 6) determine the expected variability for individual tests in the Cooper and SORT, 7) determine the relationship between the Cooper composite score and the obstacle course, and 8) determine the expected physical characteristics of suburban SWAT operators.

Importance of the Study

The importance of this study is that the Cooper test may be a reliable indicator of general physical fitness, but it may not be specific or sensitive enough to expose job-task weaknesses related to the physical preparation of SWAT operators. Having the

ability to determine these deficiencies accurately can lead to more inclusive training that leads to a better prepared operator and possibly the difference between a mission's success or failure.

Research Question(s):

This study aims to answer the following questions:

1. Is the SORT battery a valid measure of SWAT operator physical readiness when compared against a criterion measure used for qualification to a SWAT team?
    a. Is the SORT battery a reliable measure across trials?
2. Is the Cooper test a valid measure of SWAT operator physical readiness when compared against a criterion measure used for qualification to a SWAT team?
3. What are the expected physical characteristics of SWAT operators?

Hypotheses:

The hypotheses for this study are as follows:

1. The SORT battery would be a valid measure of SWAT operator physical readiness based on its agreement with a criterion measure used for qualification to a SWAT team
    a. The SORT battery would demonstrate consistency/repeatability across trials
2. The Cooper test would not be a valid test when compared against a criterion measure used for qualification to a SWAT team?
3. SWAT operators would demonstrate a low to moderate level of aerobic capacity, along with moderately high levels of upper and lower body endurance.

Delimitations

1. All operators would be from the Norman Police Department of Oklahoma
2. The participant ages would range from 21-55 years of age
3. Testing would include male operators only
4. Random testing order would be assigned to each operator to account for ordering effects
5. Strenuous physical activity would be ceased 48 hours prior to testing days, although regular duty patrols and callouts would not be exclusionary. Additionally, the testing groups would be limited to those without current unresolved orthopedic injuries to prevent the exacerbation of injury or symptoms.

Limitations

1. Caffeine consumption, supplement consumption, and alcohol and tobacco consumption would be maintained as normal to keep testing as similar to the operators' daily lives as possible, which could have an effect on the results
2. The study would employ a non-random, convenience sample, and the research would only apply to the specific population of part-time SWAT operators being tested

Assumptions

1. Tests would be conducted uniformly, and all data collectors would be consistent with each other when applying faults and timing of repetitions.

2. Learning and training effects would be accounted for via the use of a familiarization trial and previous participation in a data collection using the SORT battery
3. Operators would give maximal effort throughout testing

Operational Definitions

Special Operator: a highly trained soldier or law enforcement officer that conducts highly-technical or extremely dangerous missions/tasks that exceed the skill preparation, mental training, and physical preparation of general law enforcement or military personnel.

Cooper test: a physical fitness test designed by Kenneth H. Cooper for the US military in 1968 consisting of a 1.5 mile run for time, 60 seconds of pushups for maximum repetitions, and 60 seconds of sit-ups for maximum repetitions.

Yo-Yo Intermittent Recovery test (Yo-Yo): a variation of the beep test, part of the yo-yo test series developed by the Danish soccer physiologist Jens Bangsbo. There are two versions of this test: Level 1 & 2 (a beginners and advanced level)

Tactical Athlete: Firefighters, special forces operators, military personal, law enforcement officers, and SWAT operators.

Chapter 2

Review of Literature

Introduction

Tactical athletics encompasses military, law enforcement, firefighting, and other rescue professions. Much like traditional athletes, tactical athletes rely on physical ability and skills mastered for their respective tasks (15). However, tactical athletes do not have an "offseason" to train and prepare for their occupational tasks. These athletes are expected to respond to physical and psychological events that can be sporadic and unpredictable (15). Therefore, it is vital to be well prepared to face any task that may be encountered, and part of this preparation includes maintaining physical fitness standards. Specific testing for traditional sports, or training for the competition, is used and training towards the tests should be implemented for tactical athletes as well, especially given the nature of importance in their occupations. Training and testing the physical demands of firefighters, general LEOs, correctional officers, soldiers, and special operations groups have all been researched (1, 2, 3, 6, 9, 12). Little research has been done on SWAT teams, either suburban and/or urban. The research that has been done is not highly specific and states that specific training and testing and should be further researched to better prepare operators for the tasks they would experience on the job (4, 8, 2). The aim of this review is to examine occupational specific training and physical fitness programs on tactical athlete populations.

Methods of Review

Searches for tactical athletes, SWAT, SWAT training, and tactical athlete testing, and training were conducted via Pubmed. Articles were deemed relevant based

on the methods used to create tests or training methods for specific groups of tactical athletes. These groups included firefighters, special forces operators, correctional officers, and police officers.

Findings

Exercise Testing and Occupation Specific Training in Firefighters

In a study by Pawlak et al. (2015), 20 male structural firefighters were recruited to participate in a job specific tactical training program that was specific to structural firefighting. The purpose of this study was to examine how training with firefighting gear would affect their Simulated Fire Ground Test (SFGT) over a 12-week period. All participants had their peak VO_2 tested, hand-grip strength assessed, and flexibility assessed. Two randomly assigned groups of 10 were used, a supervised exercise group and a control group. The exercise group was supervised by a certified strength and conditioning specialist who was a former firefighter. The exercise group did variations of cardiovascular work, bodyweight work (push-ups, sit-ups, body squats, and lunges), and static flexibility work. The resistance exercises gradually added in more firefighting gear to increase the workload and induce physiological adaptations. There were no significant changes in the fitness assessments between groups, or in body fat percentage. The exercise group also performed better on the SFGT, by decreasing their times to complete 4 of 6 tasks, where the control increased times for all 6 tasks. The exercise group also went from an 82% completion rate to 100%, whereas the control group went from 78% to 56% completion rate (12). These results show that occupation specific training can increase performance better than traditional approaches.

Exercise Testing and Occupation Specific Training in Special Forces

In a study by Cuddy et al. (2011) collected data from 114 college aged men to examine 3 training regiments to assess what factors were associated with passing a Special Operations Forces physical fitness test (PFT) over a 12-week period. The 3 groups included run-focused training (RUN), calisthenics-focused training (CAL), and generalized training which included both running and calisthenics (CAL + RUN). The groups met 3 times a week to train on their respective training protocols. Every week the subjects completed a PFT that included pull-ups for a minute, sit-ups for 2 minutes, push-ups for 2 minutes, and a 1.5-mile run. The findings showed that the CAL + RUN group were more successful at passing the PFT compared with the RUN or CAL groups. The RUN group showed better performance in the 1.5 mile run than the CAL and CAL + RUN groups. The results also showed that progression in calisthenics was faster than progression in running, and that calisthenics standards are easier to attain than the running standards before and after training. To conclude, the study found that in order for a recruit to successfully reach SOF PFT standards (in 12 weeks) one had to enter having a 1.5 mile run time of less than 10:41 minutes, have a body fat percentage of less than 12.9%, and participate in a minimum of 30 minutes per day of vigorous physical activity (6). These results show that training specifically for the test/competition results in better performance. This could be said about any tactical athlete or traditional athlete.

