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The specific purpose of this report was to describe the inter-relationships between physical performance on the OPAT and APFT and BMI in college-aged (21 ± 3 y) male (n=774; BMI=25.4 ± 3.7 kg·m-2) and female (n=195; BMI=23.9 ± 2.7 kg·m-2) Army trainees. Differences between male and female trainees on the OPAT and APFT reflect the well-documented physiological differences in physical performance between men and women. However, the trainees who were the lowest APFT performers at entry were the most improved by the end of initial entry training, a pattern observed in both men and women. Physical performance on selected tests was related to BMI quartile stratification, but in a sex-specific manner. This report collectively demonstrates that the OPAT and APFT, both implemented for different purposes (occupation determination and general fitness, respectively), provide unique perspectives into Army trainee physical performance. Because important relationships exist between BMI and physical performance (performance enhanced in some cases while decreased in others, when examined in the context of increased BMI), there may be situations in which the need for increased muscular strength and power is more important than health concerns related to suboptimal BMI.

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**U.S. Army Public Health Center**

**Public Health Report**

# PHR No. S.0047229-18a
# Physical Performance on the Occupational Physical Assessment Test (OPAT), Army Physical Fitness Test (APFT), and Relationship to Body Mass Index During Initial Entry Training – OPAT Phase I



**General Medical: 500A**

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# EXECUTIVE SUMMARY
# Public Health Report No. S.0047229-18a
# Physical Performance on the Occupational Physical Assessment Test (OPAT), Army Physical Fitness Test (APFT), and Relationship to Body Mass Index during Initial Entry Training: OPAT Phase I

## 1 Purpose

The Occupational Physical Assessment Test (OPAT) was developed as a pre-enlistment screening test administered prior to entering Initial Entry Training (IET). The specific intent of this test is to identify the right Soldier for the right job(s) (e.g., military occupational specialties (MOSs)) based solely on occupational physical demands and independent of sex. The 4-event OPAT measures physical attributes related to military task performance, which includes the following:

- Interval Aerobic Run (IAR; cardiorespiratory fitness);
- Seated Power Throw (SPT; upper body muscular power);
- Standing Long Jump (SLJ; lower body muscular power); and
- Strength Deadlift (SDL; muscular strength) [1, 2].

Since the 1980s, the U.S. Army's primary means of assessing fitness has been the 3-event Army Physical Fitness Test (APFT): maximum number of push-ups (PU) and sit-ups (SU) each in 2-minutes (muscular endurance) and a 2-Mile Run for time (2-MR; cardiorespiratory fitness). Because these two test batteries have not been administered concurrently, it remains unclear if the OPAT and the APFT may provide similar or different information (e.g., performance on each of these tests is or is not correlated with one another), especially in trainees attending IET. Additionally, associations between body composition and physical performance have been noted in military and similar populations [3-6]; however, few data exist on relative measures of body composition (e.g., body mass index (BMI)) and potential influences on physical performance tests such as the APFT or OPAT in trainees.

In a collaborative effort, the U.S. Army Research Institute of Environmental Medicine (USARIEM) and the U.S. Army Public Health Center (APHC) collected physical performance data and BMI measurements as part of the OPAT Longitudinal Validation Study at three Army installations (Fort Benning, Georgia; Fort Leonard Wood, Missouri; Fort Sill, Oklahoma) between January and December 2016. The current study used a subset of data from the OPAT Longitudinal Validation Study to evaluate the relationships between performance on the OPAT, performance on APFT trials during IET, and their relationships to body mass index.

The specific purpose of this report was to describe the inter-relationships between physical performance on the OPAT and APFT and BMI in college-aged (21 ± 3 y) male (n=774; BMI=25.4 ± 3.7 kg·m$^{-2}$) and female (n=195; BMI=23.9 ± 2.7 kg·m$^{-2}$) Army trainees, using both sex-dependent and -independent stratifications.

## 2 Findings

On average, trainees completed 52.6 ± 19.5 shuttles on the IAR, threw 553.6 ± 112.2 cm on the SPT, jumped 190.1 ± 35.3 cm on the SLJ, and 73% of the group lifted the highest weight tested on the SDL (220 pounds (lb)). When comparing male and female trainee performance on the OPAT, women completed fewer IAR shuttles (-41%), and demonstrated both a shorter SPT distance (-34%) and a shorter SLJ distance (-25%). In addition, a lower proportion of women were able to lift the highest SDL weight tested (220 lb): 15% of women vs. 88% of men. On the Initial/Diagnostic APFT at the beginning of IET, trainees performed an average of 38.6 ± 17.9 PU and 49.2 ± 14.6 SU reps, and ran the 2-MR in 16.34 ± 2.35 min. Comparing by sex, women performed a lower number of PU (-52%) and SU (-10%) repetitions and ran the 2-MR slower (+19%). Although the APFT was repeated toward the end of IET, and women specifically improved their APFT performance by an average of nearly 70 (age- and sex-adjusted) points, marked sex differences in APFT performance persisted toward the end of the IET cycle (-33% PU, -5% SU, +18% 2-MR time in women relative to men). These differences on the OPAT and APFT reflect the well-documented physiological differences in physical performance between men and women. However, the trainees who were the lowest APFT performers at entry were the most improved by the end of IET, a pattern observed in both men and women. Individual OPAT and APFT events mostly demonstrated weak to moderate correlations, with the strongest correlations existing between the two cardiorespiratory fitness events: OPAT IAR and Diagnostic APFT 2-MR (r = -0.65 to -0.72).

Physical performance on selected tests was related to BMI quartile stratification, but in a sex-specific manner. For example, in men, a higher BMI (Q4 (highest) vs. Q1 (lowest)) was associated with decreased performance on the OPAT IAR (-21%) and SLJ (-7%) events as well as the APFT 2-MR (+8% slower time), but also associated with improved performance on the OPAT SPT (+16%) event. In women, a higher BMI (Q4 vs. Q1) was associated with decreased performance on the APFT 2-MR (+9% slower time), but increased performance on the OPAT SPT (+11%) event. On the OPAT SDL event in men and women, moving from low to high BMIs (Q1 to Q4), significant trends indicated that more individuals were able to lift either 180 or 220 lb (the most frequently lifted weights for women and men, respectively).

## 3 Next Steps

This report demonstrates that although the OPAT and APFT test batteries are utilized for different reasons (i.e., OPAT for proper MOS assignment and APFT for general fitness), both provide different, independent perspectives into IET trainee physical fitness. Increased BMI values were associated with both augmented and diminished performance in an event- and a sex-specific fashion for the OPAT and APFT test events. Consideration should be given for situations in which the need for superior physical performance (within specific physical attributes such as higher muscular strength and power) is greater than concerns for suboptimal body composition (such as not meeting weight-for-height or body fat percentage cut-offs). Thus, setting body composition standards for the Army should strike a balance between health concerns and the physical performance requirements associated with certain MOS assignments and successful task completion.

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# Physical Performance on the Occupational Physical Assessment Test (OPAT), Army Physical Fitness Test (APFT), and Relationship to Body Mass Index during Initial Entry Training: OPAT Phase I

## 1 REFERENCES

Appendix A provides the references cited within this document.

## 2 AUTHORITY

The U.S. Army Public Health Center's (APHC's) Injury Prevention Division (IPD) prepared this report according to APHC's responsibility under Army Regulation (AR) 40-5, Section 2-19 to provide support to the U.S. Army Medical Command (MEDCOM) for comprehensive medical surveillance to identify, prevent, and control evolving health problems [7]. The APHC and MEDCOM are responsible for support to Headquarters, Department of the Army (HQDA) G-1 and the U.S. Army Training and Doctrine Command (TRADOC) in the implementation and longitudinal validation of the Occupational Physical Assessment Test (OPAT) [8]. This report is prepared to summarize a subset of findings from the APHC's collaboration with the U.S. Army Research Institute of Environmental Medicine (USARIEM) on the TRADOC-sponsored OPAT Longitudinal Validation Study.

## 3 INTRODUCTION

### 3.1 Purpose

This report represents a subset of data from the OPAT Longitudinal Validation Study, where the specific purpose is to describe the inter-relationships between physical performance on the OPAT and Army Physical Fitness Test (APFT) and body mass index (BMI) in Army trainees in both sex-dependent and -independent stratifications.

### 3.2 Scope

In addition to applying the public health process to achieve its mission, the APHC collaborates with other MEDCOM entities to answer research questions, which aim to optimize Soldier health and readiness throughout the Soldier life cycle. In a collaborative effort, USARIEM and the APHC's IPD collected performance data and body mass index (BMI) measurements as part of the OPAT Longitudinal Validation Study at three Army installations (Fort Benning, Georgia; Fort Leonard Wood, Missouri; Fort Sill, Oklahoma) between January and December 2016. These study iterations supported Phase I of the OPAT Longitudinal Validation Study, which took place during Army trainees' Initial Entry Training (IET) cycle.

This report describes the inter-relationships between OPAT and APFT physical performance and BMI in trainees, as the OPAT was recently implemented as a pre-enlistment physical qualification assessment in this population, and interactions between these factors remain relatively unexplored. The findings in this report highlight trade-offs between augmented physical performance and suboptimal BMI. This report is part of a series of related reports documenting physical performance on the OPAT test (Phases I and II) and its relationship to injury risk mitigation and BMI in Army trainees.

### 3.3 Background

Women comprise approximately 15% of the U.S. Military with many serving alongside men in recent military campaigns, having been exposed to similar hostile enemy actions. However, the 1994 Direct Ground Combat Definition and Assignment Rule (DGCDAR) excluded women from units and positions whose primary mission was to engage in direct ground combat. In 2013, the DGCDAR was rescinded, and the U.S. Military was directed by the Department of Defense (DOD) to open all job assignments (e.g., Military Occupational Specialties; MOSs) to any capable Service member regardless of sex. Although MOSs previously closed to women would now be open to all Service members, the most important deciding factor in MOS assignment would be the ability to meet MOS-associated physical demands, with a single standard for all Soldiers. In an attempt to systematically quantify the physiological demands associated with seven Combat Arms MOSs (i.e., Infantry (11B, 11C), Combat Engineers (12B), Field Artillery (13B, 13F), and Armor (19D, 19K)), USARIEM conducted the Physical Demands Study (PDS) in which they first characterized the physical demands of 32 military-relevant tasks [9] among Soldiers from operational units. The next step conducted was to examine the relationship between simple predictive field tests of physical fitness to Soldiers' ability to perform the most relevant Combat Arms tasks to standard (i.e., Criterion Measure Task Simulations (CMTS)). Among several candidate field test batteries, the combination of tests that was best able to predict the ability to pass CMTS was chosen and is what ultimately became known as the OPAT [1, 2]. The purpose of the OPAT was, "…to develop a valid, safe, and legally defensible physical performance battery to predict a Soldier's ability to serve in each [combat] MOS." [1].

