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Functional Motor Competence and Physical Military Readiness

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FUNCTIONAL MOTOR COMPETENCE AND PHYSICAL MILITARY READINESS

by

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DEDICATION

To the veterans, active duty personnel and future service members, thank you.

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ABSTRACT

Decreased physical fitness in military age recruiting populations is problematic for the development of physical military readiness (PMR) in soldiers and presents a threat to national security. Low fitness levels, demonstrated by increased Army fitness test failures, and national data of children and adolescents, may be an indicator of a foundational problem in the physical development of potential military recruits. An adequate foundation in FMC will serve as a barrier for achieving sufficient and sustained PMR in the U.S. Military. Associations between individual, raw APFT and ACFT tests demonstrated weak (r = .26) to strong (r = .87) relationships, while raw composite APFT and ACFT totals had a strong association (r = .82). ACFT scores revealed the need for female Cadets in particular to incorporate strength and power-based training into their regimen. The FMC composites, lower extremity explosiveness (e.g. vertical jump; r = .80) and object control and projection (e.g. throwing; r = .75) demonstrated the strongest relationships with raw composite ACFT scores.

Keywords: longitudinal training, fitness, recruitment, motor skills, performance

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LIST OF ABBREVIATIONS

ACFT .... Army Combat Fitness Test

APFT .... Army Physical Fitness Test

BCT .... Basic Combat Training

FMC .... Functional Motor Competence

FC .... Functional Coordination

JROTC .... Junior Reserve Officer Training Corp

LEE .... Lower Extremity Explosiveness

OCP .... Object Control Projection

PMR .... Physical Military Readiness

PT .... Physical Training

ROTC .... Reserve Officer Training Corp

CHAPTER 1

INTRODUCTION

Physical Military Readiness (PMR), defined as the ability to meet the physical demands of any combat or duty position, accomplish the mission, and continue to win (Headquarters Department of the Army, 2012). However, PMR is a critical problem for the United States Army as between 27% and 31% of Americans aged 17-24 are automatically disqualified from Army service because they are overweight (Boivin et al., 2016). Additionally, 47% of men and 59% of women fail their initial Army Physical Fitness Test (APFT) when they arrive at Basic Combat Training (BCT) (Mission Readiness, 2010). The APFT, which BCT trainees need to pass in order to graduate, consists of two minutes of maximum repetition push-ups, two minutes of maximum repetition sit ups and a two-mile run for time (Headquarters Department of the Army, 2012).

The pervasive PMR issue is, in part, due to the decline in physical fitness and activity across childhood and adolescence in the United States (CDC, 2011; Kann et al.,2017; National Physical Activity Alliance, 2018). Only 29% of high school-aged youth meet national guidelines for physical fitness and only 12% meet both muscular strength and cardiovascular standards (CDC, 2011; Kann et al., 2017). The decrease of physical fitness levels in youth in the United States is compounded by a corresponding trend in physical activity levels.

Only 24% of children aged 5 to 19-years of age are currently meeting the national guidelines for 60 minutes of moderate-vigorous physical activity per day (National Physical Activity Plan Alliance, 2018). The decline in physical fitness and general physical activity levels in youth is, to a degree, suggested to be a function of children's diminished development of motor competence across childhood (Brian et al., 2019; Hulteen et al., 2018; Robinson et al., 2015; Stodden et al., 2008).

Functional motor competence (FMC; i.e., coordination and control required to perform a wide range of motor skills; Stodden et al., 2008) is directly linked to aspects of multiple health-related fitness constructs such as muscular strength, power, and agility through similar neuromuscular demands required in the development of various locomotor and object control skills (Stodden et al., 2008; Stodden et al., 2014). For example, skillful performance on both the standing long jump or a maximal effort throw require significant neuromuscular coordination and control to produce a complex sequence of powerful, optimally-timed movements (Campbell et al., 2010; Enoka, 2015; Escamilla & Andrews, 2009; Maffiuletti et al., 2016). FMC development also indirectly promotes cardiovascular and muscular endurance based on the activities in which these skills are consistently performed and practiced (e.g. sports, games, play; Jaakkola et al., 2015; Lima, Pfeifer, Bugge, et al., 2017; Lima, Pfeifer, Larson, et al., 2017; Sacko, Brazendale, et al., 2019 ; Sacko, Nesbitt, et al., 2019 ; Stodden et al., 2008). Additionally, FMC is foundational for the development of positive trajectories of fitness (Cattuzzo et al., 2016; Utesch et al., 2019) and a healthy weight status (Cattuzzo et al., 2016; Lima, Pfeifer, Larsen et al., 2017).

The lack of FMC developed in childhood and adolescence (Brian et al., 2019; Jaakkola et al., 2015; Lima, Pfeifer, Bugge et al., 2017; Lima, Pfeifer, Larson et al., 2017) may contribute to decreased fitness and an unhealthy weight status in early adulthood (Stodden et al., 2009, Stodden et al., 2013). Overall, FMC skill development improves volitional muscle recruitment and inter- and intra-muscular coordination and control (Cattuzzo et al., 2016; Stodden & Brooks, 2013; Stodden et al., 2014) that is foundational for adult-based human performance training such as hex bar deadlifts and medicine ball throws and military specific tasks like lifting and carrying heavy loads or running an obstacle course. Failure to develop competence in FMC in childhood and adolescence is detrimental to the development of strength, power, agility and muscular and cardiorespiratory endurance, which impacts future PMR.

Additionally, if these physical constructs are not developed by the time a solider reaches active duty, they might not be exposed to FMC related movements due to the APFT only assessing muscular (push-ups, sit-ups) and cardiovascular endurance (two-mile run). Due to the limited scope of the APFT, U.S. Army physical training has focused on mainly cardiorespiratory and muscular endurance (Ricks, 2015) at the expense of holistic PMR; including strength, explosive power and agility. However, since the APFT was created in 1980, the U.S. Army has found itself fighting wars in urban centers (Gentile et al., 2017) which requires high intensity sprints and agility-based movements in order to navigate from room to room, which demands a high level of anaerobic endurance, defined as the ability to repeatedly perform high intensity, low duration activities (Clemente-Suárez & Robles-Pérez, 2013a; Clemente-Suárez & Robles-Pérez, 2013b).

Additionally, in the time since the initial implementation of the APFT, soldiers have had to carry heavier and heavier loads (Fish & Scharre, 2018). From World War I until 2001 the average weight soldiers carried was around 80lbs (Fish & Scharre, 2018). However as of 2017, U.S Army soldiers routinely carried loads between 96 to 140 pounds, with an average of 119 pounds (United States Government Accountability Office, 2017). The issue of increased weight being carried by soldiers is compounded when they have to fight in an urban environment that requires fast agile movements while being burdened with greater than 100lbs of gear.

Due to the changes in the physical requirements of modern combat; that the APFT was not holistic in its scope of assessment and the PMR issues of training to pass the APFT, the U.S. Army created the Army Combat Fitness Test (ACFT). The ACFT was developed to better reflect the physical demands of modern combat, which includes many of the same neuromuscular demands inherent in advanced FMC performance (Lima, Pfeifer, Bugge et al., 2017; Lima, Pfeifer, Larson et al., 2017). The ACFT includes measures of muscular strength, defined as "the ability of a muscle to exert a maximal force through a given range of motion or at a single given point" (Nindl et al., 2015 p. 217), with the leg tuck and three repetition maximum deadlift. In addition to assessing strength, the ACFT includes a measure of explosive power with the standing medicine ball throw, defined as "the amount of force a muscle can exert as quickly as possible" (Nindl et al., 2015 p. 217). The sprint drag carry event of the ACFT assesses agility and anaerobic endurance, defined as "the ability to rapidly and accurately change the direction of the whole body in space" (Nindl et al., 2015 p. 217) and the ability to repeatedly perform high intensity movement for short durations, respectively (Clemente-Suárez & Robles-Pérez, 2013a; Clemente-Suárez & Robles-Pérez, 2013b). Strength, power, agility and anerobic endurance are not directly measured in the APFT (Nindl et al., 2015).

However, the ACFT, like the APFT, does include a measure of muscular endurance with the hand release push-ups, defined as “the capacity of a muscle to repeatedly exert a submaximal force through a given range of motion or at a single point over a given time” (Nindl et al., 2015 p. 217). Both tests also assess cardiorespiratory endurance, defined as “the ability of the cardiovascular system to continue training for extended periods of time,” with a two-mile run (Nindl et al., 2015 p. 217). It is important to note the differences in scoring systems between the APFT and ACFT as well. The APFT uses a scoring matrix that takes into account a soldier’s sex and age, meaning women and older service members standards are lower than that of men being tested. However, the ACFT has done away with the sex and age matrix by instead requiring soldiers to score at a certain level that corresponds to their military occupation. For example, soldiers in the infantry have to score higher than those in cyber security positions, regardless of age and sex.

The U.S. Army has spent a considerable amount of time and money in developing a new fitness test with the hope it will be the catalyst in promoting holistic fitness within the service (Headquarters US Army Center for Initial Military Training, 2019). However, because the ACFT has not yet been implemented fully within the U.S. Army, there is a gap in understanding how the APFT and ACFT relate to each other as well as what the overall failure rates are.

Additionally, due to the inclusion of new measures and physical components being tested, it is crucial to examine the scoring differences between sex. For example, the leg tuck in the ACFT requires upper body and trunk strength similar to that of a pull up; however when the APFT was created pull ups were excluded due to research at the time showing few women could perform the movement (Knapik & East, 2014). Lastly, since the ACFT is purported to be an accurate measure of the PMR components required to perform on the modern battlefield, investigating the relationships between the ACFT and FMC can potentially shed light on FMC levels required to serve in the U.S. Army. Therefore, this dissertation will serve to inform those responsible for PMR training of the physical components that should be emphasized during training for men and women to be successful on the ACFT. Additionally, by investigating the link between the ACFT and FMC, we can potentially add a developmentally appropriate movement skill component to PMR training and measurement.

Purpose

Study 1

The purpose of Study 1 was to explore U.S. Army PMR test scores within a convenience sample of U.S. Army Reserve Officer Training Corp (ROTC) Cadets and to examine potential differences in scores by sex on both the APFT and ACFT as well as determining possible differences in failure rates. ROTC Cadets were recruited for this dissertation for three reasons, first they are affiliated with the U.S. Army and are required to perform and pass the APFT and ACFT according to U.S. Army standards.

Second, in addition to having to perform the U.S. Army PMR tests, ROTC Cadets take part in rigorous field training exercises similar to those at basic combat training (BCT) as well as other soldering tasks. Third, ROTC Cadets are an accessible population; it would not have been feasible to gain access to test a BCT company in the U.S. Army. A descriptive-analytic cross-sectional design that used a convenience sample examined the relationships between the APFT and the ACFT. The findings from this study were used to report the scoring differences between sex and provided the ACFT data needed for Study 2.

Study 2

The purpose of Study 2 was to examine associations between FMC and ACFT scores within a convenience sample of enlistment age, U.S. Army affiliated adults. A descriptive-analytic cross-sectional design was used to examine the relationships between the ACFT and FMC using individual and composite measures of FMC and ACFT performance scores.

Significance and Innovation

Significance

This dissertation is significant as it demonstrates the potential impact that transitioning to the ACFT will have due to the difference in scores and failure rates between sex especially because of the inclusion of new physical components. As stated above, when the APFT was created, pull ups were removed from the test as research at the time showed few females could perform a single repetition (Knapik & East, 2014). However, the leg tuck in the ACFT requires a similar level of strength and mobility as the pull up, which could cause female test failures to increase. Therefore, the results from this dissertation can help identify the physical constructs that should be focused on during PMR training for women and men. Additionally, since the ACFT is purported to be an accurate measure of the PMR components required to perform on the modern battlefield, by investigating the relationships between the ACFT and FMC we can potentially shed light on FMC levels required to serve in the U.S. Army. Thus, this dissertation has the potential to significantly impact how the Army addresses not only current physical training, but also in how they organize future force PMR initiatives.

Innovation

This dissertation will be the first to examine the relationships between the APFT and ACFT as well as a comprehensive, multidimensional (i.e., object control, lower extremity explosiveness and functional coordination) FMC battery and PMR, assessed by the ACFT. Thus, we are proposing the development of a foundation of functional motor competence (FMC) will be a critical antecedent mechanism that will significantly impact recruitment and retention of in the U.S. Army.