Similarly, a study by Carlson & Jaenen (2012) developed a preselection physical fitness training program for applicants trying to join a Canadian Special Operations Regiment (CSOR). This study included 71 participants, 46 being from varying branches

of Canada's military. A graded exercise test (GXT) was conducted to gather information on VO_2 peak, and a Wingate test was used to gather anaerobic power. Continuous push-up, sit-up, and pull-up tests were conducted and recorded, along with hand grip strength. One rep max (1RM) tests were conducted for bench press and back squat, and a vertical jump test was administered to examine muscular power. These tests were all conducted to determine the general physical fitness of the participants. Physical movements were separated from the 9 physically demanding sessions in the CSOR Assessment Center (AC). These sessions contain various tasks that were designed to simulate the tasks performed by CSOR operators. The physical movements were then examined for their respective frequencies during the CSOR AC. Heart rate was taken during these sessions to determine intensity of each session. Next, the researchers examined each of the sessions to determine the physical fitness components that were important in completing the tasks in each session. With this research, a 12-week training program was developed based on the physical demands of the CSOR AC. The program included 10 physical tests to help the participants monitor their training over the 12-week time period. The program included 4 muscular strength and endurance circuits. The metabolic training component including continuous running, tempo runs, and aerobic intervals. The researchers did not test how effective their training program could be, but this information could be valuable in developing occupation specific, and physical fitness test specific, training programs for other tactical athletes. The researchers conclude with their future research including a clinical trial to examine the effectiveness of their training program and a retrospective questionnaire to determine

the success rates of the applicants that followed the program before attempting the CSOR AC (3).

Angeltveit et al. (2016), examined the validity, reliability, and performance determinants of a job-specific anaerobic capacity test for the Norwegian Navy Special Operations Command (NORNAVSOC). This led to the evacuation (EVAC) test developed for this study. This test simulates an operator having to run a distance and evacuate a person by dragging them out of the "danger zone." The test was executed on a 10x20m area with cones placed at the 5 and 15m mark on the left side, and 10 and 20m on the right side. The course had 2 laps, 1 to simulate running to the injured person, and 1 to drag the 70kg dummy wearing a 10kg plate carrier through the course. The course was timed. The study used 19 male students who passed the inclusion criteria. Only 17 of these participants finished the study. The study also included 21 NORNAVSOC operators. Testing took place on 6 days with a minimum of 48 hours of recovery between test days. The test was performed 3 times for reliability. It was tested against a 30 second Wingate test, 300m sprint, and the maximal accumulated oxygen deficit (MAOD) test for validity. The findings of the study showed that the EVAC was reliable after 1 familiarization session, and that the EVAC test correlated with the Wingate and 300m sprint tests. These 2 tests also accounted for 65% of the variance in the EVAC test performance. The NORNAVSOC operators also reported that the EVAC test was work relevant. It was concluded that the EVAC test can be included as an anaerobic work capacity test in this tactical athlete population, also that muscle mass, leg strength and power are important in anaerobic work with a heavy external load (1).

Exercise Testing and Occupation Specific Training in LEOs

Several studies have been conducted on LEOs and physical fitness. A study by Beck et al. (2015) examined the relationship of physical fitness measures against occupational physical ability in campus LEOs. The researchers used a convenience sample of 16 male campus LEOs from ages 24 to 51. Four testing session were conducted, with at least a day between each session. Body composition, anthropometric data, sit and reach test, agility test, and maximal bench and leg press were collected during session 1. Session 2 consisted of practice trials of the Officer Physical Ability Test (OPAT), session 3 consisted of the official OPAT, and session 4 was used to collect vertical jump, grip strength, curl-up, push-up, and a GXT. During the official OPAT, officers wore full gear, and a heart rate monitor to determine cardiovascular demand. The OPAT simulated a foot chase of a suspect and was based on commonly reported in law enforcement literature. It was checked for validity through a questionnaire given to the officers that listed each task, and each tasked was ranked for relevancy. The results showed that relative VO_2 peak and agility test time related to total OPAT time and to 3 of 7 OPAT tasks. The curl-up related to 2 of 7 tasks, absolute VO_2 peak and push-ups related to 1 task. The other fitness measures were not significantly correlated to any OPAT tasks. These findings show that agility, aerobic endurance, and muscular endurance are associated with the physical occupational tasks experienced by campus LEOs. It is suggested that campus LEOs focus on these components during exercise to improve their occupational performance at the physical level. Also, officers should maintain physical fitness at all ages if they wish to perform their best. The researchers conclude that a training program for campus LEOs should

consist of all the fitness components that related to the OPAT as it would better prepare them for completing the physical tasks on the job (2).

Jamnik et al. (2010) developed a fitness test (FITCO) for correctional officer (CO) applicants. The test included the most important, physically demanding, and frequently occurring tasks a CO experiences. The study included 67 male and 41 female experienced COs, while 155 total COs participated in the development of the FITCOs standards. The FITCO test included a cell search, response, body control, arm restraint-retraction, inmate relocation, and aerobic fitness. The response, body control, arm restraint-retraction, and inmate relocation all made up the Emergency Response Circuit (ERC). The restraining forces in the ERC were derived from forces used by female COs to control and restrain inmates. The aerobic fitness standard was derived from the VO_2 results from female COs during emergency responses. The standard for the ERC was derived from performance times of female COs who completed the test at their selected, yet work effective pace. Validity was determined by monitoring the physiological responses experienced by COs, then comparing the findings to with the results from the characterization of occupational tasks. Content validity was determined through a questionnaire of COs after their completion of FITCO. Finally, test-retest reliability was determined with 70 female and 85 male COs who completed the ERC 3 times in the same day. The FITCO test was determined to have high construct and content validity, and high test-retest reliability after familiarization 3 times (9).

