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Original Research

Maximal Aerobic Capacity as a Predictor of Performance on ACFT Total Score of ROTC Cadets

ANTHONY M. ACEVEDO†[1], ZACHARY ZEIGLER‡[1], and BRIDGET MELTON‡[2]

[1]College of Natural Sciences, Grand Canyon University, Phoenix, AZ, USA; [2]Department of Health Sciences and Kinesiology, Waters College of Health Professions, Georgia Southern University, Statesboro, GA, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 17(4): 429-437, 2024. The Army Combat Fitness Test (ACFT) is a newly developed test that assesses the combat readiness of U.S. Army soldiers. The purpose of this cross-sectional study is to determine if VO_{2max} can predict performance outcomes of the ACFT in ROTC cadets. This understanding can provide a better understanding of the aerobic demands of the ACFT. Cadets (50 males, 14 females; aged 21.43 ± 4.10 years) completed the 6-event ACFT (maximum trap-bar deadlift [MDL], standing power throw [SPT], hand-release pushups [HRPU], sprint-drag-carry shuttle run [SDC], plank [PLK], and 2-mile run [2MR]). The cadets conducted a maximal treadmill running test following the Bruce protocol. The ability of VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$) to predict ACFT performance was determined with a linear regression model. Significance was set at $p < 0.05$. VO_{2max} was significantly and positively correlated to MDL ($r = .253$, $p = .044$), HRPU ($r = .486$, $p < .001$), SDC ($r = .495$, $p < .001$), PLK ($r = .628$, $p < .001$) 2MR ($r = .612$, $p < .001$) and overall ACFT score ($r = .619$, $p < .001$) but not SPT ($r = .203$, $p = .108$). VO_{2max} significantly explained 38% ($p < .001$) of the variance on the total ACFT scores with a beta coefficient of 4.338. There is a gap in understanding how VO_{2max} impacts performance in the newly implemented ACFT. For every 1 $mL \cdot kg^{-1} \cdot min^{-1}$ increase in VO_{2max}, ACFT total scores increased by 4 points. These findings support the need for further research due to the trends of U.S. Army personnel failing the 2MR, which can be associated with an insufficient aerobic capacity.

KEY WORDS: VO_{2max}, army, military

INTRODUCTION

Physical readiness is critical for U.S. Army soldiers to conduct military operations. Physical readiness has been defined as "the ability to meet the physical demands of any duty or combat position, move lethally on the battlefield, accomplish the mission, and continue to fight, win, and come home healthy" (12). The Army has been testing physical readiness for the last 100 years by assessing physique, body composition, and ability to perform a variety of tasks, including carrying heavy loads, maneuvering around or over obstacles, lifting objects, and having a high level of endurance (1, 10). The Army Physical Fitness Test (APFT) was developed

in 1980, which tested muscular and aerobic endurance (2-minute maximal push-ups, sit-ups, and a timed 2-mile run). However, the APFT does not measure physical domains that are generally associated with combat tasks. The U.S. Army is constantly searching for ways to better prepare its soldiers for combat, which has led to the recent creation and implementation of the Army Combat Fitness Test (ACFT).

In October 2020, the ACFT was introduced, including six events that tested strength, power, agility, muscular endurance, and aerobic endurance. Soldiers must complete all six events in order and within 70 minutes or less. Each event is scored from 0 to 100, with a 60 required to pass. This enhanced physical readiness requires both anaerobic and aerobic fitness, while the duration of the ACFT is considered aerobic. Furthermore, evidence shows that most ROTC cadets fall short of passing the ACFT due to the 2-mile run (2MR) (10). Given the event duration and the final event being the 2MR, it is critical to understand the need to assess a soldier's maximal aerobic capacity (VO_{2max}) and how this is linked to ACFT performance. There is a gap in the literature examining VO_{2max} as a predictor of performance in military populations.

Assessing VO_{2max} is considered the gold standard for quantifying aerobic fitness (4). Legaz-Arrese et al. (13) showed that during the middle- and long-distance running events, using the International Amateur Athletic Federation (IAAF) scores, VO_{2max} was a strong predictor of performance with higher VO_{2max} associated with higher IAAF scores in male and female runners. Additional studies have shown that VO_{2max} increases linearly as distances increase from 100m to 5000m (7, 15). Given the 2MR equates to 3219m, these studies provide evidence that VO_{2max} is a strong predictor of aerobic performance.