CHAPTER 2

LITERATURE REVIEW

Brief History of the Reserve Officer Training Corp (ROTC)

The ROTC that exists now traces its origins back to 1819 when what is now Norwich University was founded with the goal of providing more officers for the military outside of the United States Military Academy (West Point) in a university setting (Masland & Lyons, 1959). The notion of creating more officers was again further promoted in 1839 and later in 1842 when the Virginia Military Institute and The Citadel were founded respectively (Masland & Lyons, 1959). However, during the Civil War (1861-1865) period both the North and the South continually found their respective armies commanded by non-professionals, meaning these armies were being led by personnel who had no formal training in leadership and military tactics due to the military colleges and service academies not being able to produce enough officers. (Masland & Lyons, 1959). The North especially dealt with a lack of trained military leadership during the Civil War, and because of that the Land-Grant Act of 1862, included provisions for military instruction to be included at the colleges and universities that were founded under the terms of the act (Masland & Lyons, 1959). In supplementary acts to the original Land-Grant Act, Congress authorized what was then the War Department to detail regular Army officers to colleges and universities, thus setting up the foundation for modern ROTC (Masland & Lyons, 1959).

In 1916, when World War I was beginning to ramp up for the United States, the National Defense Act was passed, which amongst other things took into account the issue seen the Civil War of not having enough qualified officers (Masland & Lyons, 1959). The National Defense Act would fully establish ROTC programs, with the goal of providing a standard course of military instruction as opposed to increasing the sizes of the established military academies (Masland & Lyons, 1959).

As of 2020, there are more than 1,700 non-military college and university ROTC programs available in the United States, making ROTC the largest commissioning source of officers, among all branches of the military (Today's Military, 2020). Essentially, ROTC is a college program that prepares young adults to become commissioned officers in the U.S. Military. For Cadets who accept a paid college scholarship from one of the service branches ROTC programs, they commit to serve in their respective service after graduation with each branch having its own program (Today's Military, 2020). The other sources of commissioned officers are the military colleges which fall into two main categories: service academies (requiring military service upon graduation) and senior military colleges (4-year institution). The U.S. service academies consist of the U.S. Military Academy, Naval Academy, Air Force Academy, Coast Guard Academy, and Merchant Marine Academy. Individuals that attend senior military colleges such as Texas A&M University Corps of Cadets, Norwich University, Virginia Military Institute, The Citadel, Virginia Polytechnic Institute and State University, and the University of North Georgia must participate in their institutions programs, however they are not obligated to serve in their respective service after graduation unless their education was paid through a scholarship (Today's Military, 2020).

In addition to completing the academic requirements associated with their institutions, students enrolled in ROTC programs are given the opportunity to develop leadership skills, basic concepts of military science, and a strong sense of honor, and responsibility helping them become effective and successful officers in the military. Due to their military affiliation and requirements, ROTC Cadets take part in service-related training exercises and have to perform, and pass, a physical fitness test that is either identical to or similar in nature to their respective branches. Thus, making ROTC programs an optimal setting for investigating the PMR testing and training related to what Cadets will have to perform once they graduate and commission.

2.1 History of U.S. Army Physical Testing and Training

Initial PMR Testing and Training Efforts

While the U.S. Army was in its infancy in the early 1800's, physical training (PT) consisted of unorganized marching drills focused on ceremony and having to perform military duties like hard manual labor (East, 2012). It wouldn't be until the mid 1850's that PT started to become organized, which also included the first known PMR test in 1858, that included a 2-mile run, which still present in the APFT and ACFT (East, 2012). However both PT training and testing were limited in its use to the United States Military Academy and did not see service wide implementation. In 1892 the U.S. Army distributed its first service wide PT training manual titled; *A Manual of Calisthenic Exercises* (Knapik & East, 2014). This manual focused on basic body weight movements that as noted should be performed vigorously and with variability, but in a safe manor where every exercise is explained and demonstrated properly (Koehler, 1892).

The manual also mentions that these movements should form the foundation of physical training and should be performed in a developmentally appropriate fashion so that soldiers have a training base and then progress to more intense and military specific physical training (Koehler, 1892).

Calisthenics, Sports and Specific Testing, World War I to World War II

At the start of World War I (1914), the basis of U.S. Army PT remained rooted in calisthenics and gymnastics. However, this all changed when Dr. Raycroft, a physical education professor, supplemented traditional PT with boxing, football, track and field and basketball (East, 2012). The implementation of sports into PT was a novel approach as it introduced the benefits of the motor skills required to play sports, which improves Functional Motor Competence (FMC, ability to perform wide range of motor skills), to hundreds of thousands of young men (East, 2012). During this period, U.S. Army commanders began to assess military specific functional fitness tests such as rucking (loaded pack marching) long distances or riding horses at a certain speed for a given distance, both of which were extremely transferable to soldiering tasks during the time period (Knapik & East, 2014).

During the World War II period (1939-1945), PMR continued to incorporate motor skills including PMR testing which measured a baseball throw, vertical jump, standing broad jump, and a running hop amongst other measures. Variations of these tasks are still used to test FMC today (East, 2012; Stodden et al., 2012; Stodden et al., 2014). Additionally, the U.S. Army distributed the FM 21-20 PT manual, which included two important principles: balance and progression (East, 2012).

Balance meant including as many basic soldering tasks as possible, which would be considered operationally specific training in a strength and conditioning context (Llyod et al., 2016). Progression, referred to gradually increasing PT intensity so that the soldier's physical development improves over time, which in contemporary strength and conditioning terms, speaks to periodization and long-term athletic development (Bompa & Haff, 2009; Llyod et al., 2016). The PMR concepts implemented during this time period focused on more holistic physical development that included the promotion of motor skills; however, U.S. PMR doctrine began to shift towards the end of the 20th century.

Health Related Fitness and the APFT

The most dramatic shift in U.S. Army PMR came after the Vietnam War (1975) when PT changed focus from more combat readiness specific training to general health-related fitness (e.g., cardiorespiratory and muscular endurance). The focus on health-related fitness included new PMR testing and the formation of the current day Army Physical Fitness Test (APFT). The rationale behind developing the APFT was multifaceted and was focused on three key points. First was the requirement that the APFT require minimal equipment and set up, which essentially limited its range of assessment from inception (East, 2012). Second, it was created when the U.S. Army was shifting away from combat readiness to health-related fitness outcomes which focused on cardiorespiratory health and fitness. Third, at the time, females were serving in the Women's Army Corp and were not integrated with their male counterparts as part of the U.S. Army as we know it today. However, in 1978 the Women's Army Corp was disbanded, and the U.S. Army became gender integrated (East, 2012).

The gender integration of the U.S. Army shaped the APFT because pull-ups were being considered for inclusion in the test. However, research at the time showed that very few women could perform a single pull-up thus it was removed from the test (Knapik & East, 2014). Overall, the current APFT lacks any FMC or military specific assessments and consists of two minutes of maximum repetitions of push-ups, two minutes of maximum repetitions of sit-ups and a two-mile run for time. Additionally, the APFT is scored according to an age and sex matrix. Thus, women and older service members do not have the same physical requirements, even though hypothetically, they could be in the same unit performing similar roles.

Changing Combat and the Introduction of the ACFT

The APFT and the emphasis on health-related fitness had a detrimental effect on the U.S. Army's PMR culture due to soldiers training for the test (Ricks, 2015), which as stated did not relate to combat readiness. Performing PT to improve APFT scores became problematic as the U.S. Army has had to increasingly engage in urban combat such as in Iraq (Gentile et al., 2017). This type of fighting is characterized by high intensity sprints and functional-based movements in order to, for example, sprint to a door, breach the door then clear the target building. These types of actions demand a high level of anaerobic endurance (the ability to repeatedly perform high intensity, short duration movements) as well as strength, agility and power (Clemente-Suárez & Robles-Pérez, 2013a; Clemente-Suárez & Robles-Pérez, 2013b; Nindl et al., 2015). Additionally, since the APFT's inception, soldiers have had to carry heavier and heavier loads during their missions (Fish & Scharre, 2018).

As of 2017, U.S. Army soldiers carried an average of 119 pounds during combat operations (United States Government Accountability Office, 2017). The issue of increased weight being carried is compounded when soldiers are having to fight in an urban environment that requires dynamic functional movement in order to complete the mission successfully. Thus, if soldiers are neglecting strength, anerobic endurance, functional movement, agility and power in their physical training, they are not holistically preparing for the modern battlefield (Nindl et al., 2015).

Due the changes in combat conditions, weight being carried and the need to implement more holistic PT, U.S. Army commanders realized that the APFT was no longer an adequate measurement of PMR. Therefore, the U.S. Army began developing a new fitness test (Army Combat Fitness Test – ACFT) which had the following goals to improve overall PMR of the force: 1. improve soldier and unit readiness, 2. transform the Army's fitness culture, 3. reduce preventable injuries and attrition, 4. enhance mental toughness and stamina (Headquarters US Army Center for Initial Military Training, 2019). The ACFT has been initially tested in the U.S. Army and is set to become the fitness test of record in 2021.

The ACFT directly measures explosive power (standing power throw), functional movement (leg tuck, sprint drag carry) and agility and anerobic endurance (sprint drag carry), strength (hex bar deadlift, leg tuck), muscular endurance (hand release push-ups) and cardiorespiratory endurance (2 mile run for time) (Headquarters US Army Center for Initial Military Training, 2019). By testing soldiers on physical components like strength, power, agility and functional movement, they will have to perform PT that improves these characteristics.

Therefore, where ‘training to the test’, as in performing PT geared just for success on APFT (cardiorespiratory and muscular endurance) was detrimental for overall PMR for modern combat, training based on underlying ACFT requirements will produce a much more holistic PMR outcome. Another PMR issue that the ACFT needed to address was the inclusion of women for combat operational roles, which was not the case in the 1980’s. The ACFT requires both males and females to score at the same minimum level based upon their military occupational specialty. (Headquarters US Army Center for Initial Military Training, 2019). Instead of an age and sex matrix, the ACFT has 3 scoring levels (heavy/black, significant/silver, moderate/gold) that correspond with standards that need to be met for a specific military occupational specialty. For example, infantry soldiers, regardless of age and sex, need to score at the highest category (heavy/ black level), whereas soldiers performing human resources duties can score in the lowest category (moderate/ gold level) (Headquarters US Army Center for Initial Military Training, 2019).

While U.S. Army PMR testing has significantly evolved based on the creation of the ACFT, the official PT doctrine has not seen a major update since 2010 (Knapik & East, 2014). Currently, PT doctrine is based on simplifying the components of PMR into three different categories: strength, endurance and mobility (Headquarters Department of the Army, 2012). Endurance refers to cardiorespiratory endurance, while strength is a global term encompassing muscular strength, muscular endurance and power (Knapik et al., 2009). Mobility is an umbrella term including balance, flexibility, coordination, speed and agility (Knapik et al., 2009). Unfortunately, this training has not been systematically linked to ACFT testing.

Therefore, with strength, power, agility and functional movement receiving a renewed focus for training due to the ACFT, it is crucial to understand how to most effectively improve PMR. Thus, future research should investigate the ability of the current PT doctrine to improve performance on the ACFT.

2.2 Functional Motor Competence (FMC) and Physical Military Readiness

The links between FMC and PMR

The inclusion of functional movement, strength, power and agility in the ACFT speaks to the dramatic shift in PMR culture where combat readiness has become much more of a priority. Functional Motor Competence (FMC; i.e., neuromuscular coordination and control needed to perform a range of motor skills) is directly linked to the health-related fitness constructs now found in the ACFT (e.g., strength, power, agility, functional movement) through shared neuromuscular demands (Campbell et al., 2010; Enoka, 2015; Escamilla & Andrews, 2009; Maffiuletti et al., 2016; Stodden et al., 2008; Stodden et al., 2014).