The findings in these investigations show that occupational specific training and testing can play a key role in readying tactical athletes for challenges they would experience on the job (1, 2, 3, 6, 9, 12). With these methods being used to train and test

their respective tactical athletes, the void in the literature for occupational specific training and testing for SWAT teams needs to be addressed. It can be hypothesized that preparing for specific physical occupational tasks would make a tactical athlete perform better on the job, and operate in a safer, more effective manner. The ability to operate safely, and effectively is vital to mission success and can mean the difference between life and death for this special population of athletes both on the individual and team level. Pryor et al. (2012) and Davis et al. (2016) both support this need based on the findings from their research. Exercise prescription for SWAT teams is important to develop the fitness required to perform on the job at the highest performance level and at the lowest risk for injury or fatality (14). Testing batteries may be developed and conducted to assess the efficacy of training programs designed to help SWAT operators improve their performance of job related tasks and validated in a SWAT population with SWAT commanders consulted as subject matter experts to strengthen their relevancy (8).

It is important to examine occupational task specific physical testing and training on tactical athletes as their physical fitness could mean the difference between a successful mission or a failure. The findings of these studies show that performance can improve on occupational related physical testing if occupational task related training is implemented (2, 3, 6, 9, 12). Also, the development of occupational task related testing can help test the skills necessary to complete job tasks safely and effectively (1, 2, 9, 12). With a lack of literature on these areas regarding SWAT operators, similar methods of testing and training may yield comparable results as other tactical athlete population.

Chapter 3

Methods

Introduction

With specific training and testing becoming frequently used in sport, it was natural for these modes of improving athletic performance to be used in the tactical athlete community. There are numerous studies that examine firefighters, LEOs, military servicemen, and special operation forces; however, the literature lacks research of occupational specific physical testing and training on SWAT operators. The purpose of this study was multifaceted: 1) to provide test-retest reliability for a novel test battery aimed at assessing job task preparedness among SWAT operators 2) to provide validation support for the SORT battery by correlating it to both a tactically authentic obstacle course used as qualification for a local SWAT team, as well as a shooting course used for SWAT qualification and lastly, 3) compare the Cooper test's agreement to the obstacle course and shooting course against the SORT battery.

Participants

The sample for this study was 10 suburban SWAT operators from the OKC Metro area, more specifically the city of Norman, OK. This sample included male operators between the ages of 21 and 55. Due to the nature of this study, the sample was a non-random convenience sample. The research in this area uses similar sampling (1, 2, 3, 4, 5, 6, 8, 9, 12, 14).

Instrumentation/Measurement Protocols

The measurement tools in this study included a scale for height and weight (Detecto, Webb City, MO, USA), weighted vests at 18.2kg (BCG/Academy, Katy, TX,

USA) and 40kg (Mir, San Jose, CA, USA) were used to simulate the weighted conditions SWAT team members operate under. Stop watches were used to keep time. One-meter lengths of PVC pipe were used across the shoulders to encourage proper form when lunging and squatting. Brightly colored cones were used at the start and finish positions for the sled drag and Yo-Yo Intermittent Recovery Test to assist the operators and data collectors visually. A weighted sled was used to simulate the dead weight of an unconscious or injured SWAT operator for the drag event. An audio recording of the Yo-Yo Intermittent Recovery Test was used to signal the start, stop, and for test pacing.

SORT Battery

The descriptions of each individual fitness test in the SORT batter were as follows:

***6 Point Weighted Lunge Test (Lunge)*:** Operators were instructed to perform lunges while equipped with a weighted vest, simulating the load of being full geared (40 kg/ 88 lbs.). Tape was used to mark each angle from the designated start point. The operator was instructed to step forward with the right leg, then the left, then right leg forward at 45-degree angle, then with the left. The operator then lunged backwards with the same pattern (4 total lunges forward, 4 total backward). This lunge pattern was repeated for 60 seconds. The test was terminated after another repetition could not be completed. Number of reps and time were recorded. PVC pipe would be placed across the shoulders to maintain an upright position. This test was designed to test hip flexibility over distance, and would address any lower body flexibility issues an operator may have.

***Loaded Push-up Test (Push-up)*:** Operators were equipped with an 18.2kg/40lb weighted vest. The vest should fit as close to the body as possible. Operators were instructed to complete as many push-ups as possible with proper form (hands shoulder width apart, elbows in). The tester only counted reps at full elbow extension. The test was 60 seconds in length. The test was terminated when the operator's form started to decline, or another rep could not be completed. Reps and time were recorded. The purpose of this test was to determine muscular endurance of the upper body and corresponding extremities. This test was also used help expose issues with core strength.

***Isometric Pullup Hold Test (Hold)*:** Operators completed an isometric hold pull-up until failure. Hand over bar/overhand grip was used. Participants started with their chin at level/slight over the bar. Test was terminated when operators could not hold the position with proper form/broke 90 degrees at the elbow. The purpose of this test was to determine isometric muscular endurance of the upper body and corresponding extremities. Time was recorded. This test mimicked holding a shield with bicep contraction, and holding an assailant during close quarters combat. Holding an assailant for 60 seconds is one of the requirements for becoming a Norman operator.

***Loaded Squat with Pause (Squat)*:** Operators completed as many squats to proper depth (90 degrees or lower), chest up, and held the position for a 5 second count while equipped with a weight vest, simulating the load of being full geared (40 kg/ 88 lbs.) (14). The vest fit as closely to the body as possible. The test lasted 120 seconds in total. The test was terminated when the operator could no longer complete another repetition. Reps and time were recorded. This test helped to determine muscular endurance in the

lower body extremities, and expose issues with core strength. PVC pipe was placed across the shoulders to maintain an upright position. This test mimicked being in a crouched position for short bursts of time while being fully geared. This is a typical movement pattern when searching a building.

***Weighted Sled Drag (Sled)*:** Operators were instructed to drag a sled for 20 meters as quickly as possible. Distances were measured on a flat surface and marked with cones. The sled was loaded to approximately 106 kg/ 278 lbs. (14). The test started when the sled broke the starting line, and ended when the sled passed the finish line. Time was once again recorded. This test simulated dragging an average sized operator, who is fully geared, to safety. It was used to determine anaerobic fitness and extremity strength.