In a review of the ACFT, Hardison et al. (10) found that > 40% of those who failed tended not to receive a passing score on the final two events: Plank (PLK) and 2MR. This novel finding suggests that the duration of the ACFT could be a factor that indicates insufficient aerobic capacity. Due to the ACFT's infancy and a limited amount of research, the purpose of this study is to examine VO_{2max} as a predictor of performance on the ACFT total score and obtain a better understanding of the aerobic demands. This greater understanding may assist in developing training programs to enhance combat readiness and ACFT performance. Since the ACFT includes aerobic activities, it would be reasonable to hypothesize that VO_{2max} would statistically predict ACFT scores. Therefore, the primary aim of this study was to test ROTC cadets' VO_{2max} as a predictor of ACFT scores. A secondary aim was to assess VO_{2max} as a predictor of performance on the 2MR. A third aim was to assess the sex differences.

METHODS

Participants

Correlation coefficients were interpreted in accordance with guidelines by Cohen (6) as small (f^2 = 0.2 – 0.14), medium/moderate (f^2 = 0.15 – 0.34), or large ($f^2 \geq 0.35$). The targeted sample size used a priori power *G power analysis (effect size = 0.3, α = 0.05, $p \leq 0.05$) 55 participants to achieve a power of .95. Participant demographics are presented in Table 1. Sixty-four ROTC

cadets (50 males, and 14 females, aged 21.43 ± 4.10 years) were recruited to participate in the study. All participants took the ACFT within 14 days of completing the VO_{2max} test. Participants were recruited from the Army ROTC program located at Grand Canyon University. The ROTC cadets were required to be actively enrolled in Grand Canyon University and the ROTC program. Participants were excluded if they were currently on light duty, pregnant, and/or have any known chronic disease or injury that can affect performance. The study was approved by the Grand Canyon University Institutional Review Board (2022-4618) and was performed by the ethical standards of the Declaration of Helsinki. This research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (17).

Table 1. Cadet descriptive data.

Total (n = 64)	Male (n = 50)	Female (n = 14)		p-value
Age (years)	21.43 ± 4.10	21.82 ± 4.22	20.07 ± 3.45	.062
Height (cm)	173.07 ± 9.06	176.01 ± 7.38	162.58 ± 6.37	< .001**
Weight (kg)	77.21 ± 17.10	80.10 ± 16.07	66.90 ± 17.23	.009*
BMI (kg m^2)	24.55 ± 5.09	25.10 ± 5.16	22.59 ± 4.41	.080
%BF	20.19 ± 9.70	17.85 ± 8.61	28.57 ± 8.96	< .001**
FFM (kg)	59.82 ± 11.55	63.65 ± 9.66	46.17 ± 6.10	< .001**

Notes: *p < .05, **p < .001
Abbreviations: BMI, Body mass index; %BF, % body fat; FFM, Fat-Free Mass
Data are mean ± SD, rounded to the nearest 0.1. The p-value signifies the significance between the sexes.

Protocol

The commanding officer recruited the participating ROTC cadets, who worked with lab staff to organize the testing schedule. The ROTC cadets came into the laboratory for one visit to complete testing. Participants were advised to avoid physical activity for 12 hours and caffeine for 4 hours before testing. All participating cadets received informed consent and were provided adequate time to read through and ask any questions. Following a signed informed consent, ROTC cadets underwent VO_{2max} testing using the treadmill.