For example, high level performance of the standing long jump requires significant neuromuscular coordination and control to produce a complex sequence of powerful, optimally-timed movements (Enoka, 2015; Maffiuletti et al., 2016). Many traditional FMC skills (e.g. jumping, hopping, skipping, leaping, throwing and striking) are classified as plyometric movements (Brooks & Stodden, 2012) in a sport performance context. Therefore, development in advanced bilateral (e.g., standing long jump and vertical jump) and unilateral (hopping, skipping, leaping) FMC/plyometric movements promote adaptations in motor unit recruitment and rate of force development similar to not only traditional explosive power exercises (i.e. standing power throw) but also muscular strength exercises (i.e. hex bar deadlift) (Escamilla & Andrews, 2009; Johnson et al., 2011; Zehr & Sale, 1994). Therefore, the development of competence in many different movement skills across childhood and adolescence is an antecedent to adult-based human performance training such as advanced plyometrics and military specific tasks like completing an obstacle course. Cardiovascular and muscular endurance also are indirectly promoted via FMC development, through the activities in which these skills are consistently performed and practiced (e.g. sports, games, play; Jaakkola et al., 2015; Lima, Pfeifer, Bugge et al., 2017; Lima, Pfeifer, Larson et al., 2017; Sacko, Brazendale, et al., 2019; Sacko, Nesbitt, et al., 2019; Stodden et al., 2008). Overall, failure to develop competence in FMC in childhood and adolescence is detrimental to the development of strength, power, and agility which impacts future physical military readiness (Cattuzzo et al., 2016; Stodden & Brooks, 2013; Stodden et al., 2009; Stodden et al., 2013 Stodden et al., 2014).

FMC training either directly or indirectly promotes the development of strength, power (Escamilla, 2009; Johnson et al., 2011; Zehr & Sale, 1994), agility (Stodden et al., 2008; Stodden et al., 2014), muscular endurance, and cardiovascular fitness (Jaakkola et al., 2015; Lima, Pfeifer, Bugge, et al., 2017; Lima, Pfeifer, Larson, et al., 2017; Sacko, Brazendale, et al., 2019 ; Sacko, Nesbitt, et al., 2019) all of which are physical components assessed by the new Army Combat Fitness Test (ACFT). The need for the underlying physical requirements that are linked to successful ACFT performance have always been crucial to PMR, however they have been deemphasized in physical training because the long-standing Army Physical Fitness Test (APFT) fails to adequately assess strength, power, agility (Nindl et al., 2015).

In contrast, the specific ACFT assessments provide greater focus on strength, power, functional movement, and agility. Overall, the majority of ACFT assessments inherently require a higher degree of dynamic multi-joint coordination and control (i.e., FMC) as compared to the APFT.

FMC and Injury Identification and Prevention

In addition to improving the critical physical components of the ACFT, FMC development has the potential to mitigate injury risk. The level of FMC needed to safely perform many of the different types of movements that comprise aspects of human performance and sport indicate FMC may be an underutilized predictor of injury (Cook et al., 2010; Runge Larsen et al., 2016; Pfeifer, Stodden & Moore, 2016; Pfeifer et al., 2019). For example, injury rates of approximately 25% of male and 50% of female recruits have been reported during Basic Combat Training (BCT) suggesting that they are not physically prepared for the rigors of BCT training (Molloy, Feltwell, Scott, & Niebuhr, 2012). BCT requires recruits to run & ruck march, do calisthenics, navigate obstacle and rope courses and perform soldiering tasks all of which are dynamic movements often requiring significant neuromuscular control and proper force absorption to prevent injury. FMC could potentially be supplemented with other movement and injury screens to create a more holistic potential injury assessment. Various locomotor skills (e.g., jumping, hopping, running and leaping) produce ground reaction forces on the order of 1.5-5.4 times an individual's body weight (Anliker et al., 2012; MacWilliams et al., 1998; Veilleux & Rauch, 2010).

Therefore, if a solider has developed a high level of performance in different locomotor tasks (e.g., a standing long jump, vertical jump, hopping, sprinting, etc.) they possess the ability to coordinate and control their neuromuscular system in an optimal fashion to produce a powerful movement that will also require them to absorb significant ground contact forces, like sprinting to a wall, jumping over it and safely dropping to the other side. FMC development may also mitigate injury risk as it promotes dynamic joint stability, and the balance to effectively react to perturbations (e.g., slips, falls, altered balance) (Stodden & Brooks, 2013). Thus, by assessing FMC based skills might provide better insight into potential injury risk and movement compensations for individuals whose sport, or job require more dynamic and explosive movement.

Improving FMC also increases bone density complexity and variability of sporting movements promotes multidirectional structural loading that includes compression, shear, bending, and torsional forces in multiple planes and axes that can enhance the development of cortical bone density and thickness (Fuchs, 2001). Thus, reducing the risk of stress fractures (Beck et al., 2000; Cosman et al., 2013), which are some of the most common injuries seen in the military, especially in young and inexperienced soldiers is important to the military (Cosman et al., 2013). The complexity and variability of sporting movements promotes multidirectional structural loading that includes compression, shear, bending, and torsional forces in multiple planes and axes that can enhance the development of cortical bone density and thickness (Fuchs et al., 2001). However, failing to promote FMC throughout childhood and adolescence could increase injury risk PMR training or during sports participation, which have similar neuromuscular demands.

The U.S. military has a long history of promoting sports programs as a way to improve health, fitness and the teamwork within units. This type of supplemental training was a specific focus of physical training during the early 1900's (Hipps, 2013; Wakefield, 1997). However, from 1993 and 2002 basketball injuries ranked second as the cause for active duty Air Force personnel missing work (Burnham et al., 2010). Coincidently, the same study noted injuries related to "slips and falls" ranked third as a cause for lost workplace time, which also speaks to the importance of an adequate foundation of FMC attributes such as dynamic joint stability, balance, and the ability to effectively react to perturbations (Burnham et al., 2010). Thus, although promoting sports participation may be an effective supplement for training for multiple reasons, not having an adequate foundation of FMC may simply exacerbate the potential for injury in soldiers.

The role of FMC in Longitudinal PMR

FMC could potentially help identify individual's level of physical readiness to enter the military and the inherent physical demands of training. However, the United States is experiencing a decline in health- related fitness and physical activity culminating in only 29% of high school-aged youth meeting guidelines for physical fitness and only 12% meeting both muscular strength and cardiovascular standards (CDC, 2011; Kann et al., 2017). The deterioration of physical fitness levels in youth in the United States is compounded by a nearly identical trend in physical activity levels as only 24% of children aged 5 to 19-years are currently meeting the national guidelines for 60 minutes of health-enhancing moderate-vigorous physical activity per day (National Physical Activity Plan Alliance, 2018).

This decline in fitness and general physical activity is, in part, due to children's diminished development of FMC (Brian et al., 2019; Hulteen et al., 2018; Robinson et al., 2015; Stodden et al., 2008). Low levels of FMC throughout childhood and adolescence contribute to negative trajectories of fitness (Cattuzzo et al., 2016; Utesch et al., 2019) and a healthy weight status (Cattuzzo et al., 2016, Lima, Pfeifer, Bugge et al., 2017; Lima, Pfeifer, Larson et al., 2017) which could track into early adulthood (Stodden et al., 2009; Stodden et al., 2013).

Thus, by promoting a foundation of FMC prior to enlisting in the military, we could potentially uncover a fundamental missing link to PMR that has not been effectively addressed in both past and current military training methods. Incorporating FMC is necessary, not only for establishing a foundation of physical fitness, physical activity, and healthy weight status levels in children and adolescents, but also to develop and sustain PMR for future generations of military personnel and current active duty military. However, developing a foundation of these skills takes years to elicit (Clark & Metcalfe, 2002; Langer, 1969). The development of coordination and control across multiple skills occurs in an invariant order, meaning skilled performance requires practice and experiences that will create movement pattern solidification in multiple steps (Clark & Metcalfe, 2002; Stodden et al., 2008) For example, development of multi-joint, explosive movements (e.g., vertical jump, standing long jump, throwing) requires the ability to not only perform active concentric and eccentric muscle actions, but also the capability to exploit neuromuscular mechanisms through passive inertial loading that significantly alters coordination patterns and resultant movements (Bernstein, 1967).

The length of time needed for the development of sufficient levels of FMC is critical because potential recruits who lack an adequate foundation of FMC cannot build a movement repertoire within the limited time of BCT (i.e., 12 weeks), or even in one year. For example, by the time individuals reach the age to enroll in JROTC (i.e., high school), or even Senior ROTC, it is often assumed that they possess adequate levels of FMC to participate in military specific training like rucking and obstacle course navigation. Unfortunately, that is not the case as many of America's young adults (Stodden et al., 2009, Stodden et al., 2013) lack an adequate foundation of FMC. There is a general bias that development of FMC occurs "naturally," not understanding the amount of instruction, practice, and experiences in specific movement development and sports and games that demand effective integration of multiple skills (Stodden et al., 2008).

Therefore, it is critical to promote developmentally appropriate FMC based training prior to introducing more advanced strength and conditioning training (e.g., high level plyometric training & Olympic lifting) and to reduce potential injury (Hoffman, 2011). While the most appropriate time to develop this foundation of FMC is in childhood and adolescence, deficits in FMC can be addressed in Junior Reserve Officer Training Corps (JROTC) and ROTC populations before they commission into the military. When creating developmentally appropriate FMC and PMR programs it is critical to consider children's and adolescents' motivation to participate in physical training, which often does not mirror the motivations of adults (Lloyd et al., 2016; Stodden et al., 2013). At the start of a program, activities should provide a wide range of FMC movements to build coordination, control, and adaptability that require use of ballistic locomotor, stability, and object control skills, before focusing on technique specific drills and adult-based models of resistance training. Not only do these types of activities build a varied and complex movement skill repertoire, but they can provide motivating experiences which enhances various aspects of self-concept (Barnett et al., 2016). The FMC skill development process also allows for progressive increases in forces applied to the musculoskeletal system, as the individual's skill and effort levels increase (Stodden et al., 2013). Thus, through repeatedly performing a wide range of FMC skills in multiple practice and performance contexts, individuals are able to the benefits of improved strength, power, agility, muscular endurance and cardiovascular fitness (Lima, Pfeifer, Bugge et al., 2017; Stodden et al., 2008; Utesch et al., 2019). By integrating a progressive FMC-based PMR training philosophy across JROTC and ROTC, there is a greater potential to establish a strong foundation of PMR prior to commissioning into the military. Essentially, if a high school student enters JROTC and begins a developmentally appropriate FMC based PMR program which continues through their ROTC years, they could enter the U.S. Army with eight years of progressive PMR training. By participating in a longitudinal training plan, individuals might have greater operational capacity across their career due to entering the service with an adequate training base. Overall, as the transition in PMR assessment and training is currently being addressed in the U.S. Army, it is important to understand the potential impact that this transition will have on current and future PMR. Unfortunately, there is limited understanding of how previous assessment protocols and training regimens relate to the new assessment and physical training preparation of basic training recruits and ROTC Cadets.

Understanding these relationships will provide insight for the military on how this transition in testing and training may impact current and future generations of soldier's physical readiness.

The Purpose of This Research

The purpose of this dissertations was to explore U.S. Army PMR test scores within a convenience sample of U.S. Army ROTC Cadets and to examine potential differences in scores by sex on both the APFT and ACFT as well as determining possible differences in failure rates (Study 1). Additionally, this dissertation sought to provide an understanding of the relationship between FMC and ACFT (Study 2).

The research questions include:

RQ1a. What are the associations between APFT and ACFT performance scores?

RQ1b. What are the failure rates of the APFT and ACFT in an ROTC population?

RQ2a. What are the associations between individual and composite FMC tests (FMC measures grouped together based on movement type) and individual and composite ACFT scores?

RQ2b. Which composite of FMC measures will have the strongest relationships with individual and composite ACFT tests?

CHAPTER 3

STUDY 1: ASSOCIATIONS BETWEEN THE APFT AND ACFT

Introduction

Physical Military Readiness (PMR), defined as the ability to meet the physical demands of any combat or duty position, accomplish the mission, and continue to win (Headquarters Department of the Army, 1998), is a crucial component of a healthy, deployable, and lethal armed service. PMR testing in the U.S. Army has a long history with the first fitness test established in 1858 for the Cadets at the United States Military Academy. This test included climbing a 15-foot wall, leaping a 10-foot ditch, running two miles in 18 minutes, and walking three miles in one hour with a 20-pound pack, arms, and equipment amongst other assessments (Knapik & East, 2014). The assessments featured in this early PMR test included functional movements and military specific tasks with carry over to the battlefield thus having a focus on combat readiness. While PMR testing has evolved since 1858, reflecting the conflicts the U.S. Army was engaged in or the periods of peace, the biggest shift came in 1980. The U.S. Army overhauled its fitness test and established the Army Physical Fitness Test (APFT), which primarily focuses on muscular endurance (two minutes of maximum repetition push-ups and sit-ups and cardiorespiratory endurance (two-mile run) (Headquarters Department of the Army, 1998). The transition to this assessment protocol was based on three factors.