***Yo-Yo Test (Yo-Yo)*:** Two lines were marked 20 meters apart. Distances were measured on a flat surface and marked with cones or spray paint. Operators started with their foot behind one of the lines, and began running when instructed. They continued running between the two lines, turning when signaled by the recorded beeps. After each minute, the pace was increased. If the line was not reached in time the operator must run to the line turn and try to catch up with the pace within 2 more 'beeps'. The test was terminated if the operator failed to catch up with the pace within the two ends**.** The last stage that the operator completed was recorded and the corresponding VO_2 related to that stage was determined. This test was used to examine aerobic fitness/ aerobic capacity and recovery**.** This test has been validated in athletes to the VO_2 max (10). This also simulates change in direction, which is more applicable to this population than running on a track, or straight line running.

Research Design and Statistical Analyses

The research design was a test-retest design with statistical comparisons being made between two methods of physical fitness testing (SORT battery and Cooper test) and how they related to the Norman SWAT team's obstacle course. Two-way, random sample single measured intraclass correlations, Pearson r's, coefficient of variation, repeated measures analysis of variance (ANOVA) with Bonferroni post hoc comparisons, and paired samples t-tests were all used to make comparisons across trials and to help establish the consistency of the SORT battery.

In addition, Pearson r's were used to determine if a statistically significant relationship existed between the SORT battery and the obstacle course performed during the study (Summer 2017). This statistical approach was used to determine what level of criterion validity existed for the SORT battery. This procedure was replicated with the Cooper fitness test from 2014 and 2015 with each year's respective obstacle course performance (time in seconds) to evaluate the same parameter.

Data Collection Procedures

All testing took place over 3-4 sessions. The person(s) responsible were those in the Sport Performance Analytics Lab. Data was recorded, then entered into SPSS and excel for later analysis.

Data Management/Analysis

As previously stated, data would be recorded and entered into SPSS and excel after being coded to for confidentiality. SPSS version 23 would be used to analyze all data. Means and standard deviations were calculated and are reported for all variables.

Chapter 4

Results

The descriptive statistics can be seen in Table 2, this table demonstrates the means for height, age, weight, and all three trials of the SORT battery.

Table 2. Descriptive statistics

	Mean (n=10)	SD
Height (cm)	177.5	8.1
Mass (kg)	89.9	12.7
Age (yrs.)	35.7	5.8
YoYo (ml/kg/min)	41.7	0.4
Lunge (reps)	20.9	8.9
Pushup (reps)	37.6	10.0
Pullup Hold (sec)	47.1	18.4
Squat (reps)	13.5	4.4
Sled Drag (sec)	9.4	2.6

Correlations (Pearson r's) Among SORT Battery Metrics

Bivariate correlations were calculated to compare SORT battery metrics. The purpose of this comparison was to examine what tests may be highly related to each other to either explain the physical traits that are common to SWAT operators or to consider which metric(s) might be eliminated from the SORT battery to make testing as efficient as possible.

Table 3. Bivariate analysis of the relationships among SORT battery metrics

	Lunge	Pushup	Hold	Squat	Sled	YoYo
Lunge	**X**	0.638*	0.601	0.802**	-0.726*	0.894**
Pushup	0.638*	**X**	0.959**	0.769**	-0.041	0.790**
Hold	0.601	0.959**	**X**	0.684*	-0.024	0.769**
Squat	0.802**	0.769**	0.684*	**X**	-0.363	0.803**
Sled	-0.726*	-0.041	-0.024	-0.363	**X**	-0.537
YoYo	0.894**	0.790**	0.769**	0.803**	-0.537	**X**

*indicated statistical significance at the p<0.05 level

**indicated statistical significance at the p<0.01 level

As can be seen from Table 3, the lunge test was positively, statistically related to the pushup, squat, and Yo-Yo Intermittent Tests, while being negatively correlated to sled drag performance. There was no statistical relationship between the lunge and the pullup hold. The pushup test was positively correlated to the lunge, pullup hold, the squat, and the Yo-Yo test. The pushup, pullup hold, squat, and Yo-Yo tests were not significantly correlated to the sled drag. The squat and Yo-Yo tests were both positively and significantly correlated with the pushup, pullup hold, and with each other. The only SORT battery test that shared a significant relationship with the sled drag was the lunge ($r=-0.726$, $p<0.05$).

Reliability Assessments

To explore the consistency traits of the SORT battery, intraclass correlations (ICC's) were calculated across all 3 trials for each component of the test battery. Paired t-tests were calculated to compare trial 2 and 3 to determine if statistically significant differences existed. Lastly, coefficients of variation (COV's) across trial 2 and 3 were calculated to determine the stability of the variability in scores for each of the SORT battery tests.

ICC's and Pearson r's

The ICC's for each of the SORT tests can be found in Table 4 below.

Table 4. Intraclass correlations across Trial 1,2,3 for SORT battery tests

	Lunge	Pushup	Hold	Squat	YoYo	Sled
ICC	0.939	0.734	0.880	0.826	0.966	0.738
p-value	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001
n	10	10	10	10	10	10

Based on the ICC's reported above, the lunge and the Yo-Yo Intermittent Test demonstrated exceptional repeatability. The pullup hold and squat demonstrated excellent repeatability, while the sled drag and pushup demonstrated good agreement across trials. All tests were shown to reach statistical significance.

Pearson r's were calculated for the 2nd and 3rd trials from all tests in the SORT battery to determine if the relationship between trials grew stronger over time. The correlation coefficients are presented in Table 5 below:

Table 5. Pearson r's for Trial 1 vs. Trial2 and Trial 2 vs. Trial 3 of SORT battery tests

	Lunge	Pushup	Hold	Squat	YoYo	Sled
Trial 1 v Trial 2	0.939	0.915	0.977	0.756	0.983	0.829
p-value	p <0.001	p <0.001	p <0.001	p <0.05	p <0.001	p <0.01
Trial 2 v Trial 3	0.970	0.771	0.812	0.944	0.961	0.956
p-value	p < 0.001	p = 0.009	p = 0.008	p < 0.001	p < 0.001	p < 0.001
n	10	10	10	10	10	10

Based on the Pearson r's, the lunge, squat, Yo-Yo test, and sled drag all demonstrated very high positive relationships that were significantly significant. The pushup and hold were shown to have a good positive relationship between trials 2 and 3. These relationships were also shown to be statistically significant.

