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The Role of Strength and Power in High Intensity Military Relevant Tasks

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The Role of Strength and Power in High Intensity Military Relevant Tasks

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TABLE OF CONTENTS

ABSTRACT

INTRODUCTION: A significant amount of research has examined the physiological determinants of heavy load carriage while performing medium to long distance road marching (3.2km - 20 km). Research examining the physiological underpinnings of modern high intensity battlefield tasks is limited. This study aimed to examine the role of strength and power during high intensity combat tasks under heavy load carriage.

METHODS: 18 recreationally trained men (mean ± SD: age: 21 ± 2 years; height: 172 ± 6 cm; weight: 80 ± 13 kg) participated in this study and were timed during the performance of a high intensity combat relevant course under two randomized experimental conditions; unloaded and loaded. Subjects performed three trials under the loaded condition and three trials under the unloaded condition with a five-minute rest in between each trial. During the unloaded trial, subjects only wore a combat uniform with boots weighing ~ 3.2 kg, while during the loaded trial, in addition to the combat uniform and boots, subjects wore interceptor body armor (6.94 kg-9.10 kg) and a MOLLE rucksack weighing 30 kg. The combat relevant course performed consisted of 3 consecutive tasks, which began from the prone position, leading into a 30m sprint, followed by a 27 m zig-zag run, and ending with a 10 m casualty drag weighing ~79.4 kg.

RESULTS: Pearson correlations showed significant ($p \leq 0.05$) strong negative correlations between lower body strength (r=-0.63, -0.62), lower body power (r=-0.67, -0.67) and upper body strength (r=-0.60, -0.62) with overall performance times in the unloaded and loaded condition, respectively.

CONCLUSION: Upper body strength, and lower body strength and power are strongly related to the performance of high intensity, military tasks with and without heavy load carriage.

KEY WORDS: load carriage, military, strength, power.

CHAPTER 1

INTRODUCTION

Throughout history warfighters have continually borne heavy loads into combat. Since the U.S. civil war, the load that a U.S servicemen carries has dramatically risen, increasing the physiological strain, leading to excessive fatigue and attenuating combat effectiveness. While carrying these heavy loads a servicemen must engage in demanding activities on the battlefield, ranging from long distance marching to short explosive sprints. The speed with which the servicemen are able to maneuver on an objective carrying these loads, while performing strenuous activities, is critical to the completion of a mission and to the survivability of our men and women in the armed services.

The majority of the current research on military load carriage has examined the physiological determinants, the effects of various loads, and the training required to improve the speed of load carriage over medium to long distances, ranging from 2.5 km-25 km. This emphasis on medium to long distance load carriage reflects the tactics of past wars where servicemen would march long distances with their supplies into battle. However, combat operations have evolved from marching into battle, to conducting direct action raids, where troops are transported near or directly onto an objective and must quickly traverse the objective, performing anaerobic tasks like sprinting, lifting, pulling, crawling, and climbing, while still carrying significant loads.

With the landscape of the battlefield becoming primarily anaerobic, more studies must be performed that examine the demands of the anaerobic battlefield, so that servicemen can optimally train to meet these demands. There is limited research investigating the physiological underpinnings, and the effects of heavy load carriage during the performance of short duration,

high intensity anaerobic tasks. Therefore the purpose of this investigation is to elucidate the relationship of strength and power with short duration, high intensity military relevant tasks, while carrying heavy loads. The results of this investigation can provide further insight to strength and condition specialists and military leadership, to include power, strength and hypertrophy training into the design of physical training programs, so that optimal training can be performed to meet the demands of combat operations, to ensure mission success.