The 4-event OPAT was implemented as a pre-enlistment physical qualification assessment as of January 2017, with the intent of assigning the right Soldier to the right job. This test is comprised of the Seated Power Throw (SPT) and Standing Long Jump (SLJ) (upper- and lower body muscular power, respectively), Strength Deadlift (SDL; muscular strength), and the Interval Aerobic Run (IAR; cardiorespiratory fitness). Given the relationships of the four events with CMTS performance [1, 2], TRADOC (proponent for the OPAT) set minimum allowable physical performance standards for each of the above events that correspond to the overall physical demand level of a particular MOS referenced in DA Pamphlet (Pam) 611-21 [10]. The aim of the OPAT is to make a determination of physical aptitude before recruits begin training for an MOS using physical demand as a discriminator; much like the Armed Services Vocational Aptitude Battery (ASVAB) predicts academic- and occupationally-related aptitude.

The principal means of assessing general physical fitness in the U.S. Army continues to be the APFT. Used since the mid-1980s [11], the APFT simply represents a baseline level of fitness required for Soldiers [11, 12]. This 3-event test battery is administered to every Soldier semi-annually, unless a physical profile precludes them from taking part in these particular events [12]. Unlike the OPAT, which assesses muscular strength, muscular power, and cardiorespiratory fitness, the APFT measures a narrower spectrum of physical fitness: muscular endurance through maximum Push-ups (PU) in 2-minutes (min) and maximum Sit-ups (SU) in 2-min, as well as cardiorespiratory fitness through a 2-mile run (2-MR) for time.

Physical performance differences on the APFT between men and women have been previously demonstrated [13, 14], which are easily explained through sex-dependent physiological factors

[15]. It was expected that similar performance discrepancies in OPAT performance between male and female trainees would be observed, although sex-dependent differences on physical performance tests outside of APFT events (measuring physical capabilities other than muscular and cardiovascular endurance), such as the OPAT, are not widely documented in trainees or operational Soldiers [16]. Thus, it is unknown whether the OPAT and APFT provide similar information about IET trainees' fitness status.

Body composition refers to the proportions of body tissues (muscle, fat, bone, etc.) relative to total body mass. Certain body composition assessment methods, such as dual-energy x-ray absorptiometry (DXA) or skin fold measurements require expensive equipment and/or skilled personnel to obtain reliable and valid results. In the military, field-expediency, financial constraints, and technical expertise limit the available methods to techniques such as BMI (weight relative to height) and "tape-tests" (i.e., circumference measurements) to estimate Soldier body composition. The primary reason for assessing body composition is to ensure that Soldiers are physically capable and readily deployable at all times, which includes health concerns associated with unfavorable body composition such as high body fat (e.g., obesity) [17]. Therefore, Soldiers have their weight and height measured every 6 months according to AR 600-9, The Army Body Composition Program (ABCP) [18]. Soldiers must pass a weight-for-height standard (essentially serving as a surrogate for body fat), which has increasing allowances for increasing age. Using weight-for-height allowance tables, the corresponding maximal BMIs allowed across all ages are 26 and 27.5 $kg \cdot m^{-2}$ for women and men, respectively. These maximum allowances also imply that some Soldiers, who would be categorized as "overweight" by World Health Organization (WHO) standards, having a BMI between 25.0 and 29.9 $kg \cdot m^{-2}$, would still be able to meet Army standards. If Soldiers do not meet the sex- and age-adjusted weight-for-height standard (e.g., BMI), they undergo a secondary circumference measurement, also known as a "tape-test." Using sex-specific circumference measures (two sites for men and three sites for women) and height, body fat percentage is estimated. This conditional test of body composition helps to identify individuals who are over the weight-for-height/BMI standards, but who may not be over the body fat allowance [19]. While BMI may misclassify certain individuals due to inherent inability to distinguish between muscle and fat [20, 21], it has been previously demonstrated that BMI alone can predict those who meet or exceed ABCP body fat standards with 83% accuracy [22], and is able to serve as a surrogate of relative body fat in Soldiers [22, 23].

Researchers have consistently reported negative relationships between poor body composition and cardiovascular fitness. Specifically, for an increased BMI (increased percent body fat as well), individuals will have a diminished cardiovascular or cardiorespiratory fitness. This phenomenon has been observed in military firefighters [6], police officers [24], and U.S. Military Service members [4, 25]. The relationships between body composition and other physical fitness attributes, such as muscular strength, power, speed and agility, and even military task performance are becoming better understood through recent and ongoing research. Accordingly, APHC recently demonstrated that Soldiers with higher BMI values performed better on tests requiring muscular strength and muscular power, but at the same time performed worse on tests of speed and cardiovascular endurance [4]. Although a higher BMI is highly related with increased body fat [22, 23] and is associated with a disproportionate gain in body fat (compared to muscle mass) for corresponding rise in BMI [22], these same physically active individuals also typically have higher muscle mass and tend to be stronger. Similar findings in

Finnish Defense Forces were also recently reported [5]. Although military members may be penalized for having a higher BMI, these same Soldiers may outperform their lower-BMI counterparts on tests that represent physical attributes such as muscular strength and power [4, 5] deemed important for military service [26], but not currently measured by the APFT. Thus, trade-offs exist with regard to suboptimal body composition (e.g., suboptimal BMI) and physical performance, and should be considered in situations where MOS-related tasks might require higher levels of muscular strength and power. Additionally, a panel of subject matter experts (SMEs) rated muscular strength and power physical attributes the highest among 11 physical attributes needed for successful military task completion [26]. It remains to be determined which physical attributes may be more beneficial, or more responsible, for optimal performance related to a given MOS or specific task assignment.

Given the above, it is important to determine the relationships between conventional physical performance tests employed by the military (e.g., APFT) and the newly implemented performance tests (e.g., OPAT), as they may provide either unique or redundant information. Further, given the potential trade-offs between suboptimal body composition and physical performance, it remains to be determined how OPAT-assessed physical performance relates to body composition. Lastly, all testing that led to the OPAT development and implementation involved incumbent operational Soldiers; the data collection related to the study questions below was conducted on Army trainees within 2 weeks of arriving at their IET installation (i.e., Basic Combat Training (BCT) and One Station Unit Training (OSUT)). The current investigation is a secondary analysis of data collected from the OPAT Longitudinal Validation Study, where the specific purpose was to evaluate the inter-relationships between OPAT and APFT performance and BMI (as a surrogate of relative body composition) in trainees enrolled in IET. Relevant guiding questions for this report were:

- How did trainees perform on the OPAT and APFT?
- How did trainees' OPAT performance relate to their APFT performance and change in APFT performance (if any) during IET?
- Is OPAT or APFT performance related to BMI in trainees?

# 4 METHODS

## 4.1 Study Overview

The USARIEM Institutional Review Board approved the OPAT Longitudinal Validation study. Subjects that volunteered for the study were trainees who had recently arrived at one of three Army Installations conducting IET (Fort Benning, Georgia; Fort Leonard Wood, Missouri; and Fort Sill, Oklahoma). Prior to participating in any aspect of this study, trainees provided their verbal and written informed consent in the presence of an ombudsman following a briefing on the benefits and potential risks from participation in the study. The investigators adhered to the policies for protection of human subjects as prescribed in AR 70-25, and the research was conducted in adherence with the provisions of 32 CFR Part 219.

## 4.2 Volunteer Inclusion/Exclusion Criteria

Prospective recruits are required to pass general military health and medical clearances typical of military enlistment procedures (e.g., Military Entry Processing Station (MEPS)), and coordinated with AR 40-501, Army Standards of Medical Fitness [27] prior to enlisting. After arriving at the BCT/OSUT installations, IET trainees underwent additional medical screening while in the Reception Battalion. Initial qualification for the study required trainees to be in Reception or within 2 weeks of leaving Reception in a BCT or OSUT training unit. As part of the study, briefing and consent process, potential subjects were asked questions about prior and recent medical history, including musculoskeletal injuries. Volunteers were excluded from participating in the study if they answered "yes" to certain questions that presented contraindications to physical activity participation, or if they were unable to perform physically demanding tasks. Additional face-to-face screening took place to determine final eligibility for those who indicated "yes" to one or more screening questions.

A total of 1,181 IET trainees (n=948 men, n=233 women) were enrolled in the OPAT Longitudinal Validation Study and completed the full battery of OPAT tests at the beginning of IET between January and December 2016 at one of three IET installations (Fort Benning, Georgia; Fort Leonard Wood, Missouri; Fort Sill, Oklahoma). BCT trainees were followed through advanced individual training (AIT) at the same installation, and OSUT trainees were followed for the entire length of their training at the same installation. Because the OPAT had not yet been implemented in the accession/MOS determination process when the study was conducted, most of these trainees Soldiers had not been previously familiarized or tested with the OPAT. All OPAT testing was conducted in an indoor gym. APFT performance data at the beginning and towards the end of IET were obtained directly from trainees' training units. This report's analysis only included trainees who completed the OPAT and both instances of APFT testing (beginning and end of IET) and had height and weight measurements. These study exclusionary criteria resulted in a reduction of subjects, totaling 969 trainees (n=774 men; n=195 women). The number of female trainees in the current investigation (20% of the study population) approximated current active duty Army personnel demographics (~15% women). Height and weight were assessed using a portable stadiometer (mounted ruler with moveable head piece) and electronic scale on the same day as the OPAT testing, with BMI calculated using metric unit height and weight ($kg \cdot m^{-2}$). The men and women in the current study did not differ in age (men: 21 ± 3 vs. women: 20 ± 3 y; P=0.27), but the men were taller (175.4 ± 6.4 vs.

163.0 ± 5.9 cm) and heavier (78.3 ± 12.8 vs. 63.6 ± 8.0 kg), and had a higher calculated BMI (25.4 ± 3.7 vs. 23.9 ± 2.7 $kg \cdot m^{-2}$) compared to the women, respectively ($p<0.01$).

### 4.3 OPAT Testing and Scoring

Mentioned above, the 4-event OPAT was developed as a battery of tests to predict the successful completion of CMTSs (e.g., sandbag carry and placement, move under fire drills, dummy drags, stowing ammo, etc.) conducted at the end of IET [1]. The field-expedient OPAT tests measuring upper and lower body muscular power, lower body muscular strength, and aerobic fitness have been described in detail elsewhere [1, 2]; however, a brief explanation of each OPAT event is provided below. All OPAT-related tests were completed in a single session for each trainee cohort, and each installation provided several trainee groups, which were studied over multiple visits. As with most physical training and the standard APFT testing procedures [12], trainees were required to be in their Army Physical Fitness Uniform (APFU), which included t-shirt, shorts, socks, and sneakers while performing the tests. The trainees performed all four events in a serial fashion after having their height and weight recorded. The particular OPAT event order was determined by site location and in such a manner to facilitate testing several smaller groups of trainees simultaneously. The order of the first three events varied; however, the interval aerobic run (IAR) event was always performed last.

Although each event provides insight into a specific physical attribute, such as cardiorespiratory endurance, the lowest cut-point achieved among all four OPAT events determines the overall OPAT Physical Demand Category (PDC)/Level achieved [28]. The current study, however, only examined the raw OPAT test event data and not the specific PDCs/Levels achieved.