Repeated Measures ANOVA and Paired Samples t-tests

Repeated measures ANOVA were calculated to assess mean differences across trial 1, trial 2, and trial 3. Lunges ($F = 3.206$, $p = 0.064$), pullup holds ($F = 0.277$, $p = 0.663$), squats ($F = 0.730$, $p = 0.497$), sled drags ($F = 0.455$, $p = 0.551$), and the YoYo intermittent tests ($F = 0.425$, $p = 0.560$) showed no statistically significant differences across trials 1, 2, and 3. Pushups ($F = 8.846$, $p = 0.002$) were the only test in the SORT

battery to show a statistically significant difference in any of the trials. Participants performed more pushups in trial 1 vs. trial 2 ($p = 0.005$) and in trial 1 vs. trial 3 ($p = 0.015$). However, pushups in trial 2 and trial 3 did not differ ($p > 0.05$).

As mentioned before, mean differences were evaluated via paired samples t-tests to look specifically at the agreement of trial 1 and trial 2, as well as, trial 2 and trial 3. The mean differences for 5 of the 6 SORT battery tests (lunge, p=0.543; pullup holds, p=0.498; squats, p=0.382; Yo-Yo tests, p=0.662; sled drags, p=0.490) were all found to have no significant difference between the mean of trial 1 and trial 2. The only test that showed a statistically significant mean difference (p=0.002) was the weighted pushup test. The mean differences for all 6 tests (lunges, $p = 0.079$; pushups, $p = 0.518$; pullup holds, $p = 0.539$; squats, $p = 0.193$; Yo-Yo tests, $p = 0.518$; sled drags, $p = 0.098$) were not statistically significant between trials 2 and 3.

Coefficients of Variation – SORT Battery

For each test in the SORT battery a coefficient of variation was calculated across trials. In Table 6 below, a comparison of the trial 1,2,3 COV, the trial 1,2 COV, and trial 2,3 COV is presented for comparison:

Table 6: Coefficients of Variation Across Trials

	Trial 1,2,3	Trial 1,2	Trial 2,3
YoYo	0.94%	0.77%	0.95%
Lunge	10.18%	11.16%	7.72%
Push Up	12.75%	13.26%	8.44%
Hold	9.67%	8.02%	8.97%
Squat	11.22%	13.11%	6.71%
Sled Drag	10.84%	9.48%	5.42%

[5]

As can be seen in Table 6, the variability related to score dispersion was minimized between trial 2 and 3 compared to trial 1 and 2 or across all 3 trials. This may be an indication of the need for at least 2 familiarization trials prior to scores stabilizing across attempts.

Tests of Criterion Validity

Cooper Composite to OC 14 and 15

Composite Z scores were created to compare 2014 and 2015 Cooper test results to 2014 and 2015 obstacle course results, these results showed very strong correlations of total composite scores to their respective obstacle course results. The Pearson's R for 2014 was -.921 with an R^2 of .848. The Pearson's R for 2015 was -.867 with an R^2 of .751. Both the 2014 and 2015 comparisons were statistically significant (p=.003 and p=.000, respectively)

SORT Composite to OC17

Finally, composite Z scores for the SORT battery were created to compare the total composite scores to the 2017 obstacle course data. Trials 2 and 3 were used to create an average composite score and showed a moderately strong correlation at R= -.737 with an R^2 of .544. This correlation was statistically significant at p=.037.

Chapter 5

Discussion

The purpose of this study was to examine the test-retest reliability of a recently developed fitness test (SORT battery) and its appropriateness for use in SWAT operators to determine their capacity to successfully handle job-related tasks. Additionally, we sought to compare the SORT battery with the Cooper Fitness test to evaluate both tests' criterion validity related to the measure currently used to qualify for Norman SWAT active duty. In both cases, we evaluated the measures through use of $ICC_{2,1}$ Pearson's correlation coefficient (R), coefficients of variation (COV), and repeated measures ANOVA comparisons of mean differences over trials within the same group. The participants of this study were all men with an average age of 35.7 (±5.8) years, an average height of 177.5 (±8.1) cm, and average mass of 89.9 (±12.7) kg. This data shows similarities to Pryor's research as far as age, height, and mass are concerned (14).

Correlations among SORT battery metrics

Correlations between SORT battery metrics were analyzed to determine which tests were highly related to each other to determine common physical traits in SWAT operators, or if certain components might be removed to shorten the test battery. The results from Table 3 show that that the lunge test was positively and statistically related to the pushup, squat, and Yo-Yo intermittent tests, while being negatively correlated to the sled drag. This was a negative relationship indicating that an increase in the number of lunges resulted in a lower (better) sled drag time. This may be the result of the unilateral, lower body nature of both tests where the body weight would be supported

primarily on one leg at a time. Pushup showed a strong, positive correlation with the hold, and moderate, positive correlation with the squat, lunge, and Yo-Yo intermittent test. Hold, squat, and Yo-Yo were all significant at $p<0.01$, while the lunge test was significant at $p<0.05$. The hold showing the strongest correlation to the pushup could be explained by both tests being upper body dominant exercises. Hold showed weak to moderate positive correlations to the lunge, squat, and Yo-Yo. Lunge was not significant, while Yo-Yo was significant at $p<0.01$, and squat was significant at $p<0.05$. Squat showed moderate to strong correlations to the lunge, pushup, hold, and Yo-Yo. Lunge, pushup, and Yo-Yo were significant at $p<0.01$, while hold was significant at $p<0.05$. The Yo-Yo and lunge showing the strongest correlations could be due to them being lower body dominant exercises; however, the pushup showing a moderate to high correlation to squat could be due to both exercises requiring a certain level of core strength to be executed properly. Yo-Yo showed positive, moderately high correlations to every component except the sled drag. Every component related to the Yo-Yo test showed significance at $p<0.01$. The Yo-Yo intermittent test showing strong correlations to almost every component could be due to the Yo-Yo test's nature to intermittent recovery. These tests all showed some component of anaerobic ability, and the Yo-Yo intermittent test becomes anaerobic by nature in the later stages, with the intermittent recovery between stages being a component of cardiovascular fitness. These results show the sled drag could be removed, as it correlates statistically to only one other component and may be testing the same capacity as the lunge. However, the lunge offers the ability to also assess agility and balance as well. There is a drag component in

the obstacle course, so having a second drag movement can be redundant, and may cause unnecessary fatigue during testing.

Reliability Assessments (ICC's and Pearson R's)

The ICCs reported in Table 4 showed repeatability of SORT battery components across all three trials. The Yo-Yo Intermittent Recovery Test (.966) and lunge (.939) were both significant at $p < 0.001$, showing high repeatability. The pullup hold (.880) and squat (.826) showed moderately high repeatability and were both significant with a p value of $p < 0.001$. Sled drag (.738) and pushup (.734) showed moderate repeatability and were significant at $p < 0.001$. These results were favorable in showing the SORT battery is repeatable across all trials for all components. These results all showing statistical significance is also a good indicator that repeatability is genuine and that comparable results would be attained if the SORT was used in further research.

