RELATIONSHIPS BETWEEN SELECT ANTHROPOMETRIC VARIABLES AND PHYSICAL FITNESS TEST PERFORMANCE IN ROTC CADETS BY SEX

By

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Abstract: **PURPOSE**: The purpose of this study was to determine if relationships existed between body composition and measures of muscular endurance and aerobic fitness among male and female ROTC cadets by sex. **METHODS:** Archived data for 74 (male = 57, female = 17) Army ROTC cadets from a large Midwestern university were used for this analysis. Army Physical Fitness Test (APFT) scores for the 2-minute push-up (PU), 2-minute sit-up (SU), and 2-mile run (2MR) test were performed by cadets as part of their normal physical training. One week after performing the APFT, height, body mass, and body fat percentage (BF%) (e.g., InBody 270) were collected. Using these measurements, body mass index (BMI) and lean body mass (LBM) were then calculated. Pearson's correlations were used to determine relationships between each of the anthropometric variables and fitness tests for each sex. **RESULTS:** Male cadets were taller and heavier, performed more PUs and SUs, and had faster 2MR times than female cadets. Significant differences between height, body mass, BF%, PU, and SU performance, as well as, 2MR times were found between males and females. No significant difference was found between sexes for BMI. No significant relationships ($p > 0.05$) were discovered between any anthropometric measures and performance among male and female cadets. **CONCLUSION:** No significant relationships between fitness test performance and the selected anthropometric variables among male or female ROTC cadets were discovered. However, significant differences between sexes for height, body mass, BF%, PU and SU performance, and 2MR time were found. Additionally, male cadets were taller, larger, and performed better than female cadets. This suggests that males may have an advantage when performing military tests due to having naturally higher muscle mass, greater lung capacity, higher testosterone, and a higher strength threshold than females. Specialized training for female cadets may be beneficial in improving fitness performance and equalizing test pass rate opportunities. More research regarding specialized training for female ROTC cadets may be useful for improving female cadet fitness performance. Furthermore, more research is needed to determine the impact of these anthropometric variables on strength and occupationally related tasks in ROTC cadets.

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CHAPTER I

INTRODUCTION

Reserves Officers' Training Corps (ROTC) is a college program designed to educate, train, and prepare college students to become officers within each of the U.S. military branches (Army, Navy, Air Force, and Marine Corps) (Mele, 2020). There are more than 32,000 Army ROTC cadets and 3,600 faculty and staff at approximately 1,000 colleges across the United States, and each year approximately 5,000 Army ROTC cadets join the Army after graduating college (Mele, 2020). In order for ROTC cadets to graduate and become military soldiers, they must first meet certain physical fitness standards. For this reason, physical fitness and training are heavily emphasized within these programs.

One of the primary objectives of Army ROTC programs is to physically prepare cadets for the physical demands they will encounter in the military environment. These demands include marching, running, climbing, crawling, jumping, vaulting, combat, and swimming (Oliver et al., 2017). The Army Physical Fitness Test (APFT) has been the standard fitness evaluation used in the Army since 1985 to determine physical readiness and health of both soldiers and cadets (Leiting, 2014). The APFT included three assessments: the 2-minute push-up (PU) and sit-up (SU) tests to assess muscular endurance, and a 2-mile run (2MR) test to assess aerobic fitness. Each assessment is scored between 0 to 100, with 0 being the lowest score and 100 being the highest. These three assessments are added together with 300 being the maximum score. The standard for passing the APFT was to attain at least 60 points (180 points out of 300 for the total score) in each of the three assessments (Steed et al., 2016).

Recently, the Army has switched to a new fitness evaluation known as the Army Combat Fitness Test (ACFT). The ACFT is now used in order to improve the testing of soldiers focused more toward combat capabilities and cadets are separated by job duty rather than age or sex. Although the APFT is no longer utilized, measures included in this test can be used to determine information related to general health and fitness (i.e., muscular endurance and aerobic fitness) (Steed et al., 2016). The APFT and ACFT also share a few commonalities in that the 2MR and some type of push-up test are included in both test batteries (Roberts et al., 2021). Thus, performance in one test battery may have relevance, or be predictive, of the other.

Attaining and maintaining a healthy body composition can have a significant impact on occupational and physical performance (Crombie et al., 2012). According to Malina et al., (2011) higher fat mass tends to negatively impact activities such as running, jumping, and vaulting. In accordance, Steed et al. (2017) suggest that an individual's body fat percentage (BF%) may be important in determining muscular endurance and aerobic performance among ROTC cadets. This is concerning since according to Crombie et al. (2012) 34% of males and 38% of females in the military are considered overweight or obese. Additionally, Friedl (2018) states that minimal fat-free mass levels are crucial for injury prevention in Army personnel. This suggests that higher fat mass may not only negatively impact ROTC cadet's fitness performance, but also their general health and well-being. Thus, it is crucial for ROTC cadets to attain and maintain a healthy body composition.

Body mass index (BMI) can be defined as an anthropometric measurement found by calculating the ratio between weight (kilograms) divided by height (meters) squared (Dawes et al., 2018;

Steed et al., 2016). Ranges that represent BMI levels include underweight as less than 18.5 kg/m^2, healthy weight as 18.5 to 24.9 kg/m^2, overweight as 25 to 29.9 kg/m^2, and obese as greater than 30 kg/m^2 (Weir et al., 2020). Healthy BMI ranges may or may not impact physical fitness performance due to mixed research results (Pierce et al., 2017; Roberts et al., 2021). Roberts et al. (2021) found that BMI did not impact any fitness tests within the ACFT. In contrast, Pierce et al. (2017) found that higher BMI improved physical fitness tasks, BMI decreased 2-mile run time in men ($p < 0.01$) and women ($p = 0.025$), and BMI did not impact loaded ruck march performance ($p \geq 0.21$). Furthermore, BMI may not be the best indicator for fitness performance because it does not account for those with higher lean body mass (LBM) since BMI does not separate between LBM and fat mass. When regarding general health, BMI stands as a commonly accepted measurement of health in obese populations (Robert et al., 2021). Therefore, BMI may not be a reliable predictor of fitness performance, but it may be a predictor for general health.