CHAPTER 2

REVIEW OF LITERATURE

INTRODUCTION

Throughout history load carriage has been shown to be an essential aspect of military operations. During training and on the battlefield, servicemen are required to carry various loads, on their person or in a pack, while navigating difficult terrain. Knapik et al. (2004) [1] displayed the various loads carried throughout history, from the Greek Hoplites, to United States infantryman in Afghanistan during Operation Enduring Freedom, showing an increase in loads carried on marches. Much of the external load can be attributed to technological advances in weaponry and armor, which aim to improve the combat effectiveness and survivability, but may have negative implications on mobility and endurance due to the increase of weight. With the increase in weight leading to a greater physiological strain, efforts have been made to try to reduce the overall loads and to improve the physical capabilities of the servicemen.

Since load carriage is such a crucial component of many military occupations, it has been the focus of many investigations throughout the years. Considerable attention in the literature of military load carriage has been focused on the improvement of the physical capabilities of the servicemen to bear various loads. Specifically, most of the research has emphasized the improvement of the ability to cover medium to long distances with different loads. One aspect of soldiering requires marching longer distances for an extended period of time with heavy loads, however the battlefield also requires explosive and powerful movements under heavy loads. There are few studies within the literature that examine the explosive, anaerobic aspects of the battlefield while carrying heavy loads. The purpose of this review of literature is to provide a

brief history of the different loads that U.S servicemen have carried in battle, overview the investigations that have elucidated the physiological determinants of military load carriage, discuss the physiological variables of load carriage during short, explosive tasks, examine modes of physical training to improve military load carriage and will propose a novel solution to address some of the gaps in the scientific literature regarding military load carriage during short duration, high intensity military tasks.

BRIEF HISTORY OF MILITARY LOAD CARRIAGE

Different Loads Carried by U.S Servicemen

Throughout history servicemen have been required to carry certain equipment into battle including; weapons, armor, clothing and rations, which have weighed up to ~76 kg [2]. As early as 6th century BC, the Greek Hoplites when dressed in full battle array (breastplate, greaves, helmet, shield, spear, sword) were carrying a load between 22.5 to 32 kg, with the apsis alone (shield) weighing ~7 kg [2, 3]. Load carriage can also be traced in American history, beginning with the Civil war in 1861, up until the recent war in Afghanistan [2, 4]. The troops of the Union Army carried an average load of 20.5 and 22.5 kg, including sixty rounds of ammunition, a musket, a piece of shelter, and other various tools [5-7]. In World War I, the load of the average American servicemen increased, carrying a load between 22 to 32 kg [1, 2, 8]. Also, in World War II, during the D-Day invasion at Omaha beach, the load that the average American servicemen wore increased, with loads ranging from 27 to 41 kg [1, 2, 9, 10]. During the Korean War loads continued to rise, as seen with the 7th Marines of the 1st Battalion, being required to carry loads around 54.5 kg through the rough terrain of the Toktong Ridge [2, 11, 12]. In the Vietnam War, the average load for the American servicemen ranged from 27.5 to 32 kg [2, 13].

In 1983, during Operation Urgent Fury in Grenada, the average load that the American Soldier carried ranged from 54.5-76 kg [2, 14]. It was also reported that the 76 kg loads worn during an airfield seizure by the 75th Ranger regiment, attenuated combat effectiveness and was a primary factor in causing multiple heat injuries. In a recent study examining the Modern Warrior's Combat Load in Afghanistan during Operation Enduring Freedom, loads carried by U.S Army Soldiers depended on the type of operation being conducted, and could range from 29 to 57.5 kg [4]. Regardless of the battlefield, carrying heavy loads into battle has been a defining characteristic of U.S servicemen and continues to be an essential part of military operations today, however the significant loads carried into battle have lead to reduced performance on the battlefield.