Correlations were also calculated for all SORT components across trial 1 and 2, and across trial 2 and 3 to see if relationships grew stronger across trials. These results are shown in Table 5 and show high positive and statistical significant relations across trial 1 and 2 for all SORT components. The relationships for lunge, squat, and sled all grew across trials 2 and 3, while pushup (.915 to .771), hold (.977 to .812), and Yo-Yo intermittent test (.983 to .961) all weakened but remained statically significant. All relationships were shown to be significant across trial 1 and 2, and across trial 2 and 3. The change in the relationships might be explained as the total number of participants dropped across all trials. Further investigation is needed with more total participants across all trials to see if the relationships would strengthen or weaken across all 3 trials.

The strengthening relationships could also be contributed to a familiarization; however, familiarization tends to help relationships grow across all trials.

Repeated Measures ANOVA, Paired Samples t-tests, and Individual Differences

Mean differences across trials 1,2, and 3 were assessed with a repeated measures ANOVA. Lunges ($F = 3.206$, $p = 0.064$), pullup holds ($F = 0.277$, $p = 0.663$), squats ($F = 0.730$, $p = 0.497$), sled drags ($F = 0.455$, $p = 0.551$), and the Yo-Yo tests ($F = 0.425$, $p = 0.560$) showed no statistically significant differences across trials 1, 2, and 3. Pushups ($F = 8.846$, $p = 0.002$) were the only test in the SORT battery to show a statistically significant difference in any of the trials. The total repetitions for pushups increased from trial 1 to trial 2, and trial 1 to trial 3, but not from trial 2 to trial 3. This is indicative that the SORT components are reliable across trials.

Coefficients of Variation – SORT battery

Finally, COVs for each SORT component across trials generally showed variation between trials becoming smaller from Trials 1 and 2 to trials 2 and 3. This is demonstrated in Table 5 as all COVs over 10% from Trial 1 to 2 becoming less variable. This is evident in the lunge (11.16% to 7.72%), the pushup (13.26% to 8.44%), and the squat (13.11% to 6.71%). The only increases in variability between Trial 1 and 2, and 2 and 3 were the Yo-Yo intermittent test (.77% to .95%) and the hold (8.02% to 8.97%). All components of the SORT decreased in variability from trial 1 to compared to the variability across all 3 trials except for the Yo-Yo Intermittent Test, which increased (.77% to .94%) and the hold (8.02% to 9.67%). While lunge, pushup, squat, and sled drag all showed COVs greater than 10% across 3 trials, they decreased to under 10% variation from trial 1 and 2 to trial 2 and 3. These results could indicate

that at least two familiarization trials are needed when conducting the SORT battery. Overall the SORT battery shows favorable reliability across several statistical analyses, and supports the hypothesis that the SORT battery is a reliable measure for SWAT operators.

The SORT battery is also more reliable in the fact that there are no standards set in place. The SORT battery is a maximal effort test, where the Cooper test in place for Norman SWAT has standards for repetitions and time. The SWAT operators have no incentive to surpass the required standards, and the results for the Cooper test data in 2014 and 2015 reflect this, meaning most of the results don't represent a true maximal effort.

Tests of Criterion Validity

Correlations of Cooper Test to OC 14 and 15

The composite scores for 2014 and 2015 Cooper test compared to the obstacle course showed strong correlations (-.921 and -.867). These results show that as scores increased, the time taken to complete the obstacle course decreased. The R^2 also showed the composite scores for 2014 account for 84.8% of the variation in obstacle course scores, and for 75.1% of variation in 2015. Both tests showed statistical significance at the $p<0.01$ with a $p=.003$ and $p=.000$ respectively. This is a strong indication that the Cooper test is valid when compared to the criterion of the obstacle course.

Correlations of SORT Composite to OC 17

The SORT battery composite scores also showed favorable results when compared to the 2017 obstacle course times; as total composite scores increased, total time to complete the obstacle course decreased. The results showed a moderately strong

correlation at -.737, and the R^2 showed that the SORT composite scores accounted for 54.4% of the variation in the obstacle course scores. This correlation was also significant at the $p<0.05$ level with $p=.037$. This indicated that the SORT is likely a valid measure when compared to the criterion of the obstacle course.

While the SORT battery may not be any better than the Cooper test at determining occupational readiness in SWAT operators statistically, it encompasses a larger span of physical fitness that SWAT operators face while on duty. The SORT may be helpful in exposing weaknesses that need remediation in SWAT operators. These weaknesses can be addressed in the fitness training the operators do on their own time. This was shown in the research by Pawlak et al. (2015) with structural firefighters that trained towards their occupational testing by training while in full gear against a group that trained by general means (11). Similarly, the test developed by Angeltveit et al. (2016) showed that mission specific testing in Norwegian special forces could replace their traditional anaerobic testing as the test developed by researchers was valid when compared against a Wingate test (1).

Finally, the physical characteristics of the Norman SWAT operators showed, that for a mean age of about 36, the mean VO_2 peak taken across two trials was 42 mL/kg/min, and the mean VO_2 peak taken across three trials was 41.7 mL/kg/min indicating that their aerobic capacities were on the lower side of fair according to ACSM guidelines (13). This finding agrees with the hypothesis that the SWAT operators would show low to moderate levels of aerobic capacity. Their muscular endurance and strength could also be considered in agreement with the hypothesis. These results agree with the research conducted by Pryor et al. (2012) as far as physical

fitness traits are concerned (14). These results also agree with the findings on occupation specific testing in Norwegian special forces that leg strength is important when doing anaerobic work with a heavy load (1). The results showed our lower body muscular strength and endurance SORT tests all correlated highly, with statistical significance, to each other and the Yo-Yo Intermittent Recovery Test. The Yo-Yo Intermittent Recovery Test contains an anaerobic portion that relies on quick bouts of sprinting at the higher stages. The sample of operators that were used for our research showed muscular fitness levels comparable to the LEOs in the study by Beck et al. (2015). The findings for our study and Beck et al. (2015) show that cardiorespiratory and muscular endurance are associated with the occupational tasks that these officers and operators face while on duty, and similarly, that the samples used demonstrated good levels of upper and lower body muscular strength and endurance (2).