Purpose

Minimal research exists related to the impact of body composition on muscular endurance and aerobic fitness performance among ROTC cadets (Oliver et al., 2017; Steed et al., 2017). The purpose of this investigation was to determine if significant relationships exist between select anthropometric variables and measures of muscular endurance and aerobic fitness among male and female ROTC cadets. The researchers hypothesized that body composition and BMI would not be significantly related to performance in the 2-minute PU and SU test or 2MR among male or female cadets.

Hypotheses and Research Question

The following hypotheses will be tested at the 0.05 level of significance.

Null Hypothesis One

There will be no significant differences between male and female ROTC cadets.

Null Hypothesis Two

There will be no significant correlations between body composition and push up test (PU), sit up test (SU), or 2-mile run (2MR) time performance among male ROTC cadets.

Null Hypothesis Three

There will be no significant correlations between body mass and PU, SU, or 2MR performance among male ROTC cadets.

Null Hypothesis Four

There will be no significant correlations between LBM and PU, SU, or 2MR performance among male ROTC cadets.

Null Hypothesis Five

There will be no significant correlations between body fat and PU, SU, or 2MR performance among male ROTC cadets.

Null Hypothesis Six

There will be no significant correlations between BMI and PU, SU, or 2MR performance among male ROTC cadets.

Null Hypothesis Seven

There will be no significant correlations between BF% and PU, SU, or 2MR performance among male ROTC cadets.

Null Hypothesis Eight

There will be no significant correlations between body composition and PU, SU, or 2MR performance among female ROTC cadets.

Null Hypothesis Nine

There will be no significant correlations between body mass and PU, SU, or 2MR performance among female ROTC cadets.

Null Hypothesis Ten

There will be no significant correlations between LBM and PU, SU, or 2MR performance among female ROTC cadets.

Null Hypothesis Eleven

There will be no significant correlations between body fat and PU, SU, or 2MR performance among female ROTC cadets.

Null Hypothesis Twelve

There will be no significant correlations between BMI and PU, SU, or 2MR performance among female ROTC cadets.

Null Hypothesis Thirteen

There will be no significant correlations between BF% and PU, SU, or 2MR performance among female ROTC cadets.

Delimitations

The following delimitations may affect the results and conclusions drawn from this study.

1. ROTC cadets from only one university were investigated.

2. The APFT was conducted as the physical fitness test instead of the ACFT.

Limitations

The following limitations reflect from the delimitations of this study.

1. There were seven full days in between participants performing the APFT and collecting anthropometric measurements.
2. The physical fitness days before the APFT and anthropometric measurement collection were not controlled.
3. Nutrition and diet were not controlled.
4. There were limited physical metrics that were performed by the training staff.

Assumptions

The following statements were assumed correct when completing the results for this study.

1. Participants performed with maximal effort during each testing session.

2. The testing administrators that collected the physical performance tests and anthropometric data for the analysis in this study possessed the correct knowledge, skills, and ability to collect the information accurately and in the manner described in the methods section of this paper.

Definition of Terms

The following terms are relevant to this study.

<u>Reserve Officers' Training Corps (ROTC):</u> A university training program that trains college students to become future military officers.

<u>2 Min. Push-Up (PU) Test:</u> A test used to assess upper-body strength and muscular endurance.

2 Min. Sit-Up (SU) Test: A test used to assess both abdominal and hip-flexor muscular endurance.

2-mile run (2MR) Test: A test used to assess aerobic fitness and leg muscle endurance.

Army Physical Fitness Test (APFT): Provides a measure of upper and lower body endurance. Includes the 2-minute push-up, 2-minute sit-up, and 2-mile run tests.

Army Combat Fitness Test (ACFT): The current Army fitness test is composed of 6 events including a deadlift test, a 10-pound ball throw, hand-release push-ups, a sprint-drag-carry, a leg tuck, and a 2-mile run.

Body Composition: Percentages of fat, bone, water, and muscle in the human body.

Body Mass: A measure of body fat that is the ratio of the weight of the body in kilograms to the square of its height in meters.

Body Mass Index (BMI): A weight to height ratio with the formula of dividing weight (kilograms) by height squared (meters).

Lean Body Mass (LBM): The total weight minus fat mass. It includes organs, skin, bones, body water, and muscle mass. Also known as fat-free mass.

Lean Muscle Mass: The amount of muscle that the body is made up of.

Body Fat: The percentage of adipose tissue compared with muscle.

Body Fat Percentage (BF%): The total mass of fat divided by total body mass, then multiplied by 100.

Fat-Free Mass: Also known as LBM, fat-free mass includes internal organs, bones, muscle, water, and connective tissue.

CHAPTER II

LITERATURE REVIEW

The purpose of this literature review is to discuss the current literature on body composition and physical test performance among ROTC cadets, military soldiers, and law enforcement. In this review, the following topics will be addressed in more detail: Reserves Officers' Training Corps (ROTC); Army Physical Fitness Test; Army Combat Fitness Test; Body Composition Terms; Relationships between Anthropometric Variables and Job Task Performance organized by chronological order; Relationships between Anthropometric Variables and Aerobic and Muscular Endurance organized by author in chronological order; and Reliability and Validity of Body Composition Using the InBody 270.