#### 4.3.1 *Interval Aerobic Run (IAR)*

Known as the “beep test” or “multistage shuttle run test (MSRT),” the IAR is primarily a measure of aerobic fitness. This test is a validated predictor of one’s maximal aerobic capacity (e.g., maximal/peak oxygen uptake or $VO_2$ max/peak), given the relationship between the last shuttle achieved during the test and maximal aerobic speed [29]. In short, the individual ran between two lines marked by cones, spaced 20 m apart. An audible signal (beep) and voice are heard indicating the current level and shuttle, where the individual must reach the opposing line/cone within the time allotted for each respective shuttle. Although maximal effort was encouraged, the trainee could voluntarily terminate the test at any time, and the highest shuttle number was recorded. Otherwise, if the trainee did not reach the opposing line in two consecutive attempts, the test was terminated and the final number of consecutive shuttles achieved was recorded.

#### 4.3.2 *Seated Power Throw (SPT)*

This test of upper body muscular power was completed with the trainee sitting on the floor with a small foam block between their lower back and a wall. After resting a 2 kg medicine ball on the chest, the trainee extended their arms and threw the ball as far as possible at a 45 degree angle. The average distance of the best two of three attempts (to the nearest cm) was recorded.

#### 4.3.3 *Standing Long Jump (SLJ)*

This test of lower body muscular power was completed by having the trainee jump as far as possible (horizontally) from a marked take-off line. The trainee first performed a counter-movement (arm swing with knees bent), followed by the take-off movement. Two practice jumps were followed by three scored attempts. The average distance of the best two of three attempts (to the nearest 0.5 cm) was recorded as the final score.

#### 4.3.4 *Strength Deadlift (SDL)*

This test of lower body muscular strength was completed by having the trainee stand inside a hex-bar with pre-loaded weights set up in stations. The trainee was first instructed on proper lifting technique, which was followed by three practice attempts with an unloaded bar (60 lb). If the trainee was able to properly lift the unweighted bar, they moved to the next station to attempt the next higher weight in serial fashion (60 lb unloaded bar, 100 lb, 140 lb, 180 lb, and 220 lb). Trained cadre graders provided corrective feedback if necessary, and indicated to the trainee if they performed a successful lift. Although the trainee only had to lift the weight once at each station, each station allowed up to two lift attempts, separated by 1-minute rest interval if needed. The highest weight successfully lifted was recorded as the final score.

### 4.4 APFT Test Events

The APFT is the U.S. Army's current and primary means for assessing physical fitness, muscular endurance (maximal Push-ups (PU) and maximal Sit-ups (SU) each within 2 minutes), and cardiorespiratory fitness (Two-mile Run (2-MR)) [11, 12]. These tests and their administration procedures are described in detail in FM 7-22 [12]. Trainees in IET take a Diagnostic APFT (e.g., not for record) and must pass an APFT by the end of their IET course (e.g., for record and required for IET graduation). Therefore, other than the Diagnostic APFT taken at the beginning of IET to gauge baseline fitness, trainees were able to take subsequent iterations of the APFT in order to achieve a passing score (i.e., a minimum of 60 points in each event) by the end of IET. The APFT performance, which allowed the trainee to graduate IET, was accepted as the "Final" APFT. All APFT trials were conducted with trainees wearing the APFU, and raw data (repetitions, time) was collected at the unit level and provided to the investigators.

### 4.5 Statistical Analysis

Only trainees with complete OPAT, Diagnostic APFT, and Final APFT were included in this report. In addition to descriptive statistics, independent t-tests were used to compare mean differences on continuous variables between men and women. When variables were not continuous (e.g., discrete), such as the SDL, comparison of differences between the number of individuals who could lift a weight successfully utilized Chi-square analysis.

In order to determine the relationships between OPAT and APFT performance, Pearson Product Moment Correlations were conducted. To determine the potential influence of BMI on physical performance, subjects were stratified by quartiles of calculated BMI (creating 4 bins of approximately equal subjects in each group of increasing BMI) within sex. In a similar fashion the change in APFT scores were examined at the end of IET. Trainees' change in performance (delta) during IET was also stratified by their Diagnostic APFT performance (sorted by quartiles of initial performance similar to the BMI stratification). Physical performance data was then analyzed by BMI quartiles or by Diagnostic APFT quartiles using analysis of variance (ANOVA) depending on the research question. If the ANOVA identified a significant F Ratio, a Tukey post-hoc analysis was conducted to compare the BMI- or APFT-binned performance characteristic. For the SDL test specifically, trends for BMI quartiles within weight lifted were analyzed using the Mantel-Haenszel chi square for linear trend test.

All statistical analyses were completed using commercially available software (IBM® SPSS® Statistics for Windows, Version 21.0), and significance was accepted at $p \leq 0.05$.

## 5 RESULTS

### 5.1 Performance Outcomes

#### 5.1.1 *OPAT Performance*

On average, male and female college-aged, IET trainees performed a combined 52.6 ± 19.5 shuttles on the IAR. The study population of male and female trainees performed differently on physical fitness tests, as expected. For instance, when examined by sex, women completed 41% fewer shuttles compared to men (women: 34.0 ± 14.2 vs. men: 57.3 ± 17.8 shuttles, $P<0.01$). Similar patterns of performance were observed for the other OPAT events as well, with women performing at lower mean values compared to men: (SPT: 34% shorter distance; SJL: 25% shorter distance) (Table 1). The SDL was reported as a discrete variable since it was only possible to lift from a constrained set of weights (60, 100, 140, 180, and 220 lb), and therefore inappropriate to calculate the average weight lifted for men and women. When displayed as the number of trainees who lifted a given weight in the SDL, fewer women were able to lift the highest weight (220 lb; ~88% of men, ~15% of women), and there was a more even distribution of women who lifted each possible weight vs. men who more frequently lifted the highest weight(s) possible (Table 1). On the SDL, the most frequently lifted weight for women was 180 lb (40.5% women); while the most frequently weight lifted for men was 220 lb (87.9% men).

**Table 1. Raw OPAT Performance Data**

| | **Trainee Group** | | |
|---|---|---|---|
| **OPAT Event** | **Men (n=774)** | **Women (n=195)** | **Combined (n=969)** |
| **Interval Aerobic Run (IAR) (*shuttles*)** | 57.3 ± 17.8 | 34.0 ± 14.2 * | 52.6 ± 19.5 |
| **Seated Power Throw (SPT) (*cm*)** | 594.7 ± 81.8 | 390.4 ± 51.5 * | 553.6 ± 112.2 |
| **Standing Long Jump (SLJ) (*cm*)** | 200.3 ± 29.9 | 149.3 ± 23.4 * | 190.1 ± 35.3 |
| **Strength Deadlift (SDL) (*n, (% of sample within group)*)** | | | |
| **60 lb (unloaded bar)** | 0 (0.0%) | 1 (0.5%) | 1 (0.1%) |
| **100 lb** | 3 (0.4%) | 20 (10.3%) | 23 (2.4%) |
| **140 lb** | 21 (2.7%) | 66 (33.8%) | 87 (9.0%) |
| **180 lb** | 70 (9.0%) | 79 (40.5%) | 149 (15.4%) |
| **220 lb** | 680 (87.9%) | 29 (14.9%) ‡ | 709 (73.2%) |

Legend: OPAT = Occupational Physical Assessment Test.
Notes:
*P<0.01 Women vs. Men (Independent t-test); ‡P≤0.01 for Chi Square (sex × weight lifted, SDL Event only); Data are presented as mean ± SD, except for SDL presented as n (% of sample within sex or in the combined men and women group) of trainees that lifted a given “maximal” load (e.g., considered to be the individual’s maximal weight lifted, as they did not lift a heavier weight successfully or voluntarily in the test). Note that the highest weight possible for any individual to lift was 220 lb.

### 5.1.2 *APFT Performance*

As expected, and in line with the OPAT physical performance data, there were clear differences in performance on the Diagnostic and Final APFT iterations between men and women trainees. In both Diagnostic and Final APFT trials, women performed fewer repetitions on the PU and SU events, and ran slower than men on the 2-MR event (P<0.01 for all comparisons; Table 2).

**Table 2. Diagnostic and Final APFT Event Performance**

| | **Trainee Group** | | |
|---|---|---|---|
| **APFT Iteration/Event Data** | **Men (n=774)** | **Women (n=195)** | **Combined (n=969)** |
| **Diagnostic 2-min PU (*reps*)** | 43.1 ± 15.4 | 20.7 ± 15.8 * | 38.6 ± 17.9 |
| **Diagnostic 2-min SU (*reps*)** | 50.2 ± 14.1 | 45.3 ± 16.0 * | 49.2 ± 14.6 |
| **Diagnostic 2-MR (*time, min*)** | 15.74 ± 1.88 | 18.74 ± 2.49 * | 16.34 ± 2.35 |
| | | | |
| **Final 2-min PU (*reps*)** | 59.6 ± 13.5 | 39.7 ± 15.9 * | 55.6 ± 16.1 |
| **Final 2-min SU (*reps*)** | 63.7 ± 11.2 | 60.5 ± 13.1 * | 63.1 ± 11.7 |
| **Final 2-MR (*time, min*)** | 14.23 ± 1.22 | 16.79 ± 1.64 * | 14.74 ± 1.67 |

Legend:
APFT = Army Physical Fitness Test; 2-min = maximum number of repetitions (reps) performed within 2 minutes; PU = Push-ups; SU = Sit-ups; 2-MR = 2-mile run; time = time in decimal minutes.
Notes:
*P<0.01 vs. Men; Data are presented as mean ± SD.

In the final APFT iteration, physical performance significantly improved in both men and women. Table 3 shows that women improved by 19 Push-ups (91.8% improvement), 15 Sit-ups (33.5% improvement), and by running nearly 2 minutes faster (10.4% improvement) on their Final APFT. Men improved by 17 Push-ups (38.4% improvement), 14 Sit-ups (26.8% improvement), and by running 1.5 minutes faster (9.6% improvement) on their Final APFT. Although it appeared that women improved more than men did on all three APFT events, only the 2-MR event time improvement was significantly different when expressed as the raw (absolute) time difference (-1.95 ± 2.32 vs. -1.51 ± 1.63 min; P<0.01). However, the change in sex- and age-adjusted APFT PU and APFT Total (aggregated from all three events) points was significantly higher in women trainees. By the end of IET, the combined male and female trainee population improved by 61 total points on the APFT (Table 3).