Individual Differences Across Tests

Although mean differences are helpful for establishing test-retest reliability, it is interesting to also note the ability of a test to discern the diversity in responses to that test. In Figures 1-6 below, the mean differences for all ten participants are presented on the same scale to denote what tests showed the greatest variability in physical fitness levels among SWAT operators in this investigation.

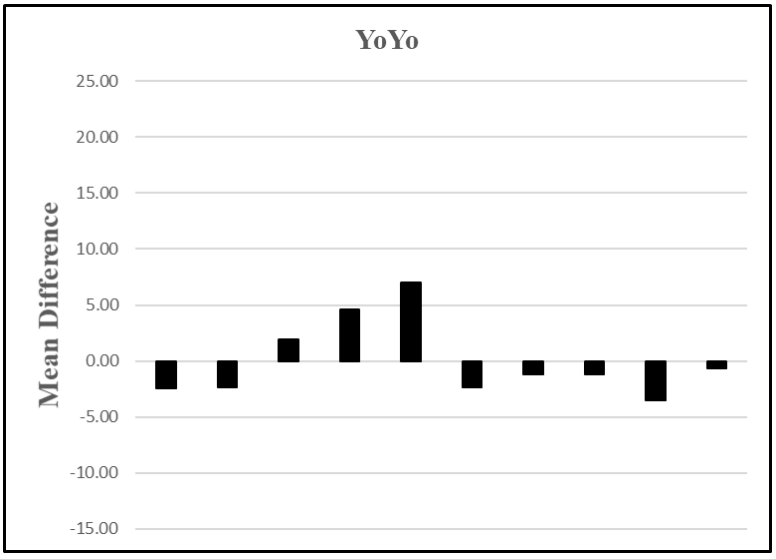

Figure 1: Yo-Yo Mean Difference Among SWAT Operators

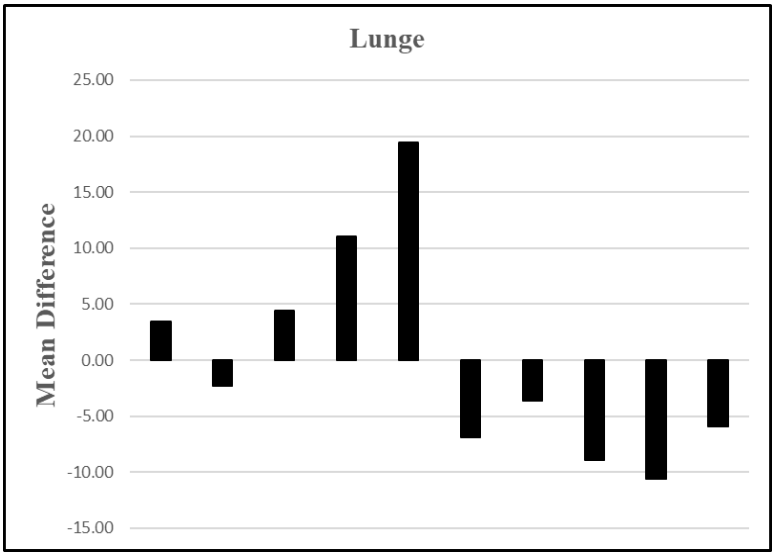

Figure 2: Lunge Mean Difference Among SWAT Operators

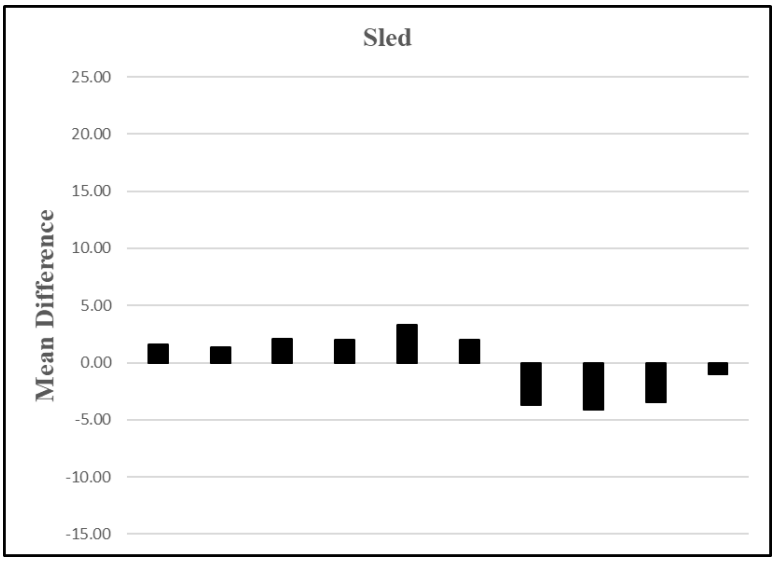

Figure 3: Sled Mean Difference Among SWAT Operators

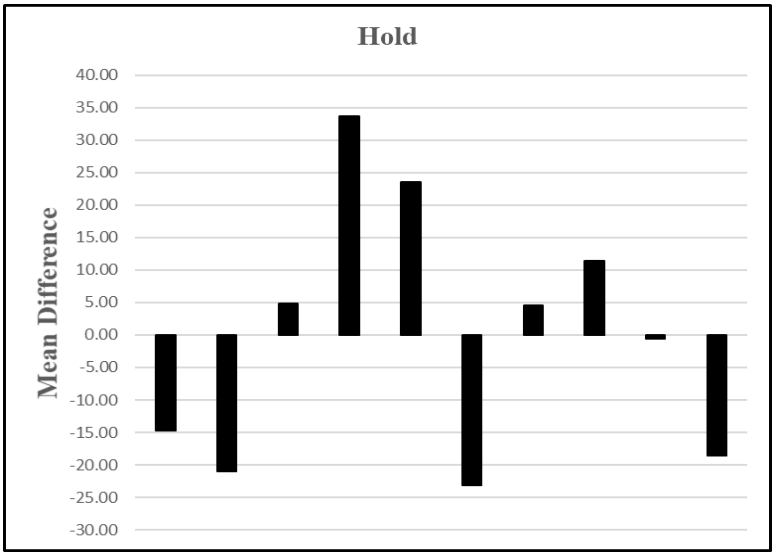

Figure 4: Hold Mean Difference Among SWAT Operators

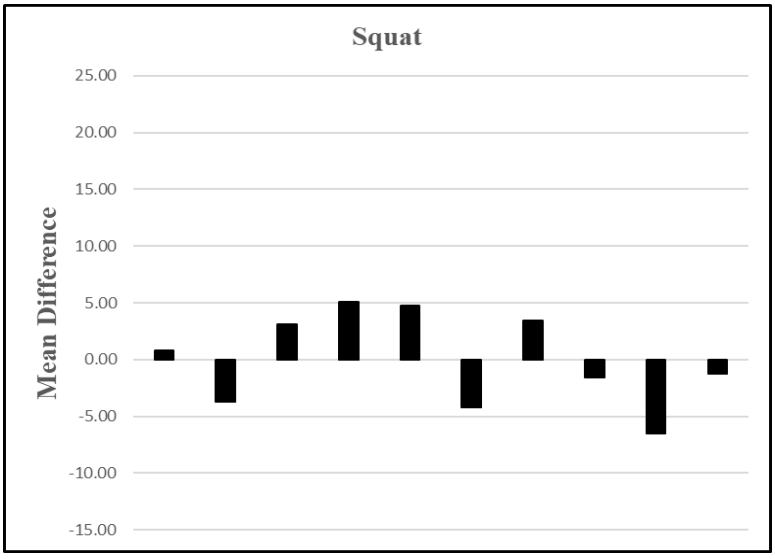

Figure 5: Squat Mean Difference Among SWAT Operators

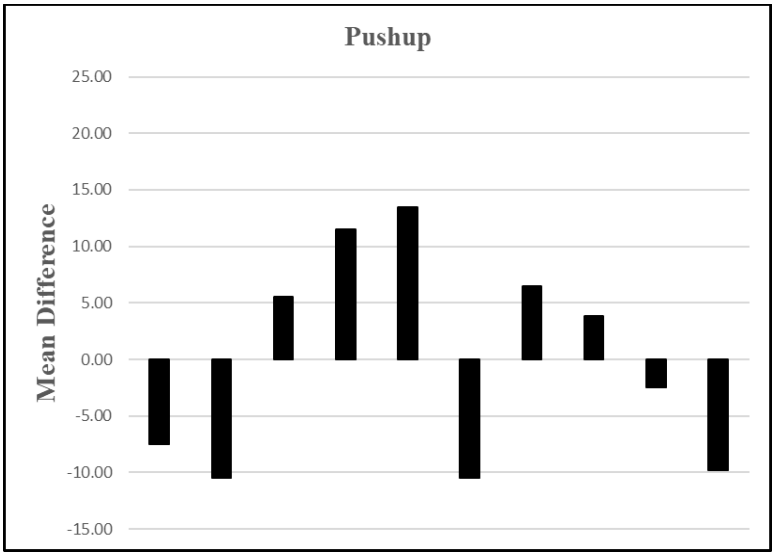

Figure 6: Pushup Mean Difference Among SWAT Operators

From the individual results presented in Figures 1-6, it appears the pushup test, pullup hold, and lunge demonstrate the greatest diversity in ability amongst the SWAT operators in the current investigation. This may be indicative of an imbalance in the training focus among the different participants, the varying injury status of the operators, or the strength to weight ratios of the operators. Markovic & Jaric (2004) examined the relationship of various tests to incremental changes in body weight. Performance in the pullup and to some degree the pushup and single leg squat were highly and disproportionately affected by increases in body weight. Allometric scaling was proposed to improve the comparisons made among these tests to other tests that are less susceptible (11). However, since standards are typically set at a criterion level, allometric scaling may be more appropriate when trying to compare improvement in SWAT operators in these tests rather than qualification for active duty. The Yo-Yo test and sled drag appear to be the two tests of the SORT battery the current cohort were most similar and gathered closely to the mean. This is not surprising considering the relatively low cardiorespiratory capacity of all participants and the regularity with which the operators practice the "down-man" drag (dragging of a 126.4 kg dummy over a 20m distance).

Limitations

The main limitations of the current investigation would be related to the attrition of operators, the lack of a direct comparison of the 2017 obstacle course results to a Cooper fitness test assessment in the present term, and an understanding of how improvements in the SORT battery test components would translate to improved job task performance. After the first familiarization trial, there was a change in Norman

SWAT command that led to a reduction from 24 to 10 participants and thus a loss of some of the statistical power to find differences and relationships among variables. However, it should be noted that the SORT battery composite scores were shown to have a statistically significant relationship with the results of the obstacle performances. As operators scored higher on the SORT battery tests, they performed the obstacle course in a shorter amount of time, indicating a better performance. With an increase in the sample size, it is expected this relationship would possibly grow stronger. Out of respect of the time demands for the SWAT operators in the current investigation who are part-time, meaning they must also serve in a typical law enforcement capacity (traffic duty, domestic callouts, etc.) and we did not assess Cooper fitness test performance.