Consequences of Carrying Heavy Loads in Combat

While carrying heavy loads, troops are required to travel long distances, traverse harsh terrain and quickly perform combat maneuvers, while under enemy fire. It can be seen throughout the history of U.S wars, that carrying a significant load reduces combat performance. During World War I, an American servicemen carried an average load of 22 to 32 kg, and the heavy load was claimed to be the primary cause of exhaustion during the short distance trench warfare [2, 15]. In World War II, during the D-Day invasion at Omaha beach, with average loads ranging between 27 to 41 kg, American troops had to initially maneuver through chest deep water, causing many to drown before ever reaching the land [2, 16]. In the Korean War, heavy loads were claimed to be the cause of many infantrymen arriving at their march destination fatigued, with average march distances of 19-32 kilometers per day [2, 12]. In Operation Urgent Fury, with loads averaging 54.5 to 76 kg, a Soldier recalled his experience as

being a “slow-moving turtle”, being unable to perform routine combat maneuvers because of the weight of the load [14]. In another observation by an American Soldier in Grenada, the excess load, in combination with the tropical heat, was thought to be the cause of a high number of heat casualties [2, 14]. During Operation Enduring Freedom, a 187th Regiment First Sergeant observed the difficulty of traversing the battlefield in a timely way due to the heavy loads carried by the soldier [1, 4].

Since load carriage attenuates performance of basic combat tasks, efforts have been made to lessen the loads that servicemen carry by developing lighter equipment [17], and by reducing the total load carried for each specific mission [4, 18]. Another avenue of improving performance of load carriage includes the development of the physical capacities of the troops, enabling them to perform a variety of combat tasks under loads without a significant performance decrement. To train properly for military load carriage, a review of the current literature examining the involved physiological systems and musculature of military load carriage is necessary. The following section will review the various studies that have elucidated the various physiological determinants of load carriage during medium to long distance marches.

PHYSIOLOGICAL DETERMINANTS OF LOAD CARRIAGE DURING MEDIUM TO LONG DISTANCE MARCHES

Maximal Oxygen Consumption

Maximal oxygen consumption or $\dot{V}O_{2max}$ is defined as the highest rate of oxygen consumption attainable during maximal exercise and is regarded as the best measure of cardiorespiratory endurance capacity [19]. Maximal oxygen uptake is suggested to be a good

predictor of success in endurance events by many exercise scientists, and has shown to be a critical component of load carriage performance. Dziados et al. [20] determined the relative contribution of size, body composition, muscular strength, muscular endurance and maximal oxygen uptake on a 10 mile maximal performance march while carrying an 18kg load and identified the variables of hamstring strength ($r = -0.42$, $p \leq 0.003$) and $\dot{V}O_{2max}$ ($r = -0.37$, $p \leq 0.01$) as the variables that most strongly correlate with performance times.

Mello et al. [21] elucidated the physiological determinants of maximal load bearing performance over a range of distances of 2, 4, 8, and 12 km with a 46.12 kg load and found a significant correlation of $\dot{V}O_{2max}$ with load bearing performance, only with the 12 km distance ($r = -0.528$) for subjects that were performing above the mean percentage of maximum heart rate. Knapik et al. [22] found a statistically significant relationship between road march completion time and absolute $\dot{V}O_{2max}$ ($r = -0.31$, $p \leq 0.01$) during a 20 km road march with 46 kg load in the rucksack. In 2001, Pandorf et al. [23] examined the correlates of load carriage performance among female soldiers and revealed that absolute $\dot{V}O_{2max}$ and 3.2 km run time were the best predictors of a 3.2 km road march performance across three different loads. The coefficients of correlation between absolute $\dot{V}O_{2max}$ and 3.2 km road march time for soldiers carrying the 14, 27, and 41 kg loads, respectively, were -0.64, -0.61, and -0.70. Lyons et al. [24] investigated the influence of aerobic fitness on the metabolic and cardiovascular demands of a load carriage task. With participants carrying loads of 0, 20, and 40 kg at 4 kph for 60 min on gradients of 0, 3, 6, 9%, absolute $\dot{V}O_{2max}$ produced the strongest correlation ($r = -0.64$, $p \leq 0.01$) with the metabolic demand of heavy load carriage. In 2007 Beekley et al. [25] examined the effects of heavy load carriage during constant speed road marching and found that increasingly heavy loads of 30%, 50%, and 70% of lean body mass carried in a rucksack resulted in a linear increase of $\dot{V}O_2$ and

heart rate, showing that the heavier the load, the greater the metabolic cost, which may negatively impact road march performance. The results of these various investigations have elucidated the role that absolute $\dot{V}O_{2max}$ and relative $\dot{V}O_{2max}$ have with load carriage performance and evidence suggests that absolute $\dot{V}O_{2max}$ is a predictor of load carrying ability over medium to long distances. Other physiological factors have also been identified to influence load carriage ability, which will be discussed in the following sections.