First, was the requirement that testing require minimal equipment and set up so it could be administered at any location. This first requirement essentially limited its range of assessments (East, 2012). Second, the APFT created when the U.S. Army was shifting away from combat readiness to health-related fitness outcomes (i.e., cardiorespiratory health and fitness) (East, 2012). Third, the Women's Army Corp was disbanded in 1978 as the U.S. Army became gender integrated (East, 2012). The shift away from combat specific readiness assessments in PMR testing (e.g. rucking, obstacle courses, rope climbing or pull- ups) also led to a transition away from combat readiness centered physical training. Essentially, the focus on cardiorespiratory and muscular endurance in the APFT led to training that directly promoted these physical components at the expense of strength, power, functional movement, and agility (Ricks, 2015).

Since the creation of the APFT, the U.S. Army has been involved in heavy urban combat in Somalia (1993) and more recently in Iraq (2003-present), with the focus of future military planning on fighting in massive urban centers. (Gentile et al., 2017). Urban fighting requires high intensity sprints and power and agility-based movements (e.g. pushing over an obstacle and jumping over a barrier) in order to navigate from room to room and between buildings which demands a high level of anaerobic endurance, the ability to repeatedly perform high intensity, low duration activities (Clemente-Suárez & Robles-Pérez, 2013a; Clemente-Suárez & Robles-Pérez, 2013b). Compounding the more frequent incidence of urban combat is the increase in weight soldiers have to carry during operations (Fish & Scharre, 2018). As of 2017, U.S Army soldiers routinely carry loads between 96 to 140lbs, with an average of 119lbs (United States Government Accountability Office, 2017).

Therefore, soldiers are fighting in an environment that requires fast and agile movement while being burdened with a substantial amount of weight. As the APFT does not directly measure power, agility, anaerobic endurance or maximum strength, it does not directly comprehensively measure physical constructs environments, the U.S. Army created a new PMR test (Army Combat Fitness Test - ACFT) that purportedly assesses the physical characteristics required for current combat demands. Another important influence that drove the development of a new PMR test is the inclusion of women in front line role within the Department of Defense, meaning that women are expected to physically perform to similar, if not the same, standards as their male counter parts.

The ACFT includes tests to directly assess a) explosive power (standing power throw), b) agility and anerobic endurance (sprint drag carry) c) strength (hex bar deadlift, leg tuck), as well as d) muscular endurance (hand release push-ups) and e) cardiorespiratory endurance (2 mile run for time) (Headquarters US Army Center for Initial Military Training, 2019) (see ACFT tests in Table 3.1.). To take into account the integration of women into combat roles, the ACFT (ACFT Initial Operation Capability 1 October 2019-30 September 2020) now requires both males and females to score certain levels based upon their military occupational specialty and is no longer based on their age or sex (Headquarters US Army Center for Initial Military Training, 2019). For example, soldiers in the infantry have to score higher on the ACFT than those in the communications units. As a consequence of the implementation of the ACFT, the U.S. Army also must attempt to change the culture of PMR training away from the APFT based training specificity (e.g., muscular and cardiorespiratory endurance) to a focus on the additional performance demands of the ACFT.

Unfortunately, PMR based on the current APFT requirements has been declining over the past decades demonstrated by 47% of men and 59% of women failing their initial APFT when they arrive at Basic Combat Training (Mission Readiness, 2010). The low levels of recruit PMR are then compounded by around 27% to 31% of young Americans who are ineligible to serve due to being overweight (Mission Readiness, 2010); thus, creating a national security concern of not having enough physically fit recruits.

With the U.S. Army actively attempting to change the PMR culture by implementing the ACFT, officers will play a crucial role in setting fitness standards and acting as role models for the soldiers under their command. Over 1,000 college, university and junior college Reserve Officer Training Corp (ROTC) serve as the largest commissioning source among all branches of the military (Lopez, 2016) and is a critical training ground for developing the knowledge and skills for promoting PMR. As of 2016, ROTC is responsible for nearly 70% of new lieutenants in the Army which equals out to around 5,300 new officers a year (Lopez, 2016). ROTC Cadets will have to perform the ACFT as the official PMR test by 2022, therefore, understanding and developing their PMR levels will help provide needed alterations to physical training prior to commissioning into the U.S. Army and help to ensure they will be able to set the physical standards for their assigned units.

With the transition from the APFT to the ACFT approaching, an understanding of how the tests relate is important as it may necessitate a change in U.S. Army PMR training culture. On face value, the two tests would seem to assess different aspects of PMR (e.g., strength, agility anaerobic endurance vs. muscular endurance), with the exception of aerobic endurance (2-mile run), which is in both tests.

In addition, the removal of sex-specific scoring in the ACFT is a major change in how the two tests are scored. Therefore, to better inform current and future generations of U.S. Army soldiers, the purposes of this study were to 1. examine associations between the Army APFT and ACFT including potential score differences between sexes and 2. examine failure rates of both tests, and the relationship sex has on failure rates, in a sample of adults that were of enlistment age and are representative of an U.S. Army affiliated sample.

Methods

Participants and Setting

Sixty-seven ROTC Army cadets (50 men, 17 women) completed all assessments. Women represented 25% of the sample, which is greater than the 15% of women in the U.S. Army (Dever, 2019). Cadets' standing in the ROTC program had the following breakdown: Military Science (MS)1: 16, MS2:21, MS3:13, MS4:17. A university outdoor track and field complex and an outdoor testing location at a military instillation, both located in the South Eastern U.S., served as the settings for this study.

Measures

The APFT has the following format with the primary physical component tested in parenthesis: a. 2 minutes of maximum repetition push-ups (muscular endurance), b. 2 minutes of maximum repetition sit-ups (muscular endurance) and c. a 2-mile run for time (cardiorespiratory endurance), with all events having 10 minutes of rest between tests.

All cadets must attain a minimum of 60 points to pass (180 total), which is first based on the amount of reps performed or time to completion then graded using the age and sex scoring matrix which determines how many points that effort was worth. (Headquarters Department of the Army, 1998).

The ACFT's individual tests, rest intervals and the primary physical component that they test are shown in the order they are performed (see Table 3.1). In order to pass the ACFT, all Cadets must attain a score of at least 60 points per each event, which would equal a minimum total score to pass the test equaling 360 points. The maximum score a Cadet could receive is 600 points. Unlike the APFT, the ACFT score is not adjusted for age or sex. Scoring is therefore based off of which category that individual falls in , which is based off of their military occupation. Heavy is the highest standard and is for infantry and the most physically demanding jobs. Significant is the middle standard and for jobs that still require significant physical demand like military police. Lastly, moderate is the lowest standard and is for those who are performing non-combat jobs such as communications and cyber personnel. Scoring procedures from the Initial Operational Capability (1 October 2019-30 September 2020) were used.

Procedures

Prior to the fall semester at a university in the Southeast U.S., Cadets from a U.S. Army ROTC program were recruited to participate in the study. Those that volunteered, completed an informed consent and a health screening form to determine eligibility. Participants who were under the care of a physician that excluded them from physical activity (e.g. heart condition, chest pain, injury, pregnancy, chronic illness) were not allowed to take part in the study.

The day before initial testing, anthropometric measures (i.e., mass and height) were collected by certified ROTC Cadre according to ROTC command standards with participants wearing light weight workout clothing and without shoes. Height (centimeters) and mass (kilograms) were measured using a stadiometer and bioelectrical impedance scale, respectively (Health-o-meter 500kl, McCook, IL).

The two testing sessions were completed one week apart to allow for enough certified staff to be on hand for the APFT and ACFT during normal ROTC physical training (06:00). For both testing sessions, cadets wore physical training uniforms (shorts, t-shirt and running shoes). Prior to both the APFT and ACFT, Cadets performed the same 10-minute general warmup, led by trained research staff, that included dynamic exercises such as bend and reach, forward lunges and jogging. On test day one, following the general warmup, ROTC Cadre provided an official APFT briefing and demonstrations of performance procedures. The APFT was then administered outdoors at a track and field facility at the university. All data was recorded by certified ROTC cadre and certified drill instructors on official APFT scorecards, then entered into the ROTC database before being deidentified for data analyses.

The ACFT took place one week after the first testing session. Following the general dynamic warmup as described previously, U.S. Army certified master fitness trainer personnel provided an ACFT briefing and demonstration of the tests before testing, according to Army standards. The ACFT was performed at a military instillation in the Southeastern U.S. at an outdoor designated testing location, with the run being performed on a pavement loop with a distance of 1061 meters. Scores were recorded by master fitness trainer personnel using official ACFT scoring sheets.

Data was then entered into the ROTC database and deidentified for data analysis. ACFT failure rate was calculated according to Army ACFT standards.

Prior to conducting the study, permission was obtained from the university's human subjects review board to conduct the study and informed consent was obtained from all participants.

Data Analysis

Descriptive data (mean and standard deviations) for height, mass and APFT and ACFT measures were calculated by sex. Associations among APFT and ACFT data were analyzed in four ways. First, all individual raw scores of the APFT and ACFT were analyzed using Pearson bivariate correlations. Second, individual, adjusted scores (points based) for both the APFT and ACFT were analyzed using Pearson bivariate correlations. Third, both APFT and ACFT individual raw scores were Z-scored, and then summed to create composites and analyzed using Pearson correlations. Z-scores from tests where lower scores represented better performance (i.e., timed tests including 2-mile run, and sprint-drag carry) were transformed to align with directionality of performance. Fourth, adjusted points-based scores for individual APFT and ACFT were Z-scored and summed to create adjusted composites which Pearson correlations were then calculated from. Correlations of r = .30-0.59 signify moderate associations while those r = .60 and greater are interpreted as strong (Lomax & Hahs-Vaughn, 2013). Next, independent-samples t-tests were calculated on raw data and composite scores to examine potential sex differences in APFT and ACFT performance. Failure rates for both the APFT and ACFT were determined by U.S. Army standards and were then analyzed using a chi-square test of association to examine potential differences in failure rate by sex. All statistical analyses were conducted using SPSS 26 (IBM Corp., Armonk, NY).

Results

Table 3.2 shows participant means and standard deviations for age, height and weight; of which men and women were a similar age, (20.5yrs; 19.7yrs respectively). Table 3.3 provides means and standard deviations for all individual measures of the APFT and ACFT. Women had lower mean ACFT (307) points-based scores compared to their male counterparts (456) ($p < .001$), but not on APFT points-based scores (209 vs. 225 respectively, $p < .296$) (see Appendix A for differences between sex and individual raw APFT and ACFT tests). Independent-samples t-test between raw Zscored ACFT composite scores and sex revealed that men scored higher ($M =$ 2.0, $SD = 3.7$) compared to women ($M = -5.9$, $SD = 2.8$) ($M = 7.9$, 95% CI [5.9, 9.9], $t(65) = 7.9$, $p = .001$).

Table 3.4 displays the Pearson correlations between the individual raw, APFT and ACFT measures ranging from weak ($r = .26$, $p < .05$) to strong ($r = .87$, $p < .01$). Individual correlations between ACFT tests and APFT pushups (r = -.63 - .78) were generally stronger compared to APFT sit-ups (r = .26 - -.54) and APFT 2-mile run (r = -.47 - -.48), with the exception of the sprint-drag carry ($r = .67$) and the similar two-mile run ($r = .87$). Table 3.5 shows the adjusted (points based) individual correlations between the APFT and ACFT ranging from weak ($r = .22$) to strong ($r = .61$). Interestingly, the adjusted points-based scores revealed a generally stronger relationship between ACFT tests and APFT sit-ups (r =.37 - -.61) compared to push-ups (r = .31 - -.50) and the 2-mile run (r = .02 - .83). Pearson correlations revealed a strong association ($r = .82$, $p <$ .01) between the raw composite APFT and ACFT tests. Pearson correlations between the adjusted (points based) composite APFT and ACFT tests also demonstrated a strong association but was relatively weaker than the raw composite ($r = .64$, $p < .01$). Lastly, according to U.S. Army standards, the ACFT had an overall failure rate of 37% (12 males and 13 females failed) and the APFT had a failure rate of 35% (17 males failed, and 7 females failed). A chi-square test for association revealed there was a statistically significant difference with failure rate of the ACFT based on sex ($X^2(1) = 14.9$, $p = .001$), with women failing at a higher rate (76.5%) than men (24%) (See Table 3.6 for ACFT crosstabulation). A chi-square test for association determined there was not a statistically significant difference in failure rates of the APFT based on sex ($X^2(1) = .28$, $p = .59$) (See Table 3.7 for APFT crosstabulation).