Although a direct comparison, may help better establish what tests in the Cooper may relevant, the position of the SWAT operators and their command is a lack of agreement and representation by the tasks in the Cooper test and thus had already decided to discontinue its use as a qualifying test for SWAT active duty. Lastly, although a training intervention with pre-test and post-test comparisons of obstacle course performance would have strengthened the scope of the current investigation, it would have been premature without first establishing the reliability of the test, as well as concurrent validity. With the present results, future research will be aimed at continuing to examine the reliability of the SORT battery but also to test if a periodized training program based on SORT battery test performance can lead to an improved job task capacity and performance in a timed simulation typically experienced during high-risk SWAT callout.

Significance of Findings

The significance of the findings in this study show that the SORT battery could be used as a valid and reliable testing measure to assess the occupation specific physical fitness capabilities of SWAT operators. These results show that there could be a testing method other than the Cooper test to assess weak areas in an operator's physical fitness, and could be used to pinpoint which areas an operator should train in order to be more physically capable when situations that require SWAT teams arise.

Future Research

The results of this study could become the foundation for future research in testing the physical fitness of SWAT operators. Future studies should include a simulated SWAT operation and SORT test measured at baseline. Once weaknesses are identified in SORT scores, and age is accounted for, a control group and a training group should be used to compare training interventions. After the training group finishes the intervention, both groups would test the SORT battery and the mock operation again. The purpose of the study would be to determine if increases in SORT battery scores could cause a faster, successful operation when compared to a control group.

The SORT battery could be further refined as well; future research could examine whether certain aspects of the test are necessary if other tests highly correlate to another component within the test. Components could be removed, or others added as the test becomes stronger or less correlated to the current criterion measure. The findings of our research show that the sled drag could be a candidate for removal as it only correlates to the lunge test, and both components use similar unilateral movement.

If a SORT component causes unnecessary fatigue, it could should be removed to improve other scores and allow operators to return to duty after testing with as little detriment to job performance as possible.

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