The Reserve Officers' Training Corps (ROTC)

Reserve Officers' Training Corps (ROTC) is a program aimed at educating, training, and preparing college students to become military officers (Mele, 2020). ROTC cadets must meet fitness standards in order to be promoted to military soldiers; therefore, ROTC programs heavily prioritize physically preparing cadets for physical demands and job tasks within the military (Oliver et al., 2017). Since 1985, the APFT has been the Army's standard fitness evaluation that determines fitness readiness and health in soldiers and ROTC cadets (Leiting, 2014). Assessments within the APFT include: the 2-minute push-up (PU) and sit-up (SU) tests, and the 2-mile run (2MR) test. The PU and SU test evaluate muscular endurance, while the 2MR test evaluates aerobic endurance. These fitness evaluations are each scored between 0 (lowest score) to 100 (highest score), and all three evaluations are added together for a total score, with 300 being the maximum score. In order to pass the APFT, cadets must score at least 60 points in each of the assessments (Steed et al., 2016). Although the APFT is an adequate measure of health and fitness performance, the Army has recently switched to a new fitness assessment known as the Army Combat Fitness Test (ACFT). The ACFT focuses on combat capabilities and separates cadets by job duty instead of by age or sex. Even though the APFT is no longer used, measurements included in this test can be used to determine information related to general health and fitness (i.e., muscular endurance and aerobic fitness) (Steed et al., 2016). The APFT and ACFT are similar in that the 2MR and some type of push-up test are included in both test batteries (Roberts et al., 2021). Thus, performance in one test battery may have relevance, or be predictive, of the other.

Attaining and maintaining a healthy body composition can have a significant impact on occupational and physical performance (Crombie et al., 2012). According to Malina et al., (2011) higher fat mass tends to negatively impact activities such as running, jumping, and vaulting. In accordance, Steed et al. (2017) suggest that an individual’s body fat percentage (BF%) may be important in determining muscular endurance and aerobic performance among ROTC cadets. This is concerning since according to Crombie et al. (2012) 34% of males and 38% of females in the military are considered overweight or obese. Additionally, Friedl (2018) states that minimal fat-free mass levels are crucial for injury prevention in Army personnel. This suggests that higher fat mass may not only negatively impact ROTC cadet’s fitness performance, but also their general health and well-being. Thus, it is crucial for ROTC cadets to attain and maintain a healthy body composition.

Body mass index (BMI) can be defined as an anthropometric measurement found by calculating the ratio between weight (kilograms) divided by height (meters) squared (Dawes et al., 2018; Steed et al., 2016). Ranges that represent BMI levels include underweight as less than 18.5 kg/m^2, healthy weight as 18.5 to 24.9 kg/m^2, overweight as 25 to 29.9 kg/m^2, and obese as greater than 30 kg/m^2 (Weir et al., 2020). Healthy BMI ranges may or may not impact physical fitness performance due to mixed research results (Pierce et al., 2017; Roberts et al., 2021). Roberts et al. (2021) found that BMI did not impact any fitness tests within the ACFT. In contrast, Pierce et al. (2017) found that higher BMI improved physical fitness tasks, BMI positively impacted 2-mile Run time in men ($p < 0.01$) and women ($p = 0.025$), and BMI did not impact loaded ruck march performance ($p \geq 0.21$). Furthermore, BMI may not be the best indicator for fitness performance because it does not account for those with higher lean body mass (LBM) since BMI does not separate between LBM and fat mass. When regarding general health, BMI stands as a commonly accepted measurement of health in obese populations (Robert et al., 2021). Therefore, BMI may not be a reliable predictor of fitness performance, but it may be a predictor for general health.

Army Physical Fitness Test

Founded in 1980, the APFT was the main physical assessment for U.S. Army soldiers until 2019 (Knapik et al., 2014; McCarthy, 2020). It consisted of three fitness tests that measure muscular endurance and cardiorespiratory fitness. The APFT is composed of the push-up (PU), sit-up (SU), and 2-mile run (2MR) tests (Huang, 2016). The objective of the PU and SU tests is to complete as many repetitions as possible, with good form, in 120 seconds. The 2MR test requires participants to run a 2-mile course as fast as possible. The APFT had a maximal score of 300 points, with each assessment comprising a maximum of 100 points. In order to pass the APFT, soldiers were required to accrue at least 180 out of 300 points with a minimum of 60 points per assessment (Steed et al., 2016).

In October of 2019, the Army replaced the APFT with the ACFT (U.S. Army). The PU and SU tests were excluded from the ACFT; however, the 2MR test remained (Roberts et al., 2021). Although the PU and SU are no longer used, the fitness tests within the APFT are still valid and reliable measures of fitness and general health (Robert et al., 2021; Steed et al., 2016).

Army Combat Fitness Test

As of October 1, 2019, the ACFT is the current fitness assessment used by the U.S. Army (U.S. Army). The ACFT was designed to better prepare cadets for combat by focusing on a greater range of physical attributes required for military job tasks (i.e., strength, agility, power, etc.). The ACFT has also been promoted as better at reducing injuries associated with testing and training for the APFT (Roberts et al., 2021). Although the ACFT is currently used, the APFT is still relevant for physical fitness due to the APFT's indication of general fitness. Both evaluations share similar tests, which include the 2-mile run and a type of push-up test.

Body Composition Terms

Body composition is defined as the amount of lean body mass (LBM) in relation to fat mass within the body (Wells et al., 2006). LBM, also known as fat-free mass, is composed of all tissues in the body (e.g.., skeletal muscle, bones, organs, and connective tissues) excluding fat mass (Huang, 2016). Fat mass refers to all adipose tissue within the body (Korhonen et al., 2021). A healthy body composition range is a body mass index (BMI) weight of 18.5 to 24.9 kg/m^2 (Weir et al., 2020). Individuals who possess healthy body composition ranges tend to perform better in both health and fitness related tests (Crombie et al., 2012). Therefore, attaining and maintaining a healthy body composition level may have an impact on ROTC cadets.