Based on the sex differences observed in the independent-samples t-tests, a Pearson partial correlation, controlling for sex, was conducted to examine the association between the raw composite APFT and ACFT scores. The results showed that sex did not dramatically impact the relationship between the APFT and ACFT as the Pearson partial correlation controlling for sex still had a strong relationship ($r = .75$, $p < .01$) compared to correlation associations not controlling for sex ($r = .82$, $p < .01$).

Discussion

The purpose of this study was to provide insight into associations among Army APFT and ACFT test scores within an enlistment age and U.S. Army affiliated population. Correlation analysis revealed a strong ($r = .82$, $p < .01$) relationship between the raw score composite APFT and ACFT and a strong, yet slightly weaker relationship ($r = .64$, $p < .01$) between the adjusted (points) scored APFT and ACFT. While a significant correlation between the APFT and ACFT was not surprising noting that two tests of the APFT are quite similar to two tests (two mile run and push-ups) on the ACFT (with differences noted in the form and timing of tests), the overall strength of the association was somewhat surprising. As differences in neuromuscular demand in four of the six measures in the ACFT would seemingly preclude such a strong relationship. A potential reason behind this high correlation is that the MS2, MS3 and MS4 Cadets had begun to transition their PMR training to focus both on the APFT and ACFT requirements in the previous year. Thus, the dual training could have promoted parallel performance increases across both test batteries. However, when examining just the MS1 Cadets in the sample (n = 16), the correlations between the raw composite scores (r = .83) and the points-based composite scores (r = .56) were quite similar. Thus, the overall strength of associations between the ACFT and APFT demonstrate that the tests generally tell a similar story of Cadets overall fitness levels. As raw score associations were higher than the points-based scoring, sex differences in performance contribute to these strong relationships.

The raw score associations between the individual APFT and ACFT tests showed that, outside of the similar two 2-mile runs and push up measures the sprint drag carry (r = -.75, $p < .01$) and leg tucks (r = .74, $p < .01$) had the strongest associations with the APFT push-up test. However, correlations between APFT push-up and sit-ups (muscular endurance) generally demonstrated the lowest correlations with ACFT tests that demanded higher levels of strength and power (e.g., deadlift, r = -.31 and standing power throw, r = .26). Both the strength deadlift and the standing power throw are dynamic assessments that require whole body coordination and control to perform at a high level. Additionally, the standing power throw is considered a ballistic exercise due to it having to be performed with maximal acceleration that creates high rates of force development in order to project the ball for maximal distance (Zehr & Sale, 1994). The lower correlations among these four tests demonstrate the differences in neuromuscular requirements between two of the ACFT and the APFT.

Both leg tucks and the sprint drag carry require upper body muscular strength and endurance to grip the bar and pull yourself up and to hold the 40lb kettlebells while moving respectively Therefore, their strong relationship with the push up assessment on the APFT speaks not only to the similarity in muscular endurance, but also to the importance of upper body muscular endurance/ strength in PMR based training. With leg tucks demonstrating a potential passing issue due to low scores, upper body muscular endurance and strength should be a priority.

As compared to the APFT, Cadets' 2 mile run times were slower for the ACFT with females on average taking 1:21(minutes: seconds) longer and males 1:17 longer. This increase in time could be attributed to anaerobic fatigue (increase in lactate concentration and muscle damage from prolonged anaerobic bouts lasting longer than 30 seconds; Naharudin & Yusof, 2013). Essentially, when individuals are performing the ACFT, they are performing the 2-mile run after five other tests, with less rest than they are accustomed to during APFT test protocols (i.e., ACFT has between 2-5 minutes of rest between events, APFT has 10 minutes of rest between events). Individuals who are not accustomed to anaerobic conditioning and who do not have a base in this component will struggle to recover between tests, thus compounding fatigue. We should note however, that the APFT run was performed on a 400M NCAA regulation track and the ACFT run was performed on an outdoor 1061M pavement loop at a different testing location. Both tests were performed at 0:600 under similar environmental conditions. As the push up performed in the ACFT is slightly different with individuals having to perform a 'hand release' at the bottom position, females went from performing an average of 32 push-ups on the APFT to 20 on the ACFT and males decreased from 58 to 33. The decrease in push up repetitions on the ACFT is partially a result of the slightly different movements performed and a consistent cadence required during the ACFT test. Due to the hand-release alteration to the push up, individuals can no longer use their momentum to perform repetitions as quickly as on the APFT, which may impact differences in localized muscular fatigue between the two tests. Also, the push-ups are performed after the strength deadlift and the standing power throw in the ACFT as opposed to performing them first in the APFT, further impacting upper body muscular fatigue in the ACFT. Overall, results suggest that females in particular could benefit from the inclusion of strength and power-based training into their current PMR regimen due to their performance on the deadlift, leg tuck and power throw, and the fact that more women failed the ACFT (n=13) compared to the APFT (n=7).

Results from this study generally indicate that strength and power training should form cornerstones of a holistic PMR training program for both sexes. Additionally, it should not be assumed that push-up repetitions and 2-mile run time would be equal from the APFT to the ACFT. With the run now being performed after five other tests, with less rest, and the push-ups not being performed first, both scores could be affected by anaerobic fatigue. The significant differences between male and female scores on the ACFT are important to note, especially for those responsible for PMR training. Shown in Table 3.3, females had a mean score of 307 which is below the passing minimum of 360 with 13 of the 17 female Cadets failing the ACFT. Additionally, the female cadets struggled with the strength and power-based assessments of the ACFT with low mean scores on the deadlift (50 points), leg tuck (23 points) and standing power throw (44 points), with 60 points being the minimum requirement. The male participants had a mean score of 456 and, like their female counterparts, struggled with the leg tuck (63 points) which should be highlighted as 20% and 65% of males and females respectively failed the leg tuck test. Interestingly, when the APFT was in development during the late 1970's, pull-ups were being considered for inclusion in the test. However, studies performed at the time showed that very few women could perform a single pull-up thus it was removed from the test (Knapik & East, 2014). With both pull ups and leg tucks requiring a high degree of upper body pulling and grip strength and endurance, our results would confirm that females in particular, need to incorporate upper body strength and endurance training into their PMR regimen. The importance of trunk strength should not be ignored as an important component of the leg tuck as the assessment also requires the demonstration of greater core strength compared to that of the sit up (i.e., via a greater proportion of mass to move against gravity).

The ACFT (37%) had a similar failure rate than the APFT (35%) with (n=12) males and (n=13) females failing the ACFT and (n=17) males and (n=7) females failing the APFT. The higher percentage of females failing the ACFT, compared to the APFT, was expected due to the inclusion of strength and power assessments, which was highlighted by their statistically significant low mean scores in the deadlift, leg tuck and standing power throw. Interestingly males scored higher on the ACFT run compared to the APFT run, suggesting that anaerobic fatigue did not affect the males as much as the female Cadets during testing with respect to how the tests were scored. Additionally, the strength, power and functional movement base of the ACFT relates to a biological advantage for males (i.e., greater testosterone production in males) and potentially a greater emphasis on strength and power training by the male Cadets. It should be noted the goal of the ACFT was not to increase failure rates for either sex. Rather, the ACFT was designed to be a more representative test of PMR components required for modern combat, like strength, power, and functional movement, which the ACFT now includes. Results from the chi-square tests for association revealed that sex had a statistically significant association with ACFT failure rates; however, the APFT did not demonstrate a significant association between sex and failure rate. These results further emphasize the importance of the strength and power assessments included in the ACFT, but not the APFT.

While the current sample tested was affiliated with the U.S. Army by being ROTC Cadets, they are not necessarily representative of typical U.S. Army enrollees; therefore, these results need to be approached with caution. The ROTC environment is not similar to that of active duty service members or basic training enrollees due to many ROTC Cadets not having the same schedule and duties as their active duty and basic training counterparts. In addition, the approximately 75% of the ROTC sample consisted of individuals who had been in the ROTC program for 1-3 years, meaning they had specific training focusing on PMR and the APFT more than an incoming basic trainee. Additionally, this study was limited to one ROTC program and future studies should include comparing these results against other ROTC programs within the U.S. Army basic training and active duty components. Based on our results, a larger female sample is needed to confirm the potential issue of large numbers of female soldiers not being able to pass the ACFT. However, this sample did include a larger percentage of females (25% of the total sample) than currently represented in the US army (15%) (Dever, 2019). Lastly, the ACFT was scored using the system available at the time of testing (ACFT Initial Operation Capability 1 October 2019-30 September 2020). Future changes to this system may alter the failure rates observed in this study.

Conclusion

The results from this study provide insight on associations between the APFT and ACFT tests as well as the potential need to alter current PMR training. The need for strength, power and was confirmed by the ACFT test scores where female mean scores on the deadlift, standing power throw and leg tuck were below the 60-point minimum (males also had a mean score of 63 on the leg tuck). Additionally, 2-mile run time increased by 1:21(minutes: seconds) for females and 1:17 for males, from the APFT to the ACFT while push up repetitions decreased for both men and women. The decreases in performance for these two similar tests could be due to anaerobic fatigue caused by more tests and shorter rest periods in the ACFT protocol. Thus, making anaerobic endurance another PMR component that needs to be addressed in PMR training.

Implications

Improving soldier physical performance on the battlefield has been a critical goal of the U.S. Army since its inception, with PMR testing being a cornerstone of readiness since 1858. Recently, the U.S. Army spent considerable time and resources to train and equip the entire force to grade and perform the ACFT. By implementing the ACFT, the U.S. Army hopes to improve and change the PMR culture by promoting strength, power and agility into their physical training programs. Due to the aforementioned factors and the pending roll out of the ACFT in the U.S. Army, the investigation of new PMR training concepts are warranted to ensure we have a physically capable and deployable U.S. Army fighting force. Results from this study indicate that PMR training programs need to incorporate the new physical constructs tested in ACFT as it should not be assumed that strength, power and agility are sufficient, especially in females, to pass the test and demonstrate modern combat readiness. Failing to address this gap in PMR training could lead to an unfit and unready U.S. Army.