Maximal Oxygen Uptake (VO_{2max}): Participants were directed to the metabolic cart to assess VO_{2max} on a calibrated treadmill (Trackmaster tmx 428cp, Newton, Kansas) using a graded exercise test (Bruce protocol) for voluntary exhaustion (5). VO_{2max} is measured as milliliters of oxygen consumed in one minute per kilogram of body weight ($mL \cdot kg^{-1} \cdot min^{-1}$). Ventilation and expired gases were measured breath-by-breath using the Vmax metabolic cart (CareFusion, Franklin Lakes, NJ). VO_{2max} was measured as the average of the two highest consecutive 10s oxygen consumption values. Before testing, the gas analyzer was calibrated for volume (Hans Rudolph 5530 3 L syringe: Kansas City, MO, USA) and two-point gas composition. Face masks (Hans Rudolph, Kansas City, MO, USA) were fitted to participants to ensure a proper seal and allow simultaneous breathing at the mouth and nose. VO_{2max}, as opposed to VO_{2peak}, was verified either by a plateau of oxygen consumption (< 150 $ml \cdot min^{-1}$) with an increased stage or a respiratory exchange ratio above 1.15 (8). Heart rate (HR) was measured with a Polar HR monitor (Polar, Lake Success, NY). Ratings of perceived exertion were taken every minute throughout the test using a visual Borg scale (19). Participants conducted a five-minute

cooldown using the treadmill at 1.7 mph and 0% grade. Participants were advised that if they would like to remove the Hans Rudolph mask for any reason, all they would need to raise their hand, the test would stop, and the Hans Rudolph mask would be removed immediately.
Anthropometric Assessments: Bodyweight was measured with minimal clothing, and height was assessed without shoes worn. Participant body mass was measured to the nearest 0.01 kg and height to the nearest 0.1 cm using a stadiometer with a calibrated digital scale attached (Tree LS-PS 500). Waist circumference (WC) and hip circumference (HC) were captured using a Gulick II 150 cm anthropometric tape (model 67020) and reported to the nearest 0.1 cm. WC was captured immediately above the iliac crest, parallel to the floor, with readings taken at the end of exhalation. HC was captured at the most substantial protrusion of the buttocks (14). Measurements are described in the Anthropometric Standardization Reference Manual (14).

Body Composition: Body composition was determined using whole-body air displacement plethysmography (BOD POD, Cosmed). The BOD POD has been shown to be valid when compared to dual-energy X-ray absorptiometry (17). The BOD POD was warmed up and calibrated before the daily testing. The BOD POD captured weight using the scale associated and derived a body fat % (%BF) and fat-free mass (FFM) reading. Before the testing, participating cadets were asked to wear bathing suits or tight-fitting clothing, place a cap on their heads to cover all hair, and remove all jewelry. The test captured two measurements of 50 seconds each. A third measurement was done if there was an inconsistency with the first two measurements.

Army Combat Fitness Test (ACFT): The ROTC cadets took the ACFT with their training unit in accordance with the procedures and standards outlined by the U.S. Army Field Testing Manual (21). Official scores were collected and documented using Microsoft Excel and provided to the researchers. The ACFT consists of six events to be completed within 70 minutes or less: 3 repetition maximum deadlifts (MDL), standing power throw (SPT), hand-release push-ups (HRPU), sprint-drag-carry (SDC), plank (PLK), and a 2-mile run (2MR). It is suggested that the total work time is 34 to 37 minutes with a minimum of 17 minutes of rest time, with each event being scored from 0 to 100. A minimum score of 60 is required to pass each event, with a total of 360 to pass the ACFT. The ACFT Field Testing Manual provides a complete breakdown of each test as well as weight and scoring variations between the sexes (21).

Statistical Analysis
SPSS for Windows version 28 software (IBM, Armonk, NY) was used to analyze the data from this study. Descriptive data of age, height, weight, BMI, %BF, and ACFT scores are presented as mean ± SD. VO_{2max} data is expressed as mL $\cdot kg^{-1} \cdot min^{-1}$ and presented as mean ± SD. Significance was set a priori at $p <$ .05. Data normality was evaluated with scatter plots, and the independence of observations was confirmed via the Durbin-Watson statistic. No outliers were identified. All participants with missing data were removed from the analysis.

An independent-sample t-test was run to determine if there was a difference between males and females. Linear regression was run to understand the effect of VO_{2max} (independent variables)

on ACFT performance (dependent variable). A scatterplot was used to test the linearity between ACFT total scores against VO_{2max} values with a superimposed regression line plotted. Visual inspection of these two plots indicated a linear relationship between the variables. There was homoscedasticity and normality of the residuals.