**Table 3. Change (Delta) in APFT Performance during IET**

| | **Trainee Group** | | |
|---|---|---|---|
| **Delta APFT Event Data** | **Men (n=774)** | **Women (n=195)** | **Combined (n=969)** |
| ***Raw Data*** | | | |
| **Delta 2-min PU (*reps*)** | 16.5 ± 12.7 | 19.0 ± 17.2 † | 17.0 ± 13.8 |
| **Delta 2-min SU (*reps*)** | 13.5 ± 13.3 | 15.2 ± 14.6 | 13.8 ± 13.5 |
| **Delta 2-MR (*time, min*)** | -1.51 ± 1.63 | -1.95 ± 2.32 * | -1.60 ± 1.80 |
| | | | |
| ***Sex and age-adjusted points*** | | | |
| **Delta 2-min PU (*points*)** | 20.2 ± 15.8 | 27.5 ± 23.8 * | 21.7 ± 17.9 |
| **Delta 2-min SU (*points*)** | 19.9 ± 20.1 | 22.5 ± 22.5 | 20.4 ± 20.6 |
| **Delta 2-MR (*points*)** | 18.6 ± 19.7 | 20.1 ± 22.2 | 18.9 ± 20.2 |
| **Delta Total (*points*)** | 58.6 ± 39.0 | 69.7 ± 49.6 * | 60.9 ± 41.7 |

Legend:
APFT = Army Physical Fitness Test; 2-min = maximum number of repetitions (reps) performed within 2 minutes; PU = Push-ups; SU = Sit-ups; 2-MR = 2-mile run; time = time in decimal minutes (min).
Notes:
*P≤0.01 and †P=0.06 vs. men; Data are the change in APFT performance (raw data or adjusted points), presented as mean ± SD, calculated as Final - Diagnostic APFT event performance.

The majority of trainees improved on APFT events by the end of IET. In these cases, 93% and 88% of men demonstrated a positive delta (change above 0) for PU and SU events, respectively, indicating they performed a higher number of repetitions on these events. Further, 89% of men demonstrated a negative delta (change below 0) on the 2-MR, indicating a decreased (faster) time to run the 2-MR at the end of IET. Similarly, 95% and 89% of women demonstrated a positive delta (more repetitions) on APFT PU and SU events, respectively, and 87% demonstrated a negative delta (faster time) on the APFT 2-MR APFT event.

To examine APFT training outcomes in more detail, the trainees were stratified by quartiles of Diagnostic APFT performance within sex-specific trainee groups, which Table 4 presents. This analysis revealed a clear relationship between the Diagnostic APFT event performance (see Table 4 for Diagnostic APFT Performance Quartiles) and improvement on the Final APFT following physical training during IET (Table 5). For example, the lowest performers (combined men and women) on the Diagnostic APFT PU (Q1) improved on average by 25 repetitions on their Final APFT, and this improvement was greater ($p<0.05$) compared to the highest initial performers (Q4), who only improved by 8 repetitions (Table 5). In a similar fashion, the lowest performers on the Diagnostic APFT SU (Q1) event improved on average by 26 repetitions, while the highest performers initially (Q4) improved by 3 repetitions (Q1 vs. Q4, $p<0.05$). Finally, the slowest 2-MR performers initially (Q1) improved on average by 3.2 minutes (3 minutes, 12 seconds faster) while the fastest runners initially (Q4) only improved by 0.3 minutes (18 seconds faster) by their Final APFT (Q4 vs. Q1, $p<0.05$) (Table 5). The general trend for the largest improvements in physical performance in those with the lowest Diagnostic APFT performance—the lowest initial performers improving more than the highest initial performers ($p<0.05$), expressed either as raw (Table 5) or percent change (Table 6)—was present in both men and women.

**Table 4. Diagnostic APFT Performance Quartiles by sex**

| | Trainee Group | | | | | |
|---|---|---|---|---|---|---|
| **Diagnostic APFT Event Bins** | **Men (n=774) (n=191; 174; 209; 200)** | | **Women (n=195) (n=48; 43; 53; 51)** | | **Combined (n=969) (n=240; 239; 231; 259)** | |
| **2-min PU (*reps*)** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** |
| **Q1 (lowest)** | 1.0 - 32.0 | 24.3 ± 6.2 | 0.0 - 10.0 | 4.0 ± 3.7 | 0.0 - 25.0 | 15.8 ± 7.6 |
| **Q2** | 33.0 - 41.0 | 37.0 ± 2.6 | 11.0 - 16.0 | 13.5 ± 1.7 | 26.0 - 38.0 | 32.6 ± 3.7 |
| **Q3** | 42.0 - 51.0 | 46.3 ± 3.0 | 17.0 - 27.0 | 21.8 ± 2.9 | 39.0 - 49.0 | 43.7 ± 3.1 |
| **Q4 (highest)** | 52.0 - 107.0 | 62.9 ± 9.8 | 28.0 - 88.0 | 41.4 ± 13.8 | 50.0 - 107.0 | 60.6 ± 10.1 |
| | | | | | | |
| | **Men (n=774) (n=189; 176; 203; 206)** | | **Women (n=195) (n=47; 50; 49; 49)** | | **Combined (n=969) (n=224; 257; 245; 243)** | |
| **2-min SU (*reps*)** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** |
| **Q1 (lowest)** | 0.0 - 40.0 | 32.6 ± 6.5 | 1.0 - 33.0 | 24.2 ± 7.9 | 0.0 - 38.0 | 30.2 ± 7.2 |
| **Q2** | 41.0 - 49.0 | 45.1 ± 2.6 | 34.0 - 46.0 | 39.8 ± 3.5 | 39.0 - 49.0 | 44.3 ± 3.2 |
| **Q3** | 50.0 - 58.0 | 53.6 ± 2.7 | 47.0 - 57.0 | 51.6 ± 3.3 | 50.0 - 58.0 | 53.9 ± 2.7 |
| **Q4 (highest)** | 59.0 - 109.0 | 67.5 ± 8.5 | 58.0 - 83.0 | 64.9 ± 7.1 | 59.0 - 109.0 | 67.5 ± 8.3 |
| | | | | | | |
| | **Men (n=774) (n=194; 197; 190; 193)** | | **Women (n=195) (n=49; 49; 49; 48)** | | **Combined (n=969) (n=244; 242; 242; 241)** | |
| **2-MR (*time, min*)** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** |
| **Q1 (slowest)** | 16.78 - 25.52 | 18.20 ± 1.53 | 20.20 - 28.50 | 21.96 ± 1.78 | 17.53 - 28.50 | 19.51 ± 1.89 |
| **Q2** | 15.50 - 16.77 | 16.10 ± 0.35 | 18.43 - 20.17 | 19.34 ± 0.56 | 16.00 - 17.52 | 16.69 ± 0.47 |
| **Q3** | 14.45 - 15.47 | 14.98 ± 0.30 | 16.98 - 18.38 | 17.80 ± 0.38 | 14.68 - 15.98 | 15.32 ± 0.37 |
| **Q4 (fastest)** | 11.73 - 14.43 | 13.64 ± 0.64 | 13.12 - 16.97 | 15.80 ± 0.95 | 11.73 - 14.67 | 13.81 ± 0.68 |

Legend: APFT = Army Physical Fitness Test; 2-min = maximum number of reps performed within 2 minutes; PU = Push-ups; SU = Sit-ups; reps = repetitions; 2-MR = 2-mile run.

Notes:

Data are presented as range or mean ± SD within quartiles of Diagnostic APFT Performance; Quartiles were calculated using actual APFT performance (number of reps or time), where Q1 = lowest performance (least number of reps; slowest 2-MR times), Q4 = highest performance (highest number of reps; fastest 2-MR times); Number of trainees (n) provided per trainee group and by quartiles in order from Q1-Q4, respectively, within sex or within the combined male and female trainee groups. The information in Table 4 was used for analyses in Tables 5 and 6.

**Table 5. Raw Change in APFT Event Performance by Group-Specific Quartiles of Diagnostic APFT Performance**

| **Diagnostic APFT performance bin** | **Trainee Group** | | |
|---|---|---|---|
| **2-min PU (*reps*)** | **Men (n=774) (n=191; 174; 209; 200)** | **Women (n=195) (n=48; 43; 53; 51)** | **Combined (n=969) (n=240; 239; 231; 259)** |
| **Q1 (lowest)** | 26.8 ± 11.8 | 29.2 ± 14.6 | 25.4 ± 13.9 |
| **Q2** | 16.8 ± 9.3 * | 25.5 ± 17.9 | 20.0 ± 11.9 * |
| **Q3** | 15.0 ± 11.1 * | 15.1 ± 10.2 * | 15.5 ± 10.4 * |
| **Q4 (highest)** | 8.2 ± 10.9 * | 8.0 ± 17.4 * | 7.9 ± 12.1 * |
| | | | |
| **2-min SU (*reps*)** | **Men (n=774) (n=189; 176; 203; 206)** | **Women (n=195) (n=47; 50; 49; 49)** | **Combined (n=969) (n=224; 257; 245; 243)** |
| **Q1 (lowest)** | 25.7 ± 11.1 | 24.9 ± 14.2 | 26.2 ± 11.7 |
| **Q2** | 15.9 ± 9.0 * | 19.6 ± 10.8 | 16.4 ± 9.4 * |
| **Q3** | 10.3 ± 9.8 * | 12.3 ± 10.9 * | 10.6 ± 9.9 * |
| **Q4 (highest)** | 3.3 ± 11.3 * | 4.3 ± 13.8 * | 3.0 ± 11.8 * |
| | | | |
| **2-MR (*time, min*)** | **Men (n=774) (n=194; 197; 190; 193)** | **Women (n=195) (n=49; 49; 49; 48)** | **Combined (n=969) (n=244; 242; 242; 241)** |
| **Q1 (slowest)** | -3.19 ± 1.59 | -4.45 ± 2.34 | -3.20 ± 2.08 |
| **Q2** | -1.65 ± 0.99 * | -2.12 ± 1.52 * | -1.87 ± 1.14 * |
| **Q3** | -0.93 ± 1.07 * | -1.12 ± 1.12 * | -1.02 ± 1.12 * |
| **Q4 (fastest)** | -0.25 ± 1.13 * | -0.08 ± 1.48 * | -0.30 ± 1.21 * |

Legend:
APFT = Army Physical Fitness Test; 2-min = maximum number of reps performed within 2 minutes; PU = Push-ups; SU = Sit-ups; reps = repetitions; 2-MR = 2-mile run.
Notes:
*P≤0.05 vs. Q1 (ANOVA with Tukey post-hoc); Values are the raw change in APFT performance (raw change = Final – Diagnostic APFT) and presented as mean ± SD; APFT data were binned by quartiles of Diagnostic APFT performance with Q1 = lowest performance (least number of reps; slowest 2-MR times), Q4 = highest performance (highest number of reps; fastest 2-MR times). Number of trainees (n) provided in order for Q1-Q4, respectively, within sex or combined men and women. See Table 4 for Q1-Q4 APFT Event Bin Descriptive Info (mean ± SD, range).