Table 3.1 ACFT Measures

ACFT Measure	Measure Description	Rest Between Next Event	Physical Components Tested
Strength Deadlift	3 repetition max effort deadlift using a hexagon bar	2 minutes	Strength
Standing Power Throw	standing 10lb medicine ball power throw (thrown behind the body) for distance, 2 attempts	3 minutes	Explosive Power
Hand Release Push Up	maximum hand release pushups for 2 minutes	3 minutes	Muscular Endurance
Sprint Drag Carry	5 x 50-meter shuttles for time - sprint, drag (90lb sled), lateral (shuffle), carry (2x40lb kettlebells) and sprint	4 minutes	Anaerobic Endurance, Agility
Leg Tuck	maximum leg tucks for 1 minute	5 minutes	Strength, Muscular Endurance
2 Mile Run	2-mile run for time		Cardiorespiratory Endurance

Table 3.2 Participant Height and Weight (Means & SD)

	N	Age	Height(cm)	Weight(kg)
Male Cadets	50	20.5(3.1)	175.6(8.7)	76.9(10.6)
Female Cadets	17	19.7(1.1)	163.8(6.7)	66.5(11.3)

Table 3.3 APFT and ACFT Raw and Converted Score Means and Standard Deviations

Measure	N	Mean Raw and Converted Scores Female (*n*=17) Raw score/converted score (SD of converted score)	Male (*n*=50) Raw score/converted score (SD of converted score)
APFT Total (Max 300)	67	209/NA (±66.1)	225/NA (±50.9)
APFT Sit-up (reps)	67	58/67 (±27.6)	63/76 (±13.5)
APFT Push-up (reps)	67	32/82 (±16.3)	58/80 (±18.2)
APFT Run (min: sec)	67	18:23/60 (±31.7)	15:24/68 (±22.5)
ACFT Total (Max 600)	67	307/NA (±82.7)	456/NA (±72.2)
ACFT Deadlift (lbs)	67	125/50 (±21.9)	237/80 (±16)
ACFT Standing Power Throw (M)	67	4.6/44 (±25.9)	8.6/73 (±10.3)
ACFT Push-up (reps)	67	20/58 (±22.3)	33/74 (±9.7)

ACFT Sprint Drag Carry (min: sec)	67	2:25/68 (±5.3)	1:47/91 (±10.2)
ACFT Leg Tuck (reps)	67	1/23 (±32.2)	8/63 (±34)
ACFT Run (min: sec)	67	19:44/57 (±28)	16:41/77 (±15)

Note: APFT= 2 minutes of Sit Ups, 2 minutes of Push Ups, 2-mile run. ACFT=Strength Deadlift, Standing Power Throw, Hand Release Push Ups, Sprint Drag Carry, Leg Tucks and 2 Mile Run

Table 3.4 Individual Raw Score APFT and ACFT Pearson Correlations

ACFT Measure	APFT Push Ups	APFT Sit Ups	APFT 2 Mile Run
Strength Deadlift	.721**	.315**	-.473**
Standing Power Throw	.696**	.260*	-.486**
Hand Release Push Up	.783**	.475**	-.481**
Sprint Drag Carry	-.756**	-.461**	.674**
Leg Tuck	.749**	.493**	-.472**
2 Mile Run	-.633**	-.548**	.872**

Note: **Correlation significant at the .01 level (2-tailed), *Correlation significant at the .05 level (2-tailed)

Table 3.5 Individual Points Scored APFT and ACFT Pearson Correlations

ACFT Measure	APFT Push Ups	APFT Sit Ups	APFT 2 Mile Run
Strength Deadlift	.379**	.378**	.229
Standing Power Throw	.313**	.427**	.254**
Hand Release Push Up	.449**	.516**	.350**
Sprint Drag Carry	.386**	.435**	.476**
Leg Tuck	.507**	.556**	.363**
2 Mile Run	.419**	.611**	.833**

Note: **Correlation significant at the .01 level (2-tailed), *Correlation significant at the .05 level (2-tailed)

Table 3.6 ACFT Crosstabulation

ACFT Crosstabulation	Pass	Fail	Total
Male Count	38	12	50
Expected Count	31.3	18.7	50
% Within Male	76%	24%	100%
Female Count	4	13	17
Expected Count	10.7	6.3	17
% Within Female	23.5%	76.5%	100%

Table 3.7 APFT Crosstabulation

APFT Crosstabulation	Pass	Fail	Total
Male Count	33	17	50
Expected Count	32.1	17.9	50
% Within Male	66%	34%	100%
Female Count	10	7	17
Expected Count	10.9	6.1	17
% Within Female	58.8%	41.2%	100%

CHAPTER 4

STUDY 2: ASSOCIATIONS BETWEEN FUNCTIONAL MOTOR COMPETENCE AND THE ARMY COMBAT FITNESS TEST

Introduction

The U.S. is experiencing a secular decline in health-related fitness and general physical activity in children and adolescents (CDC, 2011; Kann et al., 2017), which has unexpectedly jeopardized national security (Mission Readiness, 2010). Currently, between 27% and 31% of 17-24-year-olds are ineligible to serve in the military due to obesity and low fitness levels, thus dramatically limiting the number of potential recruits (Boivin et al., 2016). This pervasive Physical Military Readiness (PMR) issue is impacted by a secular decline in fitness levels in children and adolescents as only 29% of high school-aged youth meeting national guidelines for physical fitness and only 12% meeting both muscular strength and cardiovascular standards (CDC, 2011; Kann et al., 2017). The deterioration of physical fitness levels in youth in the U.S. is compounded by a similar trend in physical activity levels as only 24% of children 5 to 19 years of age are currently meeting the U.S. national guidelines for 60 minutes of health-enhancing moderate-vigorous physical activity per day (National Physical Activity Plan Alliance, 2018

The decline in physical fitness and general physical activity levels in youth is hypothesized to be influenced by a decrease in the development of motor competence across childhood (Hulteen et al., 2018; Robinson et al., 2015; Stodden et al., 2008). Functional motor competence (FMC; i.e., neuromuscular coordination and control required to perform various motor skills; Stodden et al., 2008) is crucial for the development of positive trajectories of multiple aspects of health-related fitness (Cattuzzo et al., 2016; Utesch et al., 2019), physical activity (Robinson et al., 2015) and a healthy weight status (Cattuzzo et al., 2016; Lima, Pfeifer, Larson et al., 2017). An inadequate foundation of FMC developed throughout childhood and into adolescence (Brian et al., 2019; Jaakkola et al., 2015; Lima, Pfeifer, Bugge et al., 2017; Lima, Pfeifer, Larson et al., 2017) also is suggested to translate to diminished fitness and increased obesity in early adulthood (Stodden et al., 2009, Stodden et al., 2013). Neuromuscular demands required during effortful performance of various locomotor and object control/projection skills are similar to those found in multiple aspects of health-related fitness components (i.e., muscular strength, power and agility; Meyer et al., 2011; Stodden et al., 2008; Stodden et al., 2014). For example, skillful performance of the standing long jump, used to assess FMC since the 1950's, requires total body coordination and control to produce a multi-joint sequence of powerful, optimally-timed movements (Enoka, 2015; Lane et al., 2017; Maffiuletti et al., 2016).

Development of FMC related movement patterns such as the standing long jump, vertical jump and hopping promote adaptations in inter/intra muscular control and motor unit recruitment similar to traditional strength and power exercises such as those commonly found in human performance programs (e.g., hex bar deadlift, medicine ball power throws). Additionally, FMC development indirectly improves cardiovascular and muscular endurance based on the activities in which these skills are consistently performed and practiced with high effort (e.g. sports, games, play; Jaakkola et al., 2015; Lima, Pfeifer, Bugge, et al., 2017; Lima, Pfeifer, Larson, et al., 2017; Sacko, Brazendale, et al., 2019; Sacko, Nesbitt, et al., 2019). Failure to develop a broad foundation of FMC in childhood and adolescence is detrimental to the development and application of strength, power, agility and cardiorespiratory endurance, which potentially impacts one's ability to perform PMR based training and activities such as running an obstacle course, maneuvering in urban combat with the required equipment or loading a heavy artillery shell.

Physical development attributes involved in the development of FMC are all underlying physical requirements assessed by the new Army Combat Fitness Test (ACFT). The ACFT was created to assess the physical demands of modern combat which have been deemphasized because the long-standing Army Physical Fitness Test (APFT) does not directly measure strength, agility, power and functional movement (Nindl et al., 2015). The APFT directly measures muscular (push-ups, sit-ups) and cardiovascular endurance (two-mile run), which shaped the PMR culture by focusing on training that directly promoted only these physical requirements (Nindl et al., 2015). Essentially, four of the six ACFT assessments require a greater foundational emphasis of complex multi-joint coordination and control (i.e., FMC) as compared to the APFT. The development of FMC promotes inter- and intra-muscular coordination and control via volitional muscle recruitment and the exploitation of reflexive neuromuscular mechanisms associated with high concentric and eccentric loading (Anliker et al., 2012; Campbell, Stodden & Nixon, 2010; MacWilliams et al., 1998; Stodden et al., 2009; Stodden & Brooks, 2013; Veilleux & Rauch, 2010). These underlying mechanisms are foundational and applicable to modern combat demands and more advanced military training contexts like running, jumping, leaping, crawling, dragging and balancing in an obstacle course setting and ACFT tests.

While the ACFT's implementation will assist in changing the U.S. Army PMR culture by testing strength, power, agility and functional movement (in addition to cardiovascular and muscular endurance), it is being implemented at a time when recruit aged Americans are as unfit, physically inactive (Kann et al., 2017; National Physical Activity Plan Alliance, 2018) and may not possess a sufficient foundation of FMC (Brian et al., 2019; De Meester et al., 2018). Without a foundation of FMC, traditional resistance training that produces increases in strength in specific movement forms (i.e., squats, bench press, etc.) will not promote the most effective increase in functional performance demanded in modern combat scenarios such as dragging a downed teammate, climbing over walls and barriers and sprinting to a breach point. As the ACFT is scheduled to be the Army's fitness test of record in 2021, it is important to understand the potential impact that developing FMC may have on potential recruits' physical readiness. Therefore, the purpose of this study is to examine the relationship between FMC and ACFT performance within a sample of an enlistment aged a U.S. Army affiliated population.

Methods

Participants and Setting

Data for this study was obtained from 59, 17-31year old ROTC Army Cadets (Male *N*=45, *Mage*=20.2, SD = 2.8; Female *N*=14, *Mage*=19, SD= 1.1) who consented to participate and were part of a larger study, see Silvey et al., 2020 (submitted). Cadets' standing in the ROTC program had the following breakdown: Military Science (MS)1: 15, MS2:19, MS3:10, MS4:15. Women represented 23% of the sample, which is greater than the 15% of women making up the U.S. Army (Dever, 2019). A university, open, indoor space, and an outdoor testing location at a military instillation, both located in the South Eastern U.S., served as the settings for this study.

Instrumentation

Product score data from eleven FMC tasks (vertical jump, standing long jump, hopping, shuttle sprint, lateral jumps, kicking and throwing, throw and catch, supine to stand, moving sideways on blocks, balance beams) were assessed. Product oriented measures are developmentally valid and sensitive discriminators of FMC (Coppens et al., 2019; Lane et al., 2019; Logan et al., 2017; Nesbitt et al., 2018; Stodden et al., 2009; Stodden et al., 2014). Descriptions and protocols for FMC tasks are shown in Table 4.1. FMC was assessed and recorded by trained research staff.

The ACFT has the following format established by the US Army Center for Initial Military Training (2018) with rest intervals noted after each test: A) 3 repetition max effort deadlift using a hexagon bar - 2 minutes of rest, B) a standing 10lb medicine ball power throw (thrown behind the body) for distance-2 minutes of rest, C) maximum hand release pushups for 2 minutes,-3 minutes of rest D) sprint(5x50m) drag(90lb sled) carry(2x40lb kettlebells)-4 minutes of rest, E) maximum leg tucks for 1 minute,-5 minutes of rest F) a two-mile run for time. In order to pass the ACFT, all Cadets must attain a score of at least 60 points per each event, which would equal a minimum total score of 360 points. The maximum score a Cadet could receive is 600 points. Unlike the APFT, the ACFT score is not adjusted for age or sex. Scoring is therefore based on the category that an individual falls under, which is based off of their military occupation. “Heavy” is the highest standard and is required for infantry and the most physically demanding jobs. “Significant” is the middle standard and is required for jobs that still require significant physical demand like military police. Lastly, moderate is the lowest standard and is required for those who are performing non-combat jobs such as communications and cyber personnel. Scoring procedures from the Initial Operational Capability (1 October 2019-30 September 2020) were used.

Procedures

Prior to the fall semester at a university in the Southeast U.S., Cadets from a U.S. Army ROTC program were recruited to participate in the study. Those that volunteered, completed an informed consent and a health screening form to determine eligibility. Participants who were under the care of a physician that excluded them from physical activity (e.g. heart condition, chest pain, injury, pregnancy, chronic illness) were not allowed to take part in the study. The day before initial testing, anthropometric measures (i.e., mass and height) were collected by certified ROTC Cadre according to ROTC command standards with participants wearing light weight workout clothing and without shoes. Height (centimeters) and mass (kilograms) were measured using a stadiometer and bioelectrical impedance scale, respectively (Health-o-meter 500kl, McCook, IL).

The two testing sessions were completed one week apart during normal ROTC physical training (06:00). Prior to both the FMC and ACFT testing, Cadets performed the same 10-minute general warmup, led by trained research staff, that included dynamic exercises such as bend and reach, forward lunges and light jogging. On test day one, following the general warmup, Cadets performed FMC testing at a university in the South Eastern U.S. in an open, indoor space which allowed for unrestricted skill performance. Research staff tested Cadets in a circuit that included the 11 FMC tasks which were ordered to minimize fatigue in tests that required multiple trials with high levels of neuromuscular effort and to minimize testing time. Cadets had a minimum of two minutes rest between tests. All data was recorded by trained research staff, then entered into the testing database before being deidentified for data analyses.