BMI is an anthropometric measurement that is calculated by using the ratio between weight (kilograms) divided by height (meters) squared (Dawes et al., 2018; Steed et al., 2016). BMI predicts disease related to obesity and is recommended in screening for both overweight and obese in large populations (Grier et al., 2015). In addition, BMI is also used for characterizing fitness conditions and cardiovascular risk in populations such as healthy, military service members, and law enforcement (Robert et al., 2021; Pierce et al., 2017, Dawes et al., 2018). Additionally, BMI may be related to health due to its ability to classify obesity and health conditions (Prentice et al., 2001; Roberts et al.; 2021). BMI classifications include underweight as less than 18.5 kg/m^2, healthy weight as 18.5 to 24.9 kg/m^2, overweight as 25 to 29.9 kg/m^2, and obese as greater than 30 kg/m^2 (Weir et al., 2020).

Relationships between Anthropometric Variables and Job Task Performance

Williams et al. (2006)

The purpose of this study was to determine if strength, aerobic endurance, and anthropometric measurements could assess changes in load-carriage performance in 177 (male = 146, female = 31) British Army recruits. Recruits had performed strength, endurance, body composition, and load carriage with 15 kg and 25 kg tests before and after a 10-week training program. Body mass, stature, and body composition were measured using bioelectrical impedance. Pertaining to body composition, this study found that fat-free mass was a positive ($r = 0.671$; $p < 0.0005$) predictor of time completion during the 3.2-km loaded march with a backpack load of 15 kg.

Vanderburgh (2008)

Vanderburgh's (2008) review evaluated body mass bias and occupational relevance of aerobic capacity and strength endurance performance by evaluating the specific push-up, sit-up, and run test within the Army, Air Force, and Navy populations. This review found that lighter weight personnel had an advantage in PFT tests within the Army, Air Force, and Navy when compared to higher weight personnel; however, those with higher LBM performed military tasks better. This suggests that LBM is a potential determinant of military performance and is often correlated with physically demanding military tasks that focus on strength and power.

Huang (2016)

The purpose of this study was to evaluate the ACRT components of physical fitness performance. Subjects in this study included 43 physically active males who completed the ACRT in order to access fitness performance. Huang (2016) found that fat-free mass (i.e., LBM) contributed to the prediction time in the completion of the ACRT, which includes the 400-meter run, hurdles, crawl, under and over, drag, balance beam ammo carry, point-aim-move, 100-yard shuttle sprint ammo carry, and agility sprint tests ($r^2 = 0.52$, $p < 0.001$).

Pierce et al. (2017)

The author's main objective was to evaluate both fitness and military task performance by BMI in 275 male and 46 female soldiers. Soldiers were instructed to perform the APFT for performance measurements, and BMI was calculated using weight and height. Pierce et al. (2017) found that higher BMI improved physical fitness tasks, BMI positively impacted 2-mile run time in men ($p < 0.01$) and women ($p = 0.025$), and BMI did not impact loaded ruck march performance ($p \geq 0.21$). Additionally, this study found that higher BMI was associated with improved performance in physical fitness tasks involving strength and power. However, BMI is positively correlated to 2-mile run time performance in both men ($p < 0.01$) and women ($p = 0.025$) military soldiers. Pierce et al. (2017) also found that BMI values had no significant differences ($p \geq 0.21$) in military-specific tasks, such as the loaded ruck march, for both men and women. Lastly, significant ($p \leq 0.05$) relationships between BF% and BMI to measures of muscular endurance and aerobic fitness were found.

Poser (2017)

Poser (2017) suggests that LBM may be a positive predictor for military tasks, such as the fireman's carry. The author's purpose was to investigate the strength and rate of force needed to complete a modified fireman's carry test in both weighted and unweighted groups. Participants comprised of 18 male ROTC cadets who completed a fireman's carry both unweighted and weighted. Poser (2017) reported that, regardless of BF% differences and pass and fail rates, greater LBM was significantly correlated ($p < 0.001$) to faster times in the fireman's carry time trial test, and LBM was significantly correlated ($r = 0.51$; $p < 0.05$) to peak force in the fireman's carry among 18 male ROTC cadets.

Dawes et al. (2018)

The authors' purpose was to determine the physical demands of defensive tactics training and examine significant differences between defensive tactics training and BMI among 24 male state patrol officers with ranging BMI categories. Regarding body composition and fitness military job performance, Dawes et al. (2018) found that BMI may significantly impact job task performance. Results revealed a significant difference in defensive tactic scores between officers with healthy BMIs (97.92 ± 7.21). This suggests that BMI may negatively impact fitness performance.

Coakley et al. (2019)

Coakley et al. (2018) examined the predictability of 8-mile loaded march performance through anthropometric measures and Representative Military Tasks (RMTs) in British Army personnel; subjects included 135 (male = 87, female = 48) Army soldiers. During the first session, soldiers had various measurements taken, which included stature, body mass, fat-free mass, single lift performance, water can carry performance, and 1.5 mile run performance. The soldiers then completed session two, which comprised of an 8-mile loaded march. Results of this study showed that body mass and 1.5-mile run time could be used to predict 8-mile loaded march performance among Army personnel. The authors also found that male soldiers had faster 1.5 mile run and 8-mile loaded march times, higher body mass and total free-fat mass, and better single lift and water can carry test scores ($p < 0.001$) than women soldiers.

Relationships between Anthropometric Variables and Aerobic and Muscular Endurance

Crawford et al. (2011)

The purpose of this study was to compare fitness test performance between soldiers with a BF ≤ 18% and soldiers with a BF > 18%. Subjects in this study included 99 male Air Assault soldiers. Soldiers were instructed to perform a Wingate cycle test to access anerobic power and capacity. This study found that soldiers with a standard body composition of ≤ 18% BF performed significantly better in 7 of the 10 fitness tests, which included anaerobic capacity, VO_2 max, push-ups, peak isokinetic shoulder internal rotation, peak isokinetic shoulder external rotation, peak isokinetic knee flexion, and peak isokinetic knee extension. Additionally, soldiers with lower body fat levels had increased aerobic and anaerobic performance and muscular strength.