RESULTS

There was a significant difference between sexes for height, weight, %BF, FFM, and VO_{2max}. No differences were found for age and BMI (Table 1). Cadet descriptive data are shown in Table 1. Figure 2 shows VO_{2max} was significantly and positively correlated to MDL (r = .253, p = .044), HRPU (r = .486, p < .001), SDC (r = .495, p < .001), PLK (r = .512, p < .001) 2MR (r = .578, p < .001) and overall ACFT score (r = .619, p < .001) but not SPT (r = .238, p = .055).

Table 2. Cadet results.

	Total (n = 64)	Male (n = 50)	Female (n = 14)	p-value
VO_{2max} (mL·kg-1·min-1)	45.18 ± 11.44	47.80 ± 10.64	35.82 ± 9.31	< .001**
ACFT Scores				
Maximal Deadlift	86.90 ± 15.14	86.68 ± 16.28	87.71 ± 10.53	.389
Standing Power Toss	83.64 ± 15.31	83.74 ± 16.39	83.28 ± 11.09	.452
Hand-Release Pushup	87.78 ± 10.04	88.54 ± 9.89	85.07 ± 10.46	.140
Sprint-Drag-Carry	89.81 ± 12.73	91.54 ± 11.65	83.64 ± 14.86	.042*
Plank	76.89 ± 24.42	81.94 ± 18.65	58.85 ± 33.65	< .001**
2 Mile Run	77.63 ± 25.88	81.79 ± 22.42	62.78 ± 32.37	.028*
Total ACFT Score	502.76 ± 80.21	514.36 ± 72.00	461.35 ± 93.43	.014*

Note: *p < .05, **p < .001; Army Combat Fitness Test (ACFT). Data are mean ± SD, rounded to the nearest 0.1. ACFT event scores ≥ 60 are passing. The p-value signifies the significance between the sexes.

DISCUSSION

To the best of our current knowledge, this study stands as the inaugural investigation dedicated solely to exploring the connection between VO_{2max} and outcomes in ACFT performance. The initial hypothesis posited that VO_{2max} could serve as a predictive factor for performance on the ACFT total score. The analysis unveiled statistically significant linear correlations between VO_{2max} and the ACFT total score. While VO_{2max} displayed correlations with individual events, MDL was considered a weak correlation, and HRPU, SDC, PLK, and 2MR are considered moderate correlations (2). There was no correlation in the SPT event. This divergence might stem from the fact that the SPT event primarily engages the anaerobic lactic energy system through a single power movement. Notably, VO_{2max} offered an explanatory capacity of 38% concerning the variability in total ACFT scores.