Lower Body Strength

Strength is another influential factor in load carriage ability because load carriage requires muscle strength to support and move the weight of the load by muscle tissue [22]. Greater muscle strength of the upper and lower body are likely to be beneficial to load carriage performance, with individuals with greater muscle cross sectional area being capable to carry more weight. Knuttgen and Kraemer [26] define strength as the maximal force that a muscle or muscle group can generate at a specified velocity. In a study examining strength decrements from carrying various army packs on military marches, the trunk extensors, hip extensors, and knee extensors were found to have the greatest strength losses after a 7.5 mile march with loads ranging from 41 to 61 kg [27]. Dziados et al. [20] also identified hamstring muscle strength as the only significant predictor of a 10 mile road march performance while carrying a 18kg load ($r = 0.45$). Mello et al. [21] found that carrying a 46.12 kg load at distances of 8 and 12 km, the strength of the hamstrings and quadriceps, and endurance of the hamstrings and quadriceps muscles, were significant predictors of load bearing ability. Knapik et al. [22] examined the relationship of lower body strength and a 20 km road march performance with a 46 kg load and found statistically significant correlations between lower body strength measurements and road

march time. Koerhuis et al. [28] assessed dynamic lower body muscle strength parameters and their relationship to maximal load carriage capacity and observed the highest correlation with the squat exercise and maximal load carriage capacity ($r = 0.62$). These investigations elucidate the importance of lower body strength as a crucial physiological component for optimal load carriage performance at medium to long distances.

Upper body strength

In addition to maximal oxygen consumption and lower body strength, upper body strength has also shown to be a critical component of load carriage performance. Clarke et al. [27] examined strength decrements from load carriage and identified the trunk extensors as the muscle group showing the greatest strength losses after eight different marches with various loads. Knapik et al. [22] was the first to examine the relationship between upper body strength and road march performance. Utilizing a 20 km march carrying 46 kg, Knapik et al. identified abdominal strength as the only physiological measure significantly related to road march performance ($r = -0.45$, $p \leq 0.05$), after controlling for fat free mass. Knapik et al. [22] also reported low but statistically significant correlations between road march time and most of the isometric strength measures of the upper body. Kraemer et. al. [29] examined the effects of various training programs on a high intensity load carriage task and concluded that a combination of resistance training and running is necessary to improve performance on a load bearing task, with upper body strength as opposed to leg strength, playing a more critical role in a heavy load (44.7 kg), short duration load bearing task (3.2 km). Collectively, these studies show how upper body strength plays a significant role in military load carriage over medium to long distances.

Lower Body Muscular Endurance

Muscular endurance is the muscles' capacity to sustain repeated muscle actions for an extended period of time [19]. Possessing lower body muscular endurance can be advantageous during load carriage over medium to long distances, since individuals with more muscular endurance should possess a greater resistance to fatigue during longer marches. Dziados et al. [20] assessed quadriceps and hamstring endurance by performing 50 consecutive maximal contractions with a Cybex II dynamometer at an angular velocity of 180 degrees/sec. and did not find significant correlations between hamstring and quadriceps endurance and roach march time. However, Mello et al. [21] utilizing the same protocols as Dziados et al., identified hamstring endurance and quadriceps endurance as significant correlates with road march performance time when marching at 4, 8, and 12 km distances with a 46 kg load. The inconsistency of the results between the two studies may be due to the different distances and loads utilized in both of the studies. Dziados et al. utilized a 10 mile march with 18kg load, while Mello et al. utilized distances of 2, 4, 8, and 