**Table 6. Percent Change in APFT Performance Stratified by Group-Specific Quartiles of Diagnostic APFT Performance**

| Diagnostic APFT performance bin | Trainee Group | | |
|---|---|---|---|
| **2-min PU (*reps*)** | **Men (n=774) (n=191; 174; 209; 200)** | **Women (n=179) (n=32; 43; 53; 51)** | **Combined (n=953) (n=224; 239; 231; 259)** |
| **Q1 (lowest)** | 157.4 ± 342.8 | 706.3 ± 758.3 | 253.8 ± 465.8 |
| **Q2** | 46.0 ± 25.9 * | 193.8 ± 137.0 * | 63.2 ± 40.6 * |
| **Q3** | 32.7 ± 24.4 * | 72.6 ± 50.4 * | 35.7 ± 24.0 * |
| **Q4 (highest)** | 14.0 ± 17.5 * | 26.8 ± 46.3 * | 14.1 ± 20.8 * |
| | | | |
| **2-min SU (*reps*)** | **Men (n=773) (n=188; 176; 203; 206)** | **Women (n=195) (n=47; 50; 49; 49)** | **Combined (n=968) (n=223; 257; 245; 243)** |
| **Q1 (lowest)** | 85.0 ± 50.0 | 266.9 ± 760.2 | 126.5 ± 356.3 |
| **Q2** | 35.4 ± 20.3 * | 50.7 ± 30.1 * | 37.5 ± 22.3 * |
| **Q3** | 19.5 ± 18.4 * | 24.3 ± 21.5 * | 19.9 ± 18.6 * |
| **Q4 (highest)** | 5.5 ± 16.7 * | 7.8 ± 20.6 * | 5.1 ± 17.3 * |
| | | | |
| **2-MR (*time, min*)** | **Men (n=774) (n=194; 197; 190; 193)** | **Women (n=195) (n=49; 49; 49; 48)** | **Combined (n=969) (n=244; 242; 242; 241)** |
| **Q1 (slowest)** | -17.13 ± 7.13 | -20.00 ± 9.66 | -15.94 ± 9.23 |
| **Q2** | -10.24 ± 6.11 * | -10.93 ± 7.76 * | -11.19 ± 6.78 * |
| **Q3** | -6.21 ± 7.15 * | -6.26 ± 6.27 * | -6.61 ± 7.27 * |
| **Q4 (fastest)** | -1.75 ± 8.40 * | -0.17 ± 10.05 * | -2.03 ± 8.84 * |

Legend:
APFT = Army Physical Fitness Test; 2-min = maximum number of reps performed within 2 minutes; PU = Push-ups; SU = Sit-ups; reps = repetitions; 2-MR = 2-mile run.
Notes:
*P≤0.05 vs. Q1 (ANOVA with Tukey post-hoc); Values are the percent change in APFT performance (% change = ([Final – Diagnostic APFT]/Diagnostic) * 100) and presented as mean ± SD; Values displayed are the mean values for group after calculating each individual trainee's percent change in performance; APFT data were binned by quartiles of Diagnostic APFT performance with Q1 = lowest performance (least number of reps; slowest 2-MR times), Q4 = highest performance (highest number of reps; fastest 2-MR times). Number of trainees (n) provided in order for Q1-Q4, respectively, within sex or combined men and women. See Table 4 for Q1-Q4 APFT Event Bin Descriptive Info (mean ± SD, range).

### 5.1.3 *Correlation between OPAT and APFT Event Performance*

Table 7 presents correlations between OPAT and APFT event performance. The strongest correlations between OPAT and APFT (either Diagnostic or Final Iteration) were between the OPAT IAR and the APFT 2-MR, both measures of aerobic/cardiovascular fitness. This finding was observed in men and women separately (correlation coefficients for the IAR vs. 2-MR ranged from -0.36 to -0.66; P≤0.05), as well as combined men and women groups (correlation coefficients ranged from -0.65 to -0.72; P≤0.05). In general, the relationships between OPAT and APFT events were stronger in magnitude for women than for men.

The correlations between OPAT and APFT event performance were much higher for individual iterations of Diagnostic or Final APFT trials than between OPAT performance and the delta (change) in APFT event performance (Table 7). The strongest correlation between an OPAT event and the change in APFT performance was between the IAR and the change in (delta) APFT 2-MR, which was consistently observed in men (r=0.30, P<0.01) and women (r=0.45, P<0.01) separately, as well as the combined men and women group (r=0.33, P<0.01) (Table 7). Since trainees ran faster on the Final APFT 2-MR compared to the Diagnostic 2-MR, Delta 2-MR values were negative (Table 5). The positive correlation between the IAR and Delta 2-MR indicates that a higher number of IAR shuttles was correlated with a smaller absolute difference in 2-MR time (Table 7).

**Table 7. Correlation of OPAT Events vs. Diagnostic, Final, and Delta APFT Events**

| | | **Diagnostic APFT** | | | **Final APFT** | | | **Delta APFT** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **PU (*reps*)** | **SU (*reps*)** | **2-MR (*time ,min*)** | **PU (*reps*)** | **SU (*reps*)** | **2-MR (*time ,min*)** | **PU (*reps*)** | **SU (*reps*)** | **2-MR (*time ,min*)** |
| **IAR (*shuttles*)** | Men (n=774) | *0.39** | *0.31** | ***-0.63**** | *0.33** | *0.21** | ***-0.57**** | *-0.13** | *-0.15** | *0.30** |
| | Women (n=195) | *0.42** | *0.40** | ***-0.66**** | *0.21** | *0.21** | *-0.36** | *-0.20** | *-0.25** | *0.45** |
| | Combined (n=969) | ***0.54**** | *0.35** | ***-0.72**** | *0.47** | *0.24** | ***-0.65**** | *-0.16** | *-0.17** | *0.33** |
| **SPT (*cm*)** | Men (n=774) | *0.21** | *0.15** | *-0.07** | *0.16** | *0.12** | *-0.15** | *-0.09** | -0.05 | -0.03 |
| | Women (n=195) | *0.26** | *0.26** | *-0.23** | 0.10 | *0.23** | -0.05 | *-0.15** | -0.09 | *0.21** |
| | Combined (n=969) | *0.49** | *0.21** | *-0.43** | *0.45** | *0.17** | ***-0.52**** | *-0.12** | *-0.08** | *0.08** |
| **SLJ (*cm*)** | Men (n=774) | *0.35** | *0.23** | *-0.34** | *0.34** | *0.21** | *-0.31** | -0.07 | *-0.07** | *0.16** |
| | Women (n=195) | *0.27** | *0.21** | *-0.34** | *0.15** | *0.24** | *-0.21** | -0.11 | -0.02 | *0.21** |
| | Combined (n=969) | ***0.53**** | *0.26** | ***-0.53**** | ***0.50**** | *0.23** | ***-0.54**** | *-0.10** | *-0.08** | *0.19** |
| **SDL (*lb*)** | Men (n=774) | *0.18** | *0.12** | *-0.12** | *0.16** | 0.05 | *-0.11** | -0.05 | *-0.08** | 0.06 |
| | Women (n=195) | 0.12 | *0.17** | *-0.16** | 0.04 | *0.17** | 0.03 | -0.07 | -0.03 | *0.19** |
| | Combined (n=969) | *0.43** | *0.19** | *-0.43** | *0.40** | *0.14** | *-0.44** | *-0.09** | *-0.08** | *0.15** |

Legend: APFT = Army Physical Fitness Test; PU = Push-ups; SU = Sit-ups; 2-MR = 2-mile run; reps = repetitions performed within 2 minutes; IAR = Interval aerobic run; SPT = Seated Power Throw; SLJ = Standing Long Jump; SDL = Strength Deadlift.
Notes: Correlation coefficient (Pearson Product Moment Correlation, *r*) values italicized with * are considered significant at p≤0.05. Bolded values represent a stronger correlation at (*r*) ≥ 0.50.

## 5.2 BMI-related Performance Outcomes

To determine the influence of BMI on performance outcomes, the trainees were stratified by BMI quartiles within sex-specific trainee groups, which Table 8 presents. Subsequent physical performance analyses by BMI quartiles in Section 5.2 (Tables 9 through 13) were based on data in this Table.

**Table 8. BMI Group-Specific Quartiles**

| | **Trainee Group** | | | |
|---|---|---|---|---|
| | **Men (n=774) (n=193; 194; 193; 194)** | | **Women (n=195) (n=47; 50; 49; 49)** | |
| **BMI Quartile** | **Range** | **Mean ± SD** | **Range** | **Mean ± SD** |
| **Q1 (lowest BMI)** | 17.32 - 22.59 | 20.88 ± 1.24 | 17.82 - 21.62 | 20.13 ± 1.04 |
| **Q2** | 22.63 - 25.14 | 23.94 ± 0.75 | 21.70 - 24.29 | 23.19 ± 0.77 |
| **Q3** | 25.16 - 28.11 | 26.56 ± 0.84 | 24.32 - 25.96 | 25.13 ± 0.49 |
| **Q4 (highest BMI)** | 28.15 - 39.11 | 30.34 ± 1.92 | 25.97 - 29.82 | 27.15 ± 0.85 |

Notes:
Data are presented as range or mean ± SD within quartiles of BMI; Quartiles were calculated using weight and height (BMI = weight (*kg*) / (height (*m*))$^{-2}$), where Q1 = lowest BMI (least amount of weight per height), Q4 = highest BMI (highest amount of weight per height). Number of trainees (*n*) provided per trainee group and by quartiles in order from Q1-Q4 within sex or within the combined male and female trainee groups. The information in Table 8 was used for analyses in Tables 9 through 13.

### 5.2.1 *OPAT Event Performance by Quartiles of BMI*

OPAT event performance was related to BMI (see Table 8 for BMI Quartile Descriptive Information) in both men and women. In men specifically, a higher BMI was associated with a lower number of IAR shuttles (Q4: 48.1 ± 13.6 vs. Q1: 60.9 ± 17.1 shuttles, P<0.05), a greater SPT distance thrown (Q4: 637.7 ± 84.8 vs. Q1: 548.9 ± 67.6 cm, P<0.05), and a shorter SLJ distance jumped (Q4: 191.7 ± 28.8 vs. Q1: 206.7 ± 27.1 cm, P<0.05) (Table 9). In women, a higher BMI was associated with greater SPT distance thrown (Q4: 417.7 ± 47.3 vs. Q1: 375.0 ± 44.9 cm, P<0.05) (Table 9).