The ACFT took place one week after the first testing session. Following the general dynamic warmup as described previously, U.S. Army certified master fitness trainer personnel provided an ACFT briefing and demonstration of the tests before testing, according to Army standards. The ACFT was performed at a military instillation in the Southeastern U.S. at an outdoor designated testing location, with the run being performed on a pavement loop with a distance of 1061 meters. Scores were recorded by master fitness trainer personnel using official ACFT scoring sheets. Data was then entered into the ROTC database and deidentified for data analysis. ACFT failure rate was calculated according to Army ACFT standards.

Prior to conducting the study, permission was obtained from the university's human subjects review board to conduct the study and informed consent was obtained from all participants.

Data Analysis

Descriptive data (mean and standard deviations) for individual FMC measures were calculated. All individual FMC and individual raw ACFT data were converted into Z-scores for subsequent analyses. Next, an ACFT composite was created by summing all individual Z-scored ACFT tests. Individual Z-scored FMC measures also were summed to create each of the following composites: Lower Extremity Explosiveness (LEE: Lateral Jumps, Vertical Jump, Standing Long Jump, Shuttle Sprint, Hopping); Object Control/Projection (OCP: Throwing, Kicking, Throw and Catch);
Functional Coordination (FC: Supine to Stand, Walking Backwards, Moving Sideways) and an overall composite FMC score. Z-scores from tests where lower scores represented better performance (i.e., timed tests including 2-mile run, sprint-drag carry, shuttle run & supine to stand) were reverse coded. Data were then analyzed in two ways, first Pearson bivariate correlations were calculated based on all raw individual scores of the ACFT and its raw Z Scored summed composite, and all of the individual raw FMC measures. Second, Pearson bivariate correlations were calculated based on the individual raw scores of the ACFT and its summed Zscored composite and the summed Zscored FMC composites. Correlations of r = .30-.59 signified moderate associations while those r = .60 and greater were interpreted as strong (Lomax & Hahs-Vaughn, 2013). All statistical analyses were conducted using SPSS 26 for Macintosh (IBM Corp., Armonk, NY).

Results

Table 4.2 shows means and standard deviations for Cadet height, weight, and age. Men had an average age of 20.2yrs while the women had an average age of 19.7yrs. Means and standard deviations of raw individual measures of FMC are shown in Table

4.3. Table 4.4 below, shows Pearson correlations between individual FMC measures and individual raw ACFT scores, which ranged from $r = .06$ to $r = .81$. Also shown in Table 4.4 are the individual FMC tests associations with the raw composite ACFT score, which ranged from $r = .21$ to $r = .86$, with tests in the LEE and OCP category generally having stronger relationships than those in the FC category. Composite FMC and individual raw ACFT test associations, shown below in Table 4.5, ranged from $r =. 17$ to $r = -.78$). The FMC composites LEE ($r = .80$, $p < .01$) and OCP ($r = .756$, $p < .01$) both demonstrated strong relationships with the ACFT while FC ($r = .37$, $p < .01$) demonstrated a moderate association.

Discussion

The purpose of this study was to investigate associations between FMC and the ACFT as it was designed to be a more comprehensive assessment of the physical constructs emphasized in modern combat such as strength, power, agility and functional movement, as well as cardiorespiratory endurance. Of the 11 individual FMC measures tested, vertical jump demonstrated the strongest association with overall ACFT score ($r = .86$, $p < .01$), followed by standing long jump ($r = .81$, $p < .01$) and then kicking ($r = .71$, $p < .01$) and throwing ($r = .71$, $p < .01$). These results suggest that underlying neuromuscular demands associated with performance of LEE and OCP measures are overall, strongly aligned with performance on the ACFT. In addition, the composite LEE and OCP scores indicate similar strengths of associations (Table 4.4: LEE $r = .80$, $p < .01$; OCP $r = .756$, $p < .01$). These results suggest that developing a broad foundation of locomotor and object projection/control skills in childhood and adolescence is highly beneficial for promoting ACFT performance for individuals entering the military. The development of locomotor and object control/ projections skills inherently demands high levels of effort (Cattuzzo et al., 2016; Croix & Korff, 2013; Girard et al., 2005; Langendorfer et al., 2011) including the effective manipulation of and individual's entire body mass with high ground reaction forces in multiple movement planes (Anliker et al., 2012; MacWilliams et al., 1998; Veileux & Rauch, 2010), high levels of concentric and eccentric muscle contractions (Cattuzzo et al., 2016; Croix & Korff, 2013; Girard et al., 2005; Langendorfer et al., 2011) and persistent practice (Campbell et al., 2010; Duffield et al., 2004; Stodden et al., 2008). The aforementioned physical training and performance attributes also are necessary to improve ACFT test performance through more advanced resistance and conditioning training.

Developing a requisite broad foundation of FMC in childhood and adolescence via quality physical education programs and youth sport is a traditional route through which motor skill development has been promoted (Robinson et al., 2015). Similarly, U.S. Army PMR testing had historically embraced concepts of FMC as in the test of the early 1940's which included a baseball throw, basketball throw, a standing long jump, vertical jump and a running hop (East, 2013). Unfortunately, the traditional grass roots programs (e.g., physical education and youth sports) that are thought to provide all youth with adequate experiences to develop a broad foundation of FMC are not enough as time allocated for physical education has been systematically diminished in many states across the U.S. (Shape America, 2016). In addition, economic cost to participate in youth sports programs has increased (Aspen Institute, 2019) which can limit participation in sports as children age. Thus, many youth are not provided adequate experiences or instruction to adequately develop their FMC or physical fitness across childhood and adolescence. Data from Brian et al. (2019) and De Meester et al., (2018) provide examples of this emergent problem as data from multiple regions of the U.S. demonstrated 75% of children from ages 3-12 performed at or below the 25$^{\%tile}$ in an assessment that measures 12 fundamental locomotor and object projection/control skills (e.g., hop, jump, run, throw, kick, catch). As motor skill development and fitness, or lack thereof, tracks across childhood and adolescence (Ahnert et al., 2009; Henrique et al., 2018; Lima et al., 2019; Rodrigues et al., 2016), children who do not develop and adequate foundation of FMC are at risk for demonstrating a motor skill proficiency barrier (Brian et al., 2020; Seefeldt, 1980) that is linked to physical activity and fitness deficits that track across childhood (De Meester et al., 2018) and into adulthood (Stodden et al., 2013).

Results of this study strongly support the previously noted data; thus providing a strong cautionary note to the U.S. Military that physical development of future service members begins in childhood; not when recruits enter basic training. It is often assumed that by the time an individual reaches the age to enroll in Junior Reserve Officer Training Corp (JROTC; i.e., high school), or even Senior ROTC, they possess adequate levels of FMC and fitness to participate in military specific training like rucking and obstacle course navigation. However, that is not the case as many of America's youth (Brian et al., 2019; DeMeester et al., 2018) and young adults (Stodden et al., 2009) lack a sufficient foundation of both FMC that is linked to physical fitness, obesity and physical activity levels.

While these data support the critical importance of developing a foundation of FMC prior to promoting progressively intensive external loads in traditional strength and conditioning exercises (e.g., deadlift, squat, bench, Olympic lifts) as well as PMR specific tasks and training (e.g., rucking, obstacle course navigation, loading tank shells), entry level ROTC Cadets and entry level military soldiers can systematically integrate FMC training into their training program. One such method to integrate FMC into training programs is to introduce warm-up routines that focus on dynamic multi-joint movement patterns that enhance functional capabilities. Warm-up routines provide repeated opportunities for consistent FMC development, and like typical strength and conditioning programs, should progress in the complexity and intensity of movements (i.e. neuromuscular and functional coordination) as functional capabilities develop. After an individual has performed a progressively rigorous FMC-based warm up over the course of an appropriate training cycle, they will be ready for more advanced and higher intensity FMC-based movements, such as plyometrics. Developing FMC with a particular focus on the dynamic and ballistic movements of LEE and OCP, which demonstrated strong associations to the strength, agility, power and functional movement-based tests of the ACFT, will provide a foundation of neuromuscular coordination and control to adequately perform ACFT assessments that require a similar neuromuscular foundation. From an operational standpoint, more advanced physical function will enhance a soldier's capability to successfully perform general physical tasks required by their military occupation and potentially reduce the risk of work-related injuries.

While LEE and OCP demonstrated strong relationships with the ACFT and its individual tests, the FC tests generally demonstrated weaker relationships with the ACFT. While all of the LEE and OCP tests include multi-joint ballistic skills (i.e., linked to explosive force production), the FC tests require whole body coordination that do not demand as high a degree of power production. However, they do require underlying FMC attributes including dynamic balance, multiplanar movements and dynamic ranges of motion in multiple joints that are foundational to all movement forms and may be predictive of long-term injury risk. For example, Burnham et al. noted that between 1993 and 2002, injuries in the Air Force resulting from participation in basketball and slips and falls ranked second and third, respectively, in cause of active duty personnel missing work. These data speak to the importance of dynamic joint range of motion, dynamic balance and stability, and the ability to effectively react to perturbations during both routine tasks and dynamic, high intensity activities (Burnham et al., 2010; Pfiefer et al., 2019; Stodden & Brooks, 2013).

While the military has a history of promoting sport as a means to increase and sustain fitness (Wakefield, 1997), an inadequate foundation of FMC may actually increase the probability of injury in sport-related activities, as previously noted by Burnham et al (2010). Successful and sustained participation in team sports requires physical demands similar to modern combat physical requirements and inherently demands a high level of skill in multiple FMC domains (different motor skills) to be successful. Thus, participation in sports without a strong foundation of FMC and fitness may lead to both acute and chronic injury if soldiers are not physically prepared. For example, the demonstration of high levels of LEE skill performance (i.e. vertical jump, standing long jump, hopping) produces ground reaction forces 1.5-5.4 times and individual's body weight (Anliker et al., 2012; MacWilliams et al., 1998; Veileux & Rauch, 2010) in both children and adults. In childhood and adolescence, participation in skill development activities (e.g., sports, games, skill practice) promotes positive growth of bone mineral density and cortical thickness via multidirectional loading (i.e., compression, shear, bending and torsional forces) (Fuchs et al., 2001), thus potentially reducing the long-term risk of stress fractures (Beck et al., 2000; Cosman et al., 2013). As repetitive stressors linked to Military PT have been linked to high rates of acute stress fractures in military basic training (Beck et al., 2000; Cosman et al., 2013) a foundation of FMC (specifically LEE skills) developed in childhood and adolescence can provide a protective effect, via repetitive multidirectional loading, against acute and chronic bone-related injuries.

Conclusion

Data from this study provide strong preliminary evidence on the potential impact that developing and sustaining a broad foundation of FMC will have on PMR. In particular, foundational locomotor (e.g., standing long jump and vertical jump, hopping) as well as object control/reception skills (i.e., throwing and kicking) that are developed in childhood and adolescence demonstrated strong associations with ACFT performance. Tests that assess multi-joint functional coordination also are foundational to overall FMC as they assess total body coordination and control and dynamic balance that are critical to LEE and OCP performance and any functional task.

A foundation of FMC should be developed during childhood and adolescence to maximize its potential effects on PMR for current and next generations of military recruit populations. As with any human performance program, FMC training can be integrated within military PT in an appropriately progressive manner that should be based on an individual's current physical training foundation (i.e., training age). Additional evidence for the importance of FMC for long-term physical development is noted via its relative importance in both the U.S. Olympic Committee's American Development Model (United States Olympic Committee, 2016) and the National Strength and Conditioning Association's Long-Term Athletic Development Programs (Llyod et al., 2016) as a core foundation of training to not only develop high level athletes, but also to encourage increased participation in lifespan physical development. Thus, promoting a broad foundation of FMC in childhood and adolescence can have a significant impact on PMR in initial entry soldiers and as they advance through their military career. Additionally, with the impending roll-out of the ACFT as the fitness test of record in the U.S. Army, the importance of having a foundation of FMC becomes even more critical to ensure a fit and deployable fighting force.