Cuddy et al. (2011)

This study included 135 college-aged men who were categorized into three groups, where group one was run focused, group two was calisthenic focused, and group three was both run and calisthenic focused. Each group was trained three times each week for 12 total weeks. Participants performed the Special Operations Forces (SOF) physical fitness test (PFT), which included a sit-up, pull-up, push-up, and 1.5-mile run test, every Wednesday for 12-weeks total. Results revealed that participants who passed the initial Special Operations Forces (SOF) physical fitness test (PFT) had a mean BF% of 12.9 +/- 6.9 and participants who passed the SOF PFT after 12-weeks of training had a BF% of 12.9 +/- 3.9. Comparatively, participants who failed the SOF PFT had a BF% of 20.0 +/- 7.7. These findings indicate that leaner subjects may be more likely to pass aerobic and muscular endurance tests compared to their counterparts with a higher BF%.

Sporiš et al. (2011)

Researchers examined the significance of body weight on fitness tests in 42 Croatian Navy personnel. Participants completed seven fitness tests including 5-meter spring, 10-meter sprint, 20-meter sprint, squat jump, countermovement jump, standing long jump, and VO_2 max, over the course of three different days. Fifteen anthropometric measurements were also taken from the participants, which included height, body mass, fat tissue, LBM, BMI, left and right upper arm girth extension and flexion, left and right forearm girth, left and right thigh girth, and left and right calf girth. Sporiš et al. (2011) found negative relationships between BF% and performance in the 5-meter sprint ($r = -0.42$), 10-meter sprint ($r = -0.51$), 20-meter sprint ($r = -0.53$), squat jump ($r = -0.45$), countermovement jump ($r = -0.57$), and standing long jump ($r = -0.67$) in Croatian Navy personnel. Additionally, a negative relationship between BF% and VO_2 max ($r = -0.44$) was found.

Crombie et al. (2012)

The authors purpose was to investigate the relationships between body composition and fitness level in general population male students and ROTC male cadets. Participants included 37 first semester male, college students who were divided into three groups, which included low active, high active, and ROTC. Crombie et al. (2012) reported significant negative relationships between VO_2 and BF% ($r^2 = 0.267$; $p < 0.1$), as well as between total-body fat mass ($r^2 = 0.320$; $p < 0.01$) and APFT scores. This suggests that BF% may impact aerobic endurance performance, and total-body fat may affect fitness test scores.

Friedl (2012)

Friedl's (2012) brief review suggests that fat-free mass (LBM) is positively associated with work capacity and strength performance within the military soldier population. Additionally, this author states that minimal fat-free mass levels are crucial for injury prevention in Army personnel. Findings from this review suggest that higher fat mass may not only negatively impact ROTC cadet's fitness performance, but also their general health and well-being.

Maciejczyk et al. (2014)

Maciejczyk et al. (2014) accessed aerobic performance in men categorized into two groups. Group one consisted of participants with an increased body mass, high body fat, and average LBM. Group two included participants with high LBM and average body fat. Researchers found no significant differences in VO_2 max between the two groups, although a positive correlation ($r = 0.38$; $p < 0.05$) between LBM and VO_2 max was found. Additionally, body mass negatively ($r = -0.39$; $p < 0.05$) correlates with VO_2 max, and high body mass lowered VO_2 max in healthy college-aged men.

Dawes et al. (2016)

Dawes et al. (2016) found that LBM was positively and significantly related to push-up, bench press, and vertical jump performance, while fat mass was negatively related to sit-up, vertical jump, and 1.5-mile run performance among 76 male law enforcement officers. This suggests that a higher LBM may improve muscular endurance performance, while a higher fat mass may decrease both muscular and aerobic performance. Additionally, the authors found that BF% negatively and significantly ($p \leq 0.001$) related to one-repetition max bench press ($r = -0.448$), push-ups ($r = -0.413$), and vertical jump ($r = -0.566$) performance, which suggests that BF% may negatively impact physical fitness performance.

Steed et al. (2016)

Steed et al. (2016) suggest that an individual's body fat percentage (BF%) may be important in determining muscular endurance and aerobic performance among ROTC cadets. The authors' main objectives were to access the accuracy of height and circumference measurements compared to other body fat measurement methods and establish the relationships between body composition and fitness test results in 13 (male = 11, female = 2) ROTC cadets. Results revealed significant positive relationships ($r \geq 0.6$; $p < 0.05$) between BF% and 2MR time, and negative correlations ($r \geq -0.8$; $p = 0.01$) between BF% and PU repetitions performed. Furthermore, male ROTC cadets performed better in both the push-up and run time assessments when compared to female cadets; however, sex and performance differences were not statistically measured due to a small female sample size (n=2). The results from Steed et al. (2016) indicate that although there is no significance between BF% and total APFT scores, BF% may determine muscular endurance and aerobic performance in military personnel. In addition, this study revealed that higher body fat led to an impairment in both aerobic exercise and muscular endurance performance.

Roberts et al. (2021)

This study sought to characterize ROTC cadets by body composition, APFT scores, and ACFT scores, and find possible correlations between the any of the factors. Sixty-eight (male = 42, female = 26) ROTC cadets from a Midwestern university performed the both the ACFT and APFT, and had their BMI, fat-free mass, fat-free mass index, and fat mass index calculated. Roberts et al. (2021) found that BMI did not impact any fitness tests within the ACFT. In addition, no significant relationships ($r = -0.119$; $p = 0.540$) between body composition measurements and APFT test scores were found. It was also found that BF% positively ($r = 0.8$; $p = 0.001$) correlated with run time by air-displacement plethysmography and bioelectrical impedance analysis; BF% positively ($r = 0.6$; $p < 0.05$) correlated with run time by height and weight; and BF% negatively ($r = -0.8$; $p = 0.001$) related to push-up repetitions for all body composition methods in ROTC cadets. Lastly, it was found that BMI did not correlate ($r = -0.325$; $p = 0.086$) with any fitness tests in the ACFT in ROTC cadets.