**Table 9. OPAT Event Performance by BMI Group-Specific Quartiles**

| **OPAT Event by BMI** | **Trainee Group** | |
|---|---|---|
| **IAR (*shuttles*)** | **Men (n=193; 194; 193; 194)** | **Women (n=47; 50; 49; 49)** |
| **Q1 (lowest BMI)** | 60.9 ± 17.1 | 36.9 ± 15.7 |
| **Q2** | 64.5 ± 18.9 | 36.0 ± 15.5 |
| **Q3** | 55.9 ± 17.0 * | 31.3 ± 12.8 |
| **Q4 (highest BMI)** | 48.1 ± 13.6 * | 31.9 ± 11.8 |
| | | |
| **SPT (*cm*)** | **Men (n=193; 194; 193; 194)** | **Women (n=47; 50; 49; 49)** |
| **Q1 (lowest BMI)** | 548.9 ± 67.6 | 375.0 ± 44.9 |
| **Q2** | 591.4 ± 71.4 * | 389.2 ± 58.3 |
| **Q3** | 600.8 ± 77.6 * | 379.3 ± 44.1 |
| **Q4 (highest BMI)** | 637.7 ± 84.8 * | 417.7 ± 47.3 * |
| | | |
| **SLJ (*cm*)** | **Men (n=193; 194; 193; 194)** | **Women (n=47; 50; 49; 49)** |
| **Q1 (lowest BMI)** | 206.7 ± 27.1 | 151.9 ± 25.5 |
| **Q2** | 206.9 ± 28.9 | 152.2 ± 23.0 |
| **Q3** | 196.0 ± 32.0 * | 145.6 ± 18.1 |
| **Q4 (highest BMI)** | 191.7 ± 28.8 * | 147.6 ± 26.2 |

Legend:
OPAT = Occupational Physical Assessment Test; IAR = Interval aerobic run; SPT = Seated Power Throw; SLJ = Standing Long Jump.
Notes:
*P≤0.05 vs. Q1 (ANOVA with Tukey post-hoc); Values are mean ± SD; OPAT data were binned by BMI quartiles with Q1 = lowest BMI, Q4 = highest BMI. Number of trainees (n) provided in order for Q1-Q4 within sex. See Table 8 for Q1-Q4 BMI descriptive information (mean ± SD, range).

**Table 10. OPAT SDL Event Performance (Maximal Weight Lifted) by BMI Group-Specific Quartiles**

| OPAT SDL Event by BMI | SDL Maximal Weight Lifted, Men (n=774) * (*n (% of sample within quartile)*) | | | | |
|---|---|---|---|---|---|
| **SDL (*lb*)** | **60 lb** | **100 lb** | **140 lb** | **180 lb** | **220 lb §** |
| **Q1 (lowest BMI)** | - | - | 17 (8.8) | 38 (19.7) | 138 (71.5) |
| **Q2** | - | 1 (0.5) | 2 (1.0) | 24 (12.4) | 167 (86.1) |
| **Q3** | - | 2 (1.0) | 2 (1.0) | 5 (2.6) | 184 (95.3) |
| **Q4 (highest BMI)** | - | - | - | 3 (1.5) | 191 (98.5) |
| | | | | | |
| | **SDL Maximal Weight Lifted, Women (n=195)** * (*n (% of sample within quartile)*) | | | | |
| **SDL (*lb*)** | **60 lb** | **100 lb** | **140 lb** | **180 lb §** | **220 lb** |
| **Q1 (lowest BMI)** | - | 11 (23.4) | 21 (44.7) | 12 (25.5) | 3 (6.4) |
| **Q2** | - | 5 (10.0) | 19 (38.0) | 20 (40.0) | 6 (12.0) |
| **Q3** | 1 (2.0) | 2 (4.1) | 17 (34.7) | 22 (44.9) | 7 (14.3) |
| **Q4 (highest BMI)** | - | 2 (4.1) | 9 (18.4) | 25 (51.0) | 13 (26.5) |
| | | | | | |

Legend:
OPAT = Occupational Physical Assessment Test; SDL = Strength Deadlift.
Notes:
*P≤0.01 for Chi Square; § P≤0.01 for Mantel-Haenszel Chi Square for Linear Trend; OPAT data were binned by BMI quartiles with Q1 = lowest BMI, Q4 = highest BMI; SDL presented as n (% of sample within sex-specific quartile) of trainees that lifted a given “maximal” load (e.g., considered to be the individual’s maximal weight lifted, as they did not lift a heavier weight successfully or voluntarily in the test). Note that the highest weight possible for any individual to lift was 220 lb. See Table 8 for Q1-Q4 BMI descriptive information (mean ± SD, range).

During the SDL event, the weight lifted was significantly related to BMI in men and women (*Chi square, P<0.01; Table 10). We then evaluated the trend for BMI (Q1-Q4) within most frequently lifted weight in the male and female trainee groupings (men: 220 lb, women: 180 lb), where moving from Q1 to Q4 BMI (lower to higher BMI), a significant trend indicated that more individuals were able to lift these weights (§Mantel-Haenszel Chi square, P<0.01).

### 5.2.2 *APFT Event Performance by Quartiles of BMI*

Diagnostic APFT performance was related to BMI in male trainees, such that an increased BMI was associated with decreased (P<0.05) PU repetitions (Q4: 39.3 ± 13.7 vs. Q1: 44.1 ± 13.5) and SU repetitions (Q4: 46.7 ± 12.8 vs. Q1: 50.7 ± 13.9), and related to a slower (P<0.05) 2-MR time (Q4: 16.65 ± 1.88 vs. Q1: 15.37 ± 1.61 minutes) (Table 11). For female trainees, an increased BMI was only related to an increased 2-MR time on the Diagnostic APFT (Q4: 19.50 ± 2.58 vs. Q1: 17.94 ± 2.39 minutes, P<0.05) (Table 11).

**Table 11. Diagnostic APFT Event Performance by BMI Group-Specific Quartiles**

| **Diagnostic APFT Event Data by BMI** | **Trainee Group** | |
|---|---|---|
| **Diagnostic 2-min PU (*reps*)** | **Men (n=774) (n=193; 194; 193; 194)** | **Women (n=195) (n=47; 50; 49; 49)** |
| **Q1 (lowest BMI)** | 44.1 ± 13.5 | 24.1 ± 19.4 |
| **Q2** | 46.8 ± 16.9 | 21.6 ± 13.5 |
| **Q3** | 42.1 ± 16.4 | 15.9 ± 13.6 |
| **Q4 (highest BMI)** | 39.3 ± 13.7 * | 21.3 ± 15.5 |
| | | |
| **Diagnostic 2-min SU (*reps*)** | **Men (n=774) (n=193; 194; 193; 194)** | **Women (n=195) (n=47; 50; 49; 49)** |
| **Q1 (lowest BMI)** | 50.7 ± 13.9 | 46.0 ± 17.6 |
| **Q2** | 53.8 ± 15.0 | 49.7 ± 14.8 |
| **Q3** | 49.7 ± 13.6 | 42.5 ± 16.7 |
| **Q4 (highest BMI)** | 46.7 ± 12.8 * | 42.9 ± 14.1 |
| | | |
| **Diagnostic 2-MR (*time, min*)** | **Men (n=774) (n=193; 194; 193; 194)** | **Women (n=195) (n=47; 50; 49; 49)** |
| **Q1 (lowest BMI)** | 15.37 ± 1.61 | 17.94 ± 2.39 |
| **Q2** | 15.11 ± 1.60 | 18.36 ± 2.19 |
| **Q3** | 15.82 ± 2.04 | 19.14 ± 2.53 |
| **Q4 (highest BMI)** | 16.65 ± 1.88 * | 19.50 ± 2.58 * |

Legend:
APFT = Army Physical Fitness Test; 2-min = maximum number of reps performed within 2 minutes; PU = Push-ups; SU = Sit-ups; 2-MR = 2-mile run; reps = repetitions.
Notes:
***P≤0.05 vs. Q1; †P=0.06 vs. Q1;** All data are mean ± SD; APFT data were binned by BMI quartiles with Q1 = lowest BMI, Q4 = highest BMI; 2-min = maximum number of reps performed within 2 minutes; PU = Push-ups; SU = Sit-ups; reps = repetitions; Number of trainees (n) provided in order for Q1-Q4 within sex. See Table 8 for Q1-Q4 BMI Descriptive Info (mean ± SD, range).

Table 12 demonstrates that on the Final APFT, only the 2-MR time remained significantly associated with an increased BMI in male (Q4 Men: 14.59 ± 1.10 vs. Q1 Men: 14.19 ± 1.35 minutes) and female trainees (Q4 Women: 17.45 ± 1.81 vs. Q1 Women: 16.01 ± 1.50 minutes).

**Table 12. Final APFT Event Performance by BMI Group-Specific Quartiles**

| **Final APFT Event Data by BMI bin** | **Trainee Group** | |
|---|---|---|
| **Final 2-min PU (*reps*)** | **Men (n=774) (n=193; 194; 193; 194)** | **Women (n=195) (n=47; 50; 49; 49)** |
| **Q1 (lowest BMI)** | 59.6 ± 12.9 | 43.0 ± 16.8 |
| **Q2** | 62.2 ± 15.0 | 39.0 ± 15.1 |
| **Q3** | 59.5 ± 13.5 | 37.4 ± 15.6 |
| **Q4 (highest BMI)** | 57.2 ± 12.0 | 39.6 ± 16.1 |
| | | |
| **Final 2-min SU (*reps*)** | **Men (n=774) (n=193; 194; 193; 194)** | **Women (n=195) (n=47; 50; 49; 49)** |
| **Q1 (lowest BMI)** | 63.3 ± 10.9 | 61.2 ± 14.4 |
| **Q2** | 65.9 ± 12.0 | 64.3 ± 11.9 |
| **Q3** | 64.4 ± 11.2 | 59.9 ± 10.5 |
| **Q4 (highest BMI)** | 61.3 ± 10.4 | 56.6 ± 14.6 |
| | | |
| **Final 2-MR (*time, min*)** | **Men (n=774) (n=193; 194; 193; 194)** | **Women (n=195) (n=47; 50; 49; 49)** |
| **Q1 (lowest BMI)** | 14.19 ± 1.35 | 16.01 ± 1.50 |
| **Q2** | 13.84 ± 1.14 * | 16.73 ± 1.35 |
| **Q3** | 14.28 ± 1.17 | 16.92 ± 1.60 * |
| **Q4 (highest BMI)** | 14.59 ± 1.10 * | 17.45 ± 1.81 * |

Legend:
2-min = maximum number of reps performed within 2 minutes; PU = Push-ups; SU = Sit-ups; 2-MR = 2-mile run; reps = repetitions.
Notes:
***P≤0.05 vs. Q1;** All data are mean ± SD; APFT data were binned by BMI quartiles with Q1 = lowest BMI, Q4 = highest BMI; Number of trainees (n) provided in order for Q1-Q4 within sex. See Table 8 for Q1-Q4 BMI descriptive information (mean ± SD, range).

Similar to the Final APFT performance, the only event in which the change in APFT performance was dependent on BMI was the 2-MR time; however, this was only a significant relationship in men (Table 13). More specifically, male trainees with the highest BMI initially made the largest improvements in their aerobic fitness by the end of IET (Q4 Men: -2.06 ± 1.61 vs. Q1 Men: -1.18 ± 1.62 minutes, $p<0.05$).