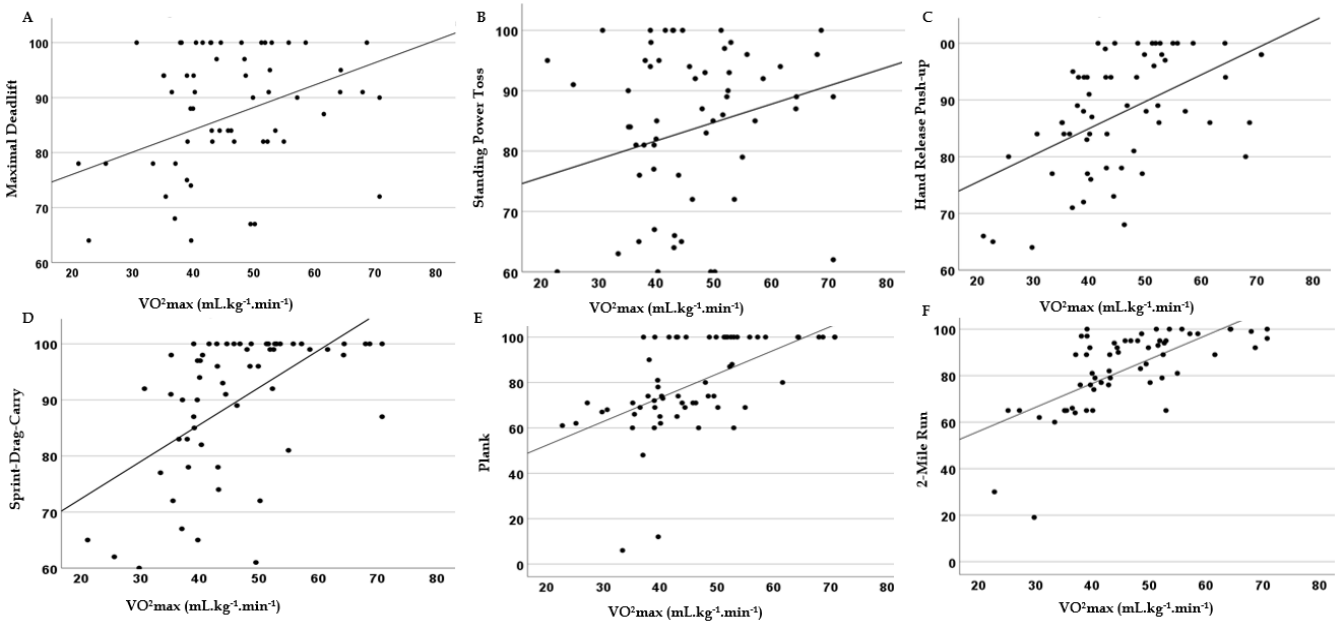

Figure 1. Relationship between VO_{2max} (mL·kg^{-1}·min^{-1}) and maximum Deadlift (A), Standing Power Toss (B), Hand-Release Pushup (C), Sprint-Drag-Carry (D), Plank (E), and 2-mile Run (F). All relationships except Standing Power Toss are statistically significant ($P < 0.001$).

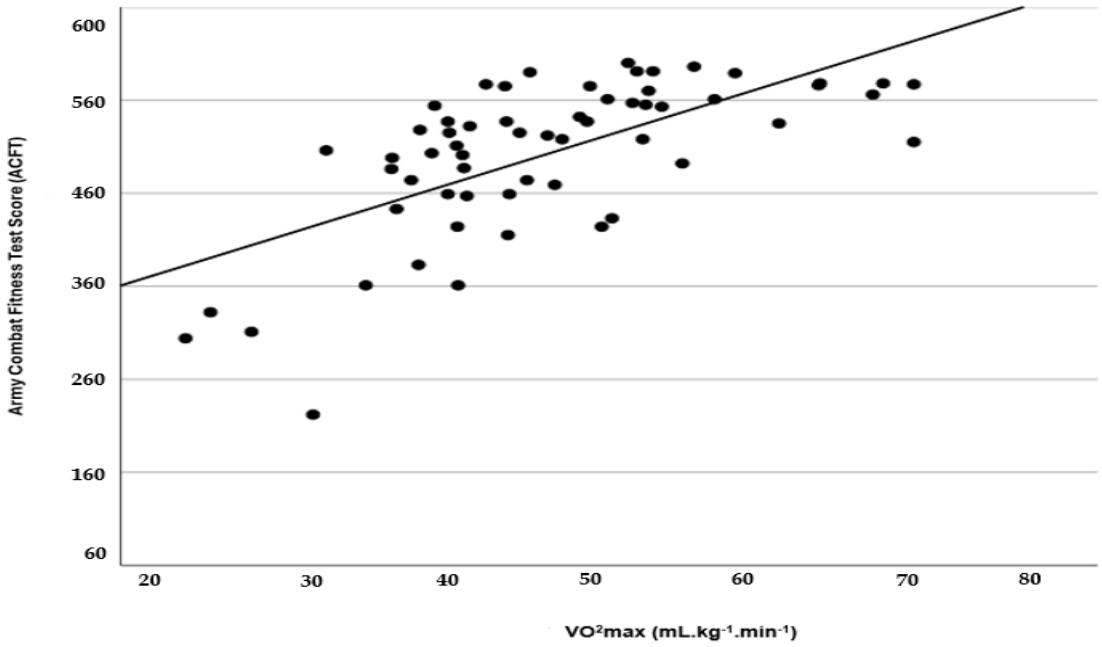

Figure 2. Relationship between VO_{2max} (mL·kg^{-1}·min^{-1}) and Army Combat Fitness Test Scores. Relationship is statistically significant at $P < 0.001$.