Implications and Practical Application

Integrating progressive FMC development in a long-term PMR training philosophy across JROTC, ROTC, and Cadet Command missions will enhance PMR prior to arriving at basic training and for commissioning of Officers. This long-term approach would also provide a larger pool of potential recruits that would have four (JROTC to enlistment; ROTC to Officer Commission) to eight years (JROTC to ROTC to Officer Commission) of progressive PMR training that prepares individuals for future success in the Military. As the lack of PMR has been noted as a threat to national security, promoting PMR with a long-term approach (i.e., from a developmental perspective lens) seems to be a logical and sustainable approach to alleviate this threat. Specifically, more effectively utilizing the current training ground infrastructure of JROTC and ROTC to promote a strong foundation of FMC and fitness can provide a long-term solution to the current problem of PMR and increase operational capacity for the U.S. Military.

Table 4.1 Product Oriented FMC Measures

Score	**Notes on Measure**
Standing Long Jump (cm)	Cadets completed 5 maximal effort trials of standing long jump. The maximum distance jumped were used for data analysis (Stodden et al., 2009)
Hopping speed (m/s)	Cadets were instructed to hop on one leg, “as fast as possible”, over 7.62 meters. The average hop time (assessed with a stopwatch) for 4 hop cycles (twice each on each leg) was divided by distance hopped to calculate hopping speed.
Shuttle Run (sec)	Cadets were told to “run as fast as they can”, sprinting 10 meters, stopping and then sprinting back to the start line, twice (down and back down and back). Two trials were performed and assessed using a stopwatch. The fastest time was reported.
Supine to Stand (sec)	Cadets started in a supine position with their hands by their sides and their feet, 50 cm from a wall. Participants were instructed to “stand up as fast as they can on the “go” command and touch a marked spot on the wall, placed at shoulder height. The fastest of 5 stop watch timed trials was reported (Nesbitt et al., 2017).
Vertical Jump (cm)	Cadets were told to “jump as high as possible” while standing next to a calibrated device designed to measure vertical jump (Vertec), 3 trials were completed. The highest jump was reported.

Kicking Velocity (m/s)	Cadets kicked an 218cm diameter playground ball with maximal effort from 7 meters at a wall – ball speed was measured with a radar gun (Stalker Radar, Plano TX). The fastest of 5 trials was reported (Stodden et al., 2009)
Throwing Velocity (m/s)	Cadets threw a tennis ball with maximal effort from 7 meters – ball speed was measured by a radar gun (Stalker Radar, Plano TX). The fastest of 5 trials was reported. (Stodden et al., 2009)
Throw/Catch (#of throw & catches	Cadets stood a distance approximately 3 times their height from a wall and threw and caught a tennis ball off the wall as many times as possible in 30 seconds, performing two trials. The best score of two trials was reported.
Walking backwards (# of steps)	Cadets walked backwards on three balance beams each 3m in length, 5cm in height, with decreasing widths of 6, 4.5 and 3cm. Cadets were given three attempts at each beam with the number of successful steps recorded. A maximum of 24 steps was be counted for each beam (i.e., 8 per trial with 3 trials per beam; maximum score is 72 steps) (Rodrigues et al., 2019)
Moving sideways on blocks(#of transfers)	Cadets began by standing with both feet on one platform (25cm x 25cm x 2cm) 3.7cm in height and holding an identical platform in their hands. Cadets were then instructed to place the second platform alongside the first and to step onto it. The first platform was then lifted and placed next to the second and the Cadet stepped onto it. This continues for 20 seconds. Each transfer from

	one platform to the next earns two points. Points in 20 seconds were summed for all 3 trials. (Rodrigues et al., 2019)
Lateral Jumps (#of jumps)	Cadets made consecutive jumps from side-to-side over a small beam (60cm x 4cm x 2cm) as quickly as possible for 15 seconds. The highest number of jumps in two trials was recorded. (Rodrigues et al., 2019)

Table 4.2 Participant Height and Weight Means (SD)

	N	**Age**	**Height(cm)**	**Weight(kg)**
Male Cadets	45	20.2(2.8)	175(8.7)	76.9(12.2)
Female Cadets	14	19.7(1.1)	162.5(6.9)	67.3(12.2)

Table 4.3. Means and Standard Deviations for Individual FMC Measures

FMC Measure	**Male Mean (SD)**	**Female Mean (SD)**
Vertical Jump (cm)	56.5 (9.9)	38.1 (5.3)
Standing Long Jump (cm)	224.9 (31.4)	161.9 (20.9)
Shuttle Sprint (sec)	10.1 (.6)	11.6 (.813)
Lateral Jumps (reps)	37.8 (5.1)	34.5 (4.18)
Hopping (m/s)	5.1 (.6)	3.9 (.6)
Beams (Steps)	45.9 (13.4)	44.0 (15.7)
Blocks (reps)	29.0 (2.6)	27.6 (2.7)
Supine to Stand (sec)	1.2 (.2)	1.4 (.2)
Kicking (m/s)	25.3 (3.1)	18.8 (1.9)
Throwing (m/s)	27.6 (5.1)	19.3 (2.7)
Throw & Catch (reps)	17.8 (3.4)	14.1 (2.3)

Table 4.4 FMC and ACFT Raw Score Correlations

FMC Raw Scores	DL	SPT	HRPU	SDC	LT	RUN	TOTAL
VJ	.753**	.813**	.709**	-.796**	.689**	-.542**	.868**
SLJ	.659**	.778**	.596**	-.799**	.598**	-.590**	.811**
SS	-.587	-.628**	-.593**	.679**	-.497**	.424**	-.667**
LJ	.373**	.409**	.351**	-.344**	.129	-.256*	.376**
Hopping	.565**	.528**	.509**	-.664**	.443**	-.485**	.644**
Beams	.065	.060	.209	-.274*	.086	-.342**	.209
Blocks	.209	.367**	.119	-.306*	.071	-.287*	.274*
STS	-.247	-.210	-.282*	.306*	-.211	.284*	-.311*
Kicking	.614**	.688**	.520**	-.761**	.479**	-.489**	.716**
Throwing	.630**	.677**	.515**	-.681**	.523**	-.466**	.705**
T&C	.433**	.514**	.361**	-.558**	.437**	-.505**	.567**

Note**Correlation significant at the 0.01 level (2-tailed), * Correlation significant at the 0.05 level (2-tailed). VJ= Vertical Jump, SLJ= Standing Long Jump, SS= Shuttle Sprint, LJ= Lat Jumps, STS= Supine to Stand, T&C= Throw and Catch. DL= Deadlift, SPT=Standing Power Throw, HRPU=Hand Release Push Up, SDC= Sprint Drag Carry, LT=Leg Tuck. ACFT total is a composite made from the summed raw Zscored individual tests.

Table 4.5 FMC Composites and ACFT Raw Score Correlations

ACFT Raw Scores	LEE	FC	OCP
Strength Deadlift	.698**	.246	.638**
Standing Power Throw	.750**	.301*	.715**
Hand Release Push Up	.632**	.288*	.531**
Sprint Drag Carry	-.780**	-.419**	-.761**
Leg Tuck	.560**	.174	.548**
2 Mile Run	-.546**	-.431**	-.556**
ACFT Raw Composite Total	.800**	.375**	.756**

Note: **Correlation significant at the 0.01 level (2-tailed), * Correlation significant at the 0.05 level (2-tailed). LEE: SLJ, VJ, Sprint, Lat Jumps, Hop; FC: Beam, Blocks, STS; OCP: Kick, Throw, Throw & Catch. ACFT total is a composite made from the summed raw Zscored individual tests

CHAPTER 5

FUTURE RESEARCH CONSIDERATIONS & CONCLUSION

Future Research Considerations

This sample was tested in a small sample of ROTC Cadets, which may not be generalized to an entry level military population. Thus, sampling from basic training recruits is warranted to gain a broader picture of how physical military readiness and functional motor competence relate to all recruit age, U.S. Army affiliated populations. In addition, as there were noted differences in both ACFT and FMC performance between men and women, additional research assessing differences in failure rates between men and women is warranted to understand its potential impact on the entire Army population. Further research also is warranted to investigate the potential of FMC to predict injury. Individuals who enter the military without a foundation of FMC and physical fitness may be at higher risk due to the high intensity physical training associated with basic training.

Conclusion

This dissertation represented the first study to measure associations between a multi-dimensional FMC test battery and the ACFT. While past U.S. Army fitness tests have included measures similar to those that were performed in our functional motor competence battery (e.g. standing long jump, baseball throw) these types of assessments, have been shunned since the mid 1970’s in favor of assessments more aligned with general health-related fitness. However, the ACFT assesses strength, power, and agility which demonstrate similar neuromuscular demands that are linked functional motor competence

Our results indicate that the assessments of lower extremity explosiveness and object control and projection strongly relate to overall ACFT scores and individual tests such as the strength deadlift, overhead power throw, and the sprint drag carry. Therefore, we posit that FMC training should be included in the physical training doctrine from an early age. For example, by the time individuals reach the age to enroll in JROTC (i.e., high school), or even Senior ROTC, it is assumed they possess sufficient levels of FMC to participate in military specific training like rucking and obstacle course navigation. However, that is not the case since many of American youth (Brian et al., 2019) and young adults (Stodden et al., 2009) lack an adequate foundation of FMC. Therefore, there should be a concerted effort to develop of multi-joint functional movement skills in JROTC, as well as for Senior ROTC, as these adaptations require time and can't necessarily be developed over the nine weeks of BCT. Therefore, if a high school student enrolls in JROTC and begins a developmentally appropriate FMC based PMR program which then continues through their ROTC years, they could enter the U.S. Army with eight years of progressive PMR training.

In addition to outlining the potential importance of FMC within the realm of PMR, this dissertation provides initial insight on how males and females will score on the upcoming ACFT. Our results indicate that females could struggle with the strength (deadlift, leg tuck) and power (overhead throw) based assessments now featured in the test; therefore, physical training needs to reflect these potential deficits. However, the physical constructs of strength and power would be beneficial to all service members as it will improve overall physical military readiness.

Limitations and Delimitations

Limitations

While our population is affiliated to the U.S. Army by being ROTC Cadets, they are not U.S. Army enrollees, active duty or reserve service members. The ROTC is not entirely identical to their active, reserve and BCT counterparts as they are also college students, are not deploying or getting ready to until graduation, nor do they generally have the soldering responsibilities and duties that those in active and reserve units perform on a daily basis. Therefore, these results need to be approached with caution when extrapolating our results to the U.S. Army as a whole. This study was limited to one university's ROTC program thus, future studies should include investigating these claims amongst other ROTC programs, the military academies in the U.S. For this study, the ACFT was scored using the system available at the time of testing (ACFT Initial Operation Capability 1 October 2019-30 September 2020) however, future changes to this system may alter the scores observed in our study.

Delimitations

Investigating the differences in PMR tests scores between male and female Cadets was one of the aims of Study 1, and while more female participants would have been ideal, this study includes a larger percentage of females than currently represented in the US army (15%) (Dever, 2019). Additionally, to ensure the accuracy of the PMR testing, all APFT and ACFT scoring was conducted by certified Army staff including ROTC instructors and Drill Sargent's and Master Fitness School personnel from a military instillation in the South East U.S.

To minimize any training effect from the APFT and FMC testing performed at the first testing session, the ACFT was performed one week after, additionally Cadet physical training was minimized during the week between testing sessions.

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APPENDIX A

SUPPLEMENTARY DATA ANALYSIS

Raw PMR Measure	**Male Mean (SD)**	**Female Mean (SD)**	***t (p value)***
Strength Deadlift (lbs)	237.8 (64.8)	125.8 (50.8)	6.4 (p = .001)
Ball Throw (m)	8.6 (2)	4.6 (1)	10.4 (p = .001)
HR Push Up (reps)	33.1 (12)	20.2 (9.2)	4.0 (p = .001)
Sprint Drag Carry (sec)	107.5 (13.9)	145 (20)	-8.7 (p = .001)
Leg Tuck (reps)	8.0 (6.6)	1.1 (1.8)	6.9 (p = .001)
Two Mile Run (sec)	1001 (125.8)	1184.4 (174.1)	-4.6 (p = .001)
Push Ups (reps)	58.6 (15.6)	32.5 (10.4)	6.3 (p = .001)
Sit Ups (reps)	63.7 (13.5)	58.1 (18.2)	1.3 (p = .184)
Two Mile Run (sec)	924.1 (118)	1103.4 (142.8)	-5.1 (p = .001)