**Table 13. Change in (Delta) APFT Event Performance by BMI Group-Specific Quartiles**

| **Delta APFT Data by BMI bin** | **Trainee Group** | |
|---|---|---|
| **Delta 2-min PU (*reps*)** | **Men (n=774) (n=193; 194; 193; 194)** | **Women (n=195) (n=47; 50; 49; 49)** |
| **Q1 (lowest BMI)** | 15.5 ± 12.6 | 18.9 ± 17.2 |
| **Q2** | 15.4 ± 13.0 | 17.4 ± 17.2 |
| **Q3** | 17.4 ± 13.2 | 21.5 ± 15.9 |
| **Q4 (highest BMI)** | 17.9 ± 12.0 | 18.3 ± 18.6 |
| | | |
| **Delta 2-min SU (*reps*)** | **Men (n=774) (n=193; 194; 193; 194)** | **Women (n=195) (n=47; 50; 49; 49)** |
| **Q1 (lowest BMI)** | 12.6 ± 14.1 | 15.2 ± 14.9 |
| **Q2** | 12.1 ± 13.0 | 14.5 ± 14.5 |
| **Q3** | 14.7 ± 13.9 | 17.4 ± 13.3 |
| **Q4 (highest BMI)** | 14.6 ± 11.7 | 13.7 ± 15.9 |
| | | |
| **Delta 2-MR (*time, min*)** | **Men (n=774) (n=193; 194; 193; 194)** | **Women (n=195) (n=47; 50; 49; 49)** |
| **Q1 (lowest BMI)** | -1.18 ± 1.62 | -1.93 ± 2.27 |
| **Q2** | -1.27 ± 1.51 | -1.63 ± 2.07 |
| **Q3** | -1.53 ± 1.66 | -2.22 ± 2.53 |
| **Q4 (highest BMI)** | -2.06 ± 1.61 * | -2.04 ± 2.43 |

Legend:
2-min = maximum number of reps performed within 2 minutes; PU = Push-ups; SU = Sit-ups; 2-MR = 2-mile run; reps = repetitions.
Notes:
***P≤0.05 vs. Q1;** All data are mean ± SD; Delta APFT data were binned by BMI quartiles with Q1 = lowest BMI, Q4 = highest BMI; Number of trainees (n) provided in order for Q1-Q4 within sex. See Table 8 for Q1-Q4 BMI descriptive information (mean ± SD, range).

# 6 DISCUSSION

## 6.1 Major Findings

The current report is among the first to document the relationships between the OPAT and the APFT in male and female IET trainees. To our knowledge, this is the first report documenting the associations between the OPAT and APFT with a relative index of body composition (e.g., BMI). The main findings of this report demonstrate that—

1) There were clear differences in physical performance between men and women on both the OPAT and APFT test batteries;

2) Performance outcomes on the OPAT and APFT demonstrated weak-to-moderate correlations, with the strongest relationships existing between OPAT IAR and the Diagnostic APFT 2-MR – both measurements of cardiorespiratory fitness;

3) Individual APFT performance improvement by the end of IET was highly dependent on Diagnostic APFT performance; and

4) Selected events within OPAT and APFT test battery performance appeared dependent on BMI (data demonstrated both positive and negative performance associations with BMI), with male trainee performance more frequently related to differences in BMI than in female trainees.

## 6.2 OPAT Performance

The intent of the OPAT is to assign the "right Soldier to the right job" using one sex-independent standard [1, 2]. There were clear differences observed between men and women in their physical capabilities on the OPAT; however, this was expected given physiological differences known to mediate physical performance between men and women [15]. When expressed relative to the male trainees' mean performance, female trainees performed at lower levels on all events (IAR: 0.59 or 59%; SPT: 0.66 or 66%; SLJ: 0.75 or 75% of the male performance). On the SDL, the most frequently lifted weight for women was 180 lb (40.5% women), while the most frequently lifted weight for men was 220 lb (87.9% men). Even though the OPAT is not an outright fitness test, but rather a fitness for work test with one standard for men and women (serving as a surrogate for CMTS performance), the test provides critical insight into trainee physical performance not assessed by the current APFT. For instance, the OPAT assesses muscular power, muscular strength and cardiorespiratory fitness while the APFT assesses muscular endurance and cardiorespiratory fitness.

## 6.3 APFT Performance

APFT physical performance from the trainees in the current study approximated previously reported data in a similar basic training (e.g., IET) population [14]. The first APFT test taken in IET is considered 'diagnostic' and used only to gauge a trainee's fitness when entering military service; therefore, performance on the Diagnostic APFT will be lower in most instances compared to APFT performance by seasoned Soldiers in Operational units [30]. By the Final APFT trial (toward the end of IET) Soldiers must achieve a minimum passing score of 60 points per event and 180 total points adjusted for age and sex—the same standard operational Soldiers must achieve [12]. Accordingly, substantial improvement in male and female trainees' APFT performance was observed in the current study. Thus, performance on the Final APFT in IET was expected to be closer to APFT performance reported by Operational units where Soldiers would have trained for longer periods [25, 31]. In Table 5, men and women with the lowest performance initially (those in Q1) also improved the most in all three APFT events. Individuals with the largest potential for improvement (the lowest performers initially) would be capable of improving the most following chronic physical training, which is a concept that has foundations in one's potential trainability and the theoretical limits of human performance.

### 6.4 OPAT/APFT Relationships

The relationships between OPAT and APFT performance capabilities were examined to determine if they were providing similar information in an IET trainee cohort. As mentioned above, the strongest relationships were between the OPAT IAR (number of shuttles) and the Diagnostic APFT 2-MR (time) for men ($r$ = -0.63), women ($r$ = -0.66), or combined ($r$ = -0.72) and between the OPAT IAR and Final APFT 2-MR time men ($r$ = -0.57), women ($r$ = -0.36), or combined ($r$ = -0.65). Although the strength of these relationships was lower for the Final APFT trial compared to the Diagnostic trial in men and women, the IAR and 2-MR events still represented the strongest correlations among all comparisons. This aligns with the fact that both events measure aerobic fitness, and would be expected to be correlated. Previous research has also highlighted similarities between the IAR and other measures of cardiovascular endurance [29, 32]. Moreover, the negative relationship implies that as the number of IAR shuttles increases, the time to run 2 miles decreases—highlighting a similar degree of cardiorespiratory fitness. In addition, most other correlations, albeit significant, demonstrated weak (e.g., little to no relationship) to moderate relationships at best. Despite significant relationships between the test battery events, it appears that OPAT and APFT are providing unique information. This also is a logical conclusion since they purposefully test different aspects of performance for different reasons (i.e., OPAT for proper MOS assignment and APFT for general fitness). Therefore, these two test batteries performed at or around the same time could provide a comprehensive perspective into the physical fitness levels of incumbent Army trainees.

Another relationship explored was between the OPAT and the degree to which trainees improved in their physical fitness as measured *via* the APFT. Without regard to the different fitness domains assessed from the OPAT and APFT (partially explaining weak correlations between the two test batteries; discussed above), there was a lack of consistent and significant relationships between performance on the OPAT and the change in APFT performance by the end of IET. In line with the individual APFT iterations, the strongest correlations between OPAT and the change in APFT were between OPAT IAR and Delta 2-MR time. Unlike the individual iterations, this was a positive correlation suggesting that as the number of IAR shuttles increased (indicating a higher aerobic fitness), there was a tendency to have a (more) positive Delta 2-MR time. This may seem paradoxical given that a positive delta would theoretically represent a decrement in running performance when calculated as Final minus Diagnostic 2-MR time. However, further exploration of this relationship reveals that a more positive delta in 2-MR time actually reflects movement along the trendline from the largest negative delta (most improved 2-MR time) towards no change (least improved 2-MR time), and not an actual positive delta above zero (indicating a performance decrement). In this example, using the above-mentioned relationship, the more aerobically fit someone was at the beginning of IET, the less likely they would be to demonstrate an improvement in 2-MR time with training. The quartile analyses (Tables 5 and 6) demonstrate that the most aerobically fit group initially includes the trainees who improved the least over the course of IET and further supports this effect. Therefore, an initial OPAT event score may not adequately predict the change in APFT fitness during IET, highlighted in the lack of (strong) correlations. This once again demonstrates that these two test batteries provide unique perspectives into trainee fitness, and lends further support for the need of both operational- and health-related fitness assessments in military populations [33]. Regardless, a more plausible explanation for APFT improvement during IET is rooted in the Diagnostic APFT performance. As stated above, the trainees with the lowest APFT performance entering IET will have the highest physiological potential (e.g., performance ceiling) for improvement and therefore are likely to be the most improved on the APFT events by the end of IET.

### 6.5 BMI-related Performance Outcomes

In the simplest two-compartment model, body composition details the proportions of lean (fat-free) mass and fat mass relative to total body mass. Lean, or fat-free mass, includes skeletal muscle and bones (e.g., any tissue that does not contain fat) while fat mass includes adipose tissue (e.g., any fat stores, including both subcutaneous and visceral fat tissue). It is important to note that although BMI (weight relative to height) cannot completely discriminate between fat and lean mass, it is a field-expedient measure that can serve as a relative indicator of body fat in population-size cohorts [22, 23], especially in “high-overweight” individuals (BMI ≥ 27.5 $kg \cdot m^{-2}$) who display disproportionate gains in fat mass over lean mass [22]. According to AR 40-501, The Standards of Medical Fitness [27] and AR 600-9, the ABCP [18], these guidelines require Army recruits (and Soldiers) to meet appropriate weight-for-height or relative body fat guidelines to qualify for initial military service, and to be checked semi-annually. Most body composition guidelines in military populations are covered by a spectrum of concerns spanning military appearance, health outcomes, and combat readiness [19].

In addition to potential health concerns of not meeting weight-for-height standards [17] is the impact that poor or suboptimal body composition could have on Service members’ physical performance. For instance, multiple studies have demonstrated a well-known relationship between being overweight or overfat and poor performance on aerobic capacity tests in the military and similar populations [4, 6, 24]. Researchers are coming to understand the impact of suboptimal body composition on additional physical parameters such as muscular strength and power [4], which are thought by some SMEs to be of higher importance for military task completion than aerobic fitness [26]. Although overweight/overfat individuals may be excluded from military service, receive disciplinary actions, or have a decreased ability to be promoted, individuals with higher BMI and body fat can excel at tasks requiring muscular strength and power as compared to their lower BMI/body fat counterparts [4].

The current investigation sought to determine the impact that BMI could have on trainee physical performance. As mentioned in section 5.2.1, a significant influence of BMI on all OPAT events in men, and on two OPAT events in women was observed. In men, an increased BMI was associated with decreased number of shuttles on the IAR, a longer throwing distance on the SPT, and a shorter jumping distance on the SLJ. In women, there was an association between increased BMI and increased distance thrown on the SPT. Furthermore, moving from lower to higher BMIs, significant trends for weight lifted in both men and women indicated that more individuals could lift the higher SDL weights (e.g., ≥ 180 lb). Collectively, these observations demonstrate that certain physical attributes are enhanced with higher BMIs even though a suboptimal BMI might not be desirable from a health standpoint [17, 34]. The findings are in agreement with a recent study in an Army Soldier cohort [4]. Despite the fact that Soldiers in that study had more military experience compared to the current study population, those Soldiers with a higher BMI presented with improved muscular strength and power but also decreased speed/agility compared to those with lower BMI [4]. In addition, several physical performance attributes in that investigation were differentially affected between men and women, with male Soldier performance being affected more frequently than female Soldiers [4], another similarity to the current report. A sex-dependent explanation for why men's physical performance is affected more frequently than female performance by BMI classification is difficult to identify; however, it may be due to differences in body fat accumulation and regional adipose tissue distribution (e.g., android vs. gynoid obesity) between men and women at any given BMI value. Although it may not be possible to narrow down an exact mechanism explaining these sex-dependent differences given the current study's limitations, the data once again underscores the need for balance between strict body composition standards and understanding of which physical attributes might be required for one's MOS. This is particularly the case when trade-offs exist between these factors. For instance, a higher BMI may concomitantly provide augmented physical attributes, such as greater strength and power, which may be beneficial to some occupations [4, 35].