Despite the shift within the Army towards the ACFT, designed to encompass strength, power, speed, and agility events that reportedly lean heavily on anaerobic energy, the present findings

advocate the need for a well-developed aerobic capacity due to the overall duration of the test. These results align with earlier observations indicating that failures often occurred in the final two events (PLK, 2MR) (10). Given the recent implementation and independent assessment of the ACFT, it becomes imperative to deepen our comprehension of the demands imposed on soldiers for optimal performance and sustained physical readiness. Notably, VO_{2max} testing has existed for nearly a century and serves as the gold standard for maximal aerobic capacity assessment (3), our findings are in harmony with the notion that higher VO_{2max} levels correspond to enhanced performance (13).

Holistic Health and Fitness (12) reported that a projected VO_{2max} of 33 $mL \cdot kg^{-1} \cdot min^{-1}$ predicted a "black" score (indicative of performing at a high physical demand) on the Occupational Physical Assessment Test (OPAT), consisting of standing long jump, seated power throw, deadlift, and interval run. However, this reference does not directly correlate with the ACFT due to its inclusion of two more events and a heightened demand for aerobic capacity. Current findings reveal that ACFT non-passers exhibited a mean VO_{2max} of 32.81 ± 8.11 $mL \cdot kg^{-1} \cdot min^{-1}$. This underscores the necessity of devising fresh standards for the minimum VO_{2max} essential to attain an optimal state of combat readiness.

The practical application of these findings relates to exercise training variables. Because a high VO_{2max} predicts better scores on the ACFT test, exercise practitioners who work with Army personnel should include aerobic training in exercise programming. Data from a VO_{2max} test may also provide specific training thresholds to enhance aerobic capacity. Scribbans et al. (20) demonstrated that aerobic capacity, measured by VO_{2max}, can be equivalently enhanced through continuous training or interval training exceeding 60% VO_{2max} over an 8-week period. Although earlier research supported 8-week programs in enhancing VO_{2max}, Newman et al. (18) assessed two training regimens (high-intensity functional training and a DoD-developed program), noting no significant VO_{2max} change but a noteworthy increase in ACFT total score. While the mechanisms underlying continuous training remain contentious, interval training improvements are attributed to peripheral adaptations (16). The present study underscores the pivotal role of VO_{2max} in ACFT performance by revealing that a 1 $mL \cdot kg^{-1} \cdot min^{-1}$ VO_{2max} increment corresponds to a 4-point increase in ACFT total scores, which would be significant for those needing points to pass or improve their score for promotion or selection. This understanding could give direction on the training needed to enhance one's ACFT score.

As far as we are aware, this study is the first to explore the predictive potential of VO_{2max} in ACFT performance exclusively. An inherent constraint of this preliminary research stems from the relatively limited sample size, primarily drawn from ROTC cadets of a singular university. While no specific physical activity data were gathered, it was presumed that these cadets adhered to a structured training regimen consisting of three days of aerobic exercise and two days of resistance training. To address this, cadets were instructed to undertake the ACFT within a 14-day window following the completion of the VO_{2max} test. Notably, the study overlooked the inclusion of variables such as sleep patterns and dietary habits, both acknowledged influencers of performance (9), which represents an additional limitation. The study included

14 female cadets (21%), a slightly higher proportion than the average of 19% for U.S. Army female officers (22).

In summary, aerobic fitness is necessary to score well on the ACFT. Thus, exercise variables that enhance aerobic fitness should be included in exercise programs for Army personnel. These findings contribute to the limited body of research investigating VO_{2max} as a predictor of performance in the newly instituted ACFT. The ACFT's duration appears to exert an influence on outcomes, demanding a heightened level of aerobic capacity to excel in the final two events. These findings suggest that aerobic training should be amongst the highest priorities in enhancing combat readiness and greater ACFT scores. Further research is imperative to establish the minimal requisite VO_{2max} for assessing recruits' physical readiness to navigate the ACFT successfully.

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