Reliability and Validity of Body Composition Using the InBody 270

The U.S. Army traditionally calculates BF% by using height and circumference measurements, which includes both neck and waist circumferences. Hip circumference measurements are also included for females. Using circumference measurements is beneficial because it requires minimal training and tools, and it is easy to obtain results. However, it may not be as accurate and valid compared to traditional methods when finding BF% (Steed et al., 2016). Methods that may be more accurate in finding BF% include underwater weighing, X-ray absorptiometry (DEXA), air displacement, skinfold measurements, and bioelectrical impedance analysis (BIA). (Steed et al., 2016; Babcock et al., 2006; Larsen et al., 2021).

The InBody 270 is a multifrequency BIA system that measures body fat, body mass, and muscle mass (Larsen, 2021). Czartoryski et al. (2020) report that BIA estimates body fat and LBM by collecting physical characteristics (such as age, height, and sex) and sending a low-level electrical pulse throughout the body. Additionally, multifrequency devices tend to generate more accurate measurement values when compared to single-frequency devices (Czartoryski et al., 2020).

Larsen (2021) found that the InBody 270 is a reliable and valid tool when estimating body composition in children, although, muscle mass was overpredicted in female children. Garcia et al., (2020) reported that the InBody 270 underestimates BF% and fat mass while overestimating fat-free mass in volunteer participants (44 females and 44 males). Additionally, Czartoryski et al. (2020) found that the InBody 270 produced comparable body composition values to the DXA, and it is an acceptable and affordable alternative when compared to the DXA, measure of body composition. In support of the InBody 270, the InBody 720 has some similar measurement results. Bailey et al. (2018) found the InBody 720 to be reliable when measuring adipose tissue; however, the InBody 720 significantly underestimated BF% when compared to other measurement methods, such as the GE iDXA and BOD POD. Furthermore, Anderson et al.

(2012) found that the InBody 720 is a valid estimator of LBM, fat mass, and trunk lean mass in both men and women, while appendicular lean mass was valid in women only.

In conclusion, both the InBody 270 and InBody 720 tend to underestimate BF%, while only the InBody 270 seems to underpredict fat mass and overpredict fat-free mass (Garcia et al., 2020; Bailey, 2018). Furthermore, the InBody 270 produces results comparable to the DEXA, which is considered the gold standard for measuring body composition (Czartoryski et al., 2020; Garcia et al., 2020). Overall, research suggests the InBody 270 is an acceptable, valid, and reliable method of measuring body composition (Larsen, 2021; Czartoryski, et al., 2020).

In conclusion, there is insufficient information and mixed findings within the literature; thus, further research is needed. This literature review shows the need for further research regarding if there are relationships between anthropometric measurements and muscular endurance and aerobic fitness in ROTC cadets. In addition, this study holds a large sample size, while similar studies have exceptionally smaller populations. Overall, the literature review provided this study exceptional background information to grasp trends and to begin the study.

CHAPTER III

METHODOLOGY

Experimental Approach

Retrospective data related to anthropometric and fitness variables for one university ROTC training program were provided to the researchers to conduct this analysis. A Pearson's moment correlation was used to determine the relationships between body composition and fitness test performance among male and female ROTC cadets. The dependent variables for this study included number of repetitions in the push-up test; number of repetitions in the sit-up test; and the 2-mile run time. The independent variables included height, body mass, LBM, body fat, and BF%.

Participants

Participants included 74 Army ROTC cadets from a Midwestern university that participated in a battalion event held by the university. Of the 74 participants, 57 were male (mean ± SD: height: 180.36 ± 7.29 centimeters [cm]; body mass: 76.81 ± 9.81 kilograms [kg]; LBM: 62.62 ± 9.20 kg; body fat: 14.20 ± 5.69 kg; BF%: 18.43% ± 6.52%) and 17 were female (mean ± SD: height: 164.81 ± 4.73 cm; body mass: 66.56 ± 13.77 kg; LBM 49.68 ± 10.83 kg; body fat: 16.89 ± 6.38 kg; BF%: 25.22% ± 6.96%).

Procedures

Data was collected by a senior ROTC cadre in support to a Midwestern university's program using procedures outlined by the US Army for conducting the APFT (Appendix A Army Physical Fitness Test (APFT), 2012). Data collection for the push-up and sit-up tests were conducted at an outdoor football training facility on university grounds. The 2-mile run test was conducted outdoors on university grounds as a predetermined course to be run as fast as possible. The push-up, sit-up, and 2-mile run assessments each followed the standard APFT protocol.

2 Min. Push-Up Test

Upper-body muscular endurance was assessed through a maximal push-up test with the objective to complete as many push-ups as possible in 120 seconds. Participants started in the front-leaning rest position, which is defined as keeping the feet together or up to 12 inches apart while maintaining a "straight line" body position from the shoulders to ankles. One full repetition was defined as lowering the body until the arms were at least parallel to the ground, then fully extending the arms to the starting position. Repetitions were not counted if participants lifted their hand or foot off the ground, rested on the ground, or their technique significantly deviated from the protocol described. Participants were allowed to rest in the front-learning rest position (i.e., an isometric plank with arms fully extended). This test was terminated when participants reached volitional fatigue, proper technique was unable to be maintained, or the 2-minute time limit was achieved.

2 Min. Sit-Up Test

Both abdominal and hip-flexor muscular endurance was assessed through a maximal sit-up test with the objective to complete as many sit-ups as possible in 120 seconds. Participants started in the down position by lying flat on their backs with knees bent at a 90-degree angle. Feet were allowed to be together or up to 12 inches apart, while another individual held the participants' ankles using only their hands. Participants were instructed to keep their heels flat on the ground, and fingers interlocked behind their hands with their hands touching the ground for the starting position. A full repetition sit-up was counted by reaching the upper body to or beyond the vertical position, which is defined as the base of the neck reached above the base of the spine. After reaching the correct vertical position, participants lowered their upper bodies to the ground until their shoulder blades touched the ground. Repetitions were not counted if the vertical position was not reached, fingers were not interlocked, glutes came off the ground, excessive trunk movement (i.e., arched or concaved) occurred, or the knees exceeded the set 90-degree angle position. Participants were allowed to rest in the up position only. This test was terminated when participants reached volitional fatigue, proper technique was unable to be maintained, or the 2-minute time limit was achieved.

2-mile run (2MR)

Aerobic capacity and leg muscle endurance were assessed in the 2MR test. Participants were instructed to run the predetermined 1-lap, outdoor course as fast as possible. The 2MR time was recorded for each individual using a handheld stopwatch held by a trained professional from the ROTC cadre.

Anthropometrics

Height, body mass, and BF% were measured and collected by a senior ROTC cadre one week after performing the APFT using an InBody 270 device and portable stadiometer. Using this data, BMI was calculated using the Quetelet's equation, which is weight(kg)/height (m^2) (Salkind, 2010). Lean body mass percentage (LM%) was also calculated by subtracting BF% from 100 (i.e., LM% = 100 – BF%). Allometric scaling was used because it has been shown to reduce body mass bias in physical fitness tests. For allometric scaling values, the push-up and sit-up test scores were multiplied by body mass$^{1/3}$ and the 2MR time was multiplied by body mass$^{-1/3}$(kg) (Hendrickson, 2009).

Statistical Analysis

A Pearson's moment correlation was performed to determine the relationships between body composition and measures of muscular endurance and aerobic fitness and was separated by sex among ROTC cadets. In addition, a MANOVA model was used to determine the descriptive statistics among ROTC cadets in both sexes. The level of significance was set at $p < 0.05$ for all the statistical analyses. The correlation coefficient strength described as per Hopkins included an 'r' value between 0 to 0.30, or 0 to -0.30, was considered low; 0.31 to 0.49, or -0.31 to -0.49, moderate; 0.50 to 0.69, or -0.50 to-0.69, large; 0.70 to 0.89, or -0.70 to -0.89, very large; and 0.90 to 1, or -0.90 to -1, near-perfect or predicting relationships. All analyses were performed using IBM statistical package for the social sciences (SPSS) statistics (Version 24.0; IBM Corporation, New York, USA).

CHAPTER IV

RESULTS

Descriptive results for anthropometric measurements and fitness performance results for all male and female participants are presented in Table 1. In general, male cadets were taller, heavier, performed more push-ups and sit-ups, and were faster than female cadets.

Table 1. Descriptive data and fitness test results by sex in ROTC cadets

Measure	Female ROTC Cadets	Male ROTC Cadets
HT (cm) Female = 17 Male = 57	164.80 ± 4.93	180.36 ± 7.29
BM (kg) Female = 17 Male = 57	62.60 ± 7.30	76.81 ± 9.85
BF% Female = 17 Male = 57	25.30 ± 6.82%	18.43 ± 6.52%
BMI Female = 17 Male = 57	23.00 ± 2.23	23.53 ± 2.43
PU (reps) Female = 17 Male = 57	35.35 ± 13.05	57.90 ± 15.01
SU (reps) Female = 17 Male = 57	49.24 ± 16.60	59.72 ± 14.49
2MR (sec) Female = 14 Male = 57	1950.07 ± 207.89	1595.10 ± 240.09

Table 2. Descriptive data and fitness test results by sex in ROTC cadets

Measure	Sex Differences
HT (cm) Female = 17 Male = 57	0.001**
BM (kg) Female = 17 Male = 57	0.001**
BF% Female = 17 Male = 57	0.001**
BMI Female = 17 Male = 57	0.887
PU (reps) Female = 17 Male = 57	0.001*
SU (reps) Female = 17 Male = 57	0.037*
2MR (sec) Female = 14 Male = 57	0.001**

*= $p \leq 0.05$, **= $p \leq 0.01$

In Table 2, results for the one-way MANOVA are displayed. Statistically significant differences between height, body mass, BF%, PU, SU, and 2MR were discovered between males and females. On average, males were taller, larger, and performed better on the push-up, sit-up, and run time tests than females. No significant differences were seen between sexes for BMI.

In Table 3, the relationships between the measured anthropometric variables and fitness assessments for male ROTC cadets are displayed. Results of the Pearson's correlation revealed no significant relationships ($p > 0.05$) between any anthropometric measures and fitness performance among male cadets.

Table 3. Correlations between anthropometric variables and fitness assessments in male ROTC cadets

Variable		HT	BM	BF%	BMI
PU (reps)	Pearson's r	-0.195	-0.153	-0.081	-0.027
	p-value	0.147	0.257	0.551	0.842
SU (reps)	Pearson's r	-0.141	-0.148	-0.162	-0.047
	p-value	0.294	0.271	0.228	0.731
2MR (score)	Pearson's r	0.190	0.241	0.138	0.139
	p-value	0.157	0.071	0.306	0.304

*= $p \leq 0.05$, **= $p \leq 0.01$, ǂ= $p \leq 0.001$

Correlations between the measured anthropometric variables and fitness assessments for female ROTC cadets is shown in Table 4. Similar to the male cadets, no significant relationships ($p > 0.05$) were discovered between anthropometrics and fitness performance.

Table 4. Correlations between anthropometric variables and fitness assessments in female ROTC cadets

Variable		HT	BM	BF%	BMI
PU (reps)	Pearson's r	-0.021	-0.283	-0.053	-0.219
	p-value	0.418	0.271	0.840	0.399
SU (reps)	Pearson's r	-0.183	-0.213	0.116	-0.158
	p-value	0.482	0.412	0.659	0.546
2MR (time)	Pearson's r	-0.232	-0.097	0.057	0.279
	p-value	0.426	0.741	0.846	0.335

*= $p \leq 0.05$, **= $p \leq 0.01$, ǂ= $p \leq 0.001$

Based on these findings, the null hypothesis was accepted for the following: there was no significant correlations between: body composition and muscular endurance test performance among male ROTC cadets; body composition and 2MR time among male ROTC cadets; body mass and fitness performance among male ROTC cadets; LBM and fitness performance among male ROTC cadets; BMI and fitness performance among male ROTC cadets; BF% and fitness performance among male ROTC cadets; body composition and $V0_2$ among male ROTC cadets; body composition and muscular endurance test performance among female ROTC cadets; body composition and 2MR time among female ROTC cadets; body mass and fitness performance among female ROTC cadets; LBM and fitness performance among female ROTC cadets; BMI and fitness performance among female ROTC cadets; BF% and fitness performance among female ROTC cadets; and body composition and $V0_2$ among female ROTC cadets.

CHAPTER V

DISCUSSION

The purpose of this study was to determine if significant relationships exist between anthropometrics and measures of muscular and aerobic endurance among male and female ROTC cadets. While significant differences in performance were observed between sexes, no significant relationships were found between anthropometric measurements and physical fitness performance among male or female ROTC cadets. These findings suggest that body composition did not significantly affect muscular or aerobic endurance among the ROTC cadets in this study, while larger individuals with higher body mass and adiposity may experience a greater physiological burden when performing these tasks.

Previous research has shown significant ($p \leq 0.05$) relationships between BF% and BMI to measures of muscular endurance and aerobic fitness (Pierce et al., 2017). However, the results of this study showed no significant relationships between any anthropometric variables and measures of physical fitness in either female or male cadets. Previous research by Steed et al. (2016) found significant positive relationships ($r = 0.8$; $p = 0.001$) between BF% and 2MR time, and negative correlations ($r = -0.8$; $p = 0.001$) between BF% and PU repetitions performed. These results suggest that both larger and smaller cadets may still have satisfactory muscular endurance and aerobic performance despite anthropometric differences. However, it should be noted that 27.03% of cadets in this study were categorized as overweight or obese based on their BF% and body composition measurements. When considering BMI, 23% of cadets in this study were categorized as overweight or obese. These findings may have important health implications, as greater BF% and BMI have been linked to an increased risk of injury within military populations (Anderson et al., 2015). Based on these findings, it is important that ROTC cadets and soldiers strive to attain and maintain healthy levels of body composition to increase their overall health, well-being, and extend the occupational lifespan. Due to discrepancies between BMI and BF% measures, it is recommended that BF% be performed for a more precise classification of health status.

Sex and differences in fitness performance among ROTC cadets have been observed in several investigations, with males tending to outperform females on these tests (Roberts et al., 2021). Similarly, significant differences in fitness test performance by sex were observed in this investigation favoring male cadets on all measures. Robert et al. (2021) found that males outperformed females during each assessment of the ACFT, and significant differences were found between ACFT scores and sex ($P < 0.0001$), but not between APFT scores and sex. This may be likely because the scores were scaled by sex for the APFT. In females, only 9% passed the ACFT and 91% passed the APFT. Additionally, Steed et al. (2016) reported male ROTC cadets performed better in both the push-up and run time assessments when compared to female cadets; however, sex and performance differences were not statistically measured due to a small female sample size ($n=2$). In addition, it is important to note the large sample size of this study when compared to smaller sample sizes such as in Steed et al.'s (2016) research. Based on previous research, males tend to have better fitness performance in tests, such as the PU and 2MR tests, than females (Robert et al., 2021; Steed et al., 2016). Physiologically, Dada et al. (2017) report this may be due to lung and oxygen-carrying capacity, sex differences that result in slower female run time compared to males. Females also tend to have less absolute upper body strength in comparison to males, which may partially explain the lower scores observed in the PU when compared to males (Dada et al., 2017). Additionally, Weiss (1983) found that men had higher absolute testosterone hormone level response when weight lifting compared to women. Furthermore, males were on average taller, heavier, and had lower body fat percentages compared to their female counterparts. This may provide males with a morphological advantage in relation to females when performing many occupational tasks (Dada et al., 2017). As such, training programs for female cadets should be aimed at reducing these sex related differences to narrow the gap in physical performance between the sexes.

This study is not without limitations. Nutrition, diet, and hydration status were not controlled for in this investigation; therefore, poor nutrition and hydration levels prior to the APFT or body composition measurement collection could have potentially impacted these results. Furthermore, there were limited physical metrics performed by the training staff. Future studies should include measures of strength, power, and flexibility in addition to measures of muscular and aerobic endurance. Additionally, a larger female sample size in future research could be beneficial in finding sex differences between body composition and fitness performance in ROTC cadets.

In conclusion, no relationships were found between the selected anthropometric variables and muscular fitness and aerobic endurance in either male or female ROTC cadets. Additionally, male cadets were taller, larger, and had better fitness performance compared to their female counterparts. These findings suggest that males may have a natural advantage in military fitness tests due to generally having more muscle mass, greater lung capacity, higher testosterone levels, and greater strength capabilities when compared to females. Thus, specialized training for female ROTC cadets may prove beneficial in improving female fitness performance to match male fitness test performance in ROTC cadets. Further research over specialized training for female ROTC cadets is needed to see the effect specific training programs may have on fitness performance in female cadets.

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