In a similar analysis, comparing male and female trainee APFT performance across BMI quartiles revealed that APFT event performance (muscular and cardiorespiratory endurance) was affected more frequently in male trainees. During the Diagnostic APFT trial, male trainees with a higher BMI demonstrated decreased push-up and sit-up repetitions as well as an increased 2-MR time, whereas female trainees with a higher BMI demonstrated an increased 2-MR time only. On the Final APFT trial required for IET graduation, only the 2-MR time was increased in men and women when the highest BMI quartile was compared to the lowest BMI quartile. Therefore, considering both Diagnostic and Final APFT iterations, as well as the Delta APFT, male performance was once again affected more frequently (i.e., on more tests) than female trainee APFT performance.

How the change in APFT performance (Final - Diagnostic APFT event performance) could relate to BMI stratification (Table 13) was also examined. Interestingly, the only significant relationship observed in this analysis was the highest BMI male trainees improved the most in 2-MR time near the end of IET. One factor that cannot be adequately addressed in the current report is the degree to which the change in physical performance on the APFT was related to possible changes in BMI during IET. We did not measure height and weight again towards the end of IET when trainees took their Final APFT. However, it is speculated that the group that started in the highest BMI quartile (Q4; Table 8) likely lost the most weight, based on a previous study which demonstrated that weight loss was greatest in the heaviest/fattest recruits in basic training [36]. In the current report, those in the highest BMI quartile at the beginning of IET are the same individuals who improved the most in their APFT 2-MR (see Table 13). Therefore, one can speculate on how weight loss (and improved/lowered BMI) would contribute to the improvement in aerobic fitness by the end of IET. Considering the Diagnostic APFT performance by BMI quartiles as a model, a longer 2-MR time (lower aerobic fitness) was related to a higher BMI when comparing 2-MR times between Q1 and Q4 BMI bins in both men and women (Table 11). Therefore, one might also speculate that if a trainee lost weight—a likely scenario during basic military training (e.g., IET) [36, 37], and especially in those with higher starting BMIs [38]—the gain in aerobic fitness by the end of IET could be partially attributed to weight loss. Accordingly, observations have been described previously with a diet (caloric restriction) condition alone that resulted in weight loss and led to improvements in aerobic capacity ($VO_{2max}$, $ml \cdot kg^{-1} \cdot min^{-1}$) [39, 40], but with combined diet and exercise, changes in aerobic capacity were augmented [39, 41]. It is important to remember that the current observations between increased BMI and decreased aerobic fitness are only associative and do not imply causality. Nonetheless, although gains in aerobic fitness by the end of IET are more likely due to chronic physical training, one cannot discount the plausible and potentiating effect of weight loss on this outcome.

The above findings indicate that suboptimal BMI was associated with augmented physical performance in some cases, which is against the negative connotations typically implied, but in agreement with recently published literature [4]. However, one must also take into consideration the influence that suboptimal body composition or BMI can have on other outcomes, such as chronic disease (e.g., heart disease and metabolic disorders) and even injuries. For example, Soldiers who entered the military at a BMI ≥ 25 $kg \cdot m^{-2}$ were diagnosed with hypertension, metabolic syndrome, and dyslipidemia earlier than those Soldiers who presented with a normal BMI (18.5-25 $kg \cdot m^{-2}$) at accession [17]. An elevated risk for injury is also known to occur when expressed relative to BMI, although in most cases, this is a bi-modal relationship with slightly elevated risks at both extremes of BMI (high and low BMI) compared to normal weight/BMI individuals [42, 43]. Interestingly, the relationship between body composition and injury can be modified through physical fitness. In these cases, women who are the heaviest (highest BMI) but who are the fastest runners are partially protected against injuries [42]. It is speculated that although these women are the heaviest among their cohort, they are protected against musculoskeletal injuries [42, 44]. More research with an exploration of detailed body composition (e.g., DXA to separate muscle and adipose tissue components with greater resolution) influences on physical performance and injury outcomes is needed/recommended to draw accurate conclusions on the mechanism(s) that underlie these interactions. Current studies are ongoing to gain such perspectives.

### 6.6 Limitations

There are a few limitations to note in this report:

During the SDL event on the OPAT, the weight lifted was constrained to a limited weight set. Trainees attempted to lift weights from five pre-set weight stations (hex bar: 60 lb; or hex bar with added weight: 100, 140, 180, or 220 lb) in consecutive order until they voluntarily chose not to attempt a higher weight, could no longer successfully complete a lift, or until they reached the maximal weight tested: 220 lb. There was a ceiling effect demonstrated by the fact that that nearly all of the men (88%) lifted the highest weight possible, while the women demonstrated a more even distribution among the possible weights (see Table 1). The SDL was not a maximal effort test. How a maximal effort strength test (e.g., one repetition maximum; 1-RM) would align with CMTS performance at the end of IET remains to be determined.

One of the questions in this report was to examine OPAT performance in IET trainees. Since the current study was voluntary in nature and the trainees in this study were not made aware of the performance scores needed for a given MOS, knowing actual standards may have led to an even better event performance. In other words, OPAT performance data obtained herein may not represent trainees' best effort(s) since they were told that their performance on the OPAT would not impact their training and/or MOS assignment in any way. It is expected that both male and female recruits/trainees would perform to a higher standard if their performance dictated their MOS assignment. As of 3 January 2017, the OPAT has been required of incumbent trainees. Furthermore, current policy allows potential recruits to take the OPAT several times in order to meet the minimum standards to begin training for their contracted MOS. As incoming recruits/trainees are familiarized to the specific OPAT events and are made aware of thresholds required to meet MOS accession standards—factors that would encourage them to train for the attributes represented by OPAT— an improvement in all OPAT event scores could reasonably be expected.

## 7 CONCLUSIONS AND RECOMMENDATIONS

In the current investigation, we documented physical performance on the newly implemented OPAT in addition to the APFT. As expected, clear differences in physical performance were evident across all events and physical attributes tested within each specific test battery (OPAT: cardiorespiratory endurance, muscular power and muscular strength; APFT: muscular and cardiorespiratory endurance) between men and women. Although both test batteries rely on the collection of raw performance data, APFT standards (event points) are sex- and age-adjusted. The OPAT uses the raw data to determine if a trainee is physically ready to be trained for a specific MOS, based on MOS PDC levels. Unlike the APFT, the OPAT's scoring thresholds (e.g., PDC associated cut-points) are independent of sex and age. The functional requirement of one sex-independent standard on the OPAT is justified since all Soldiers must be physically capable of performing job-related tasks. Future studies should focus on how to optimize physical training of incoming recruits who achieve the lower OPAT levels in order that they are able to improve their performance to achieve higher OPAT levels/PDCs and perform the MOS-associated physically demanding tasks to standard.

Physical performance on selected OPAT and APFT events was dependent on BMI (a relative measure of body composition) in both men and women. Specifically, male and female trainee performance on certain tests was enhanced (e.g., OPAT SPT and SDL), while performance on other tests was negatively impacted by suboptimal body composition (e.g., APFT 2-MR). Some additional associations were sex-specific and occurred only in men. Therefore, male performance was more frequently affected by BMI than women's performance. There were marked improvements in APFT performance by the end of IET as well. The change in APFT performance could be related to several factors, including changes in weight or BMI during the course of IET; however, the most likely explanation was initial/baseline performance, where the poorest performers initially demonstrated the largest performance improvements, and the highest performers initially demonstrated the least amount of change by the end of IET.

Collectively, this report demonstrates that the OPAT and APFT, both implemented for different purposes (occupation determination and general fitness, respectively), provide unique perspectives into Army trainee physical performance. However, because important relationships exist between BMI and physical performance (performance enhanced in some cases while decreased in others, when examined in the context of increased BMI), there may be situations in which the need for increased strength and power is more important than health concerns related to suboptimal BMI. Further research is warranted to determine how to effectively balance occupationally related physical demand requirements with body composition guidelines.

## 8 Points of Contact

Questions may be directed to the Injury Prevention Division at usarmy.apg.medcom-aphc.mbx.injuryprevention@mail.mil, or commercial phone 410-436-4655, or DSN 584-4655.

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## APPENDIX A

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# GLOSSARY

## Abbreviations/Acronyms

**2-MR**
2-Mile Run

**ABCP**
Army Body Composition Program

**AIT**
Advanced Individual Training

**ANOVA**
Analysis of Variance

**AOC**
Area of Concentration

**APFT**
Army Physical Fitness Test

**APFU**
Army Physical Fitness Uniform

**APHC**
U.S. Army Public Health Center

**AR**
Army Regulation

**ASVAB**
Armed Services Vocational Aptitude Battery

**BCT**
Basic Combat Training

**BMI**
Body Mass Index

**CMTS**
Criterion Measure Task Simulations

**DGCDAR**
Direct Ground Combat Definition and Assignment Rule

**DOD**
Department Of Defense

**DXA**
Dual-Energy X-Ray Absorptiometry

**HQDA**
Headquarters, Department of the Army

**IAR**
Interval Aerobic Run

**IET**
Initial Entry Training

**IPD**
Injury Prevention Division

**MEDCOM**
U.S. Army Medical Command

**MEPS**
Military Entry Processing Station

**MOS**
Military Occupational Specialty

**MSRT**
Multistage Shuttle Run Test

**OPAT**
Occupational Physical Assessment Test

**OSUT**
One Station Unit Training

**PDC**
Physical Demand Categories

**PDS**
Physical Demands Study

**PU**
Push-ups

**SDL**
Strength Deadlift

**SLJ**
Standing Long Jump

**SME**
Subject Matter Experts

**SPT**
Seated Power Throw

**SU**
Sit-ups

**TRADOC**
U.S. Army Training and Doctrine Command

**USARIEM**
U.S. Army Research Institute of Environmental Medicine

**WHO**
World Health Organization

## Definitions

Military Occupational Specialties (MOS) listed in document:

Armor (19 series)
- 19D Cavalry scout
- 19K M1 Armor crewmember

Engineer (12 series)
- 12B Combat engineer

Field Artillery (13 series)
- 13B Cannon Crewmember
- 13F Fire Support Specialist

Infantry (11 series)
- 11B Infantryman
- 11C Indirect Fire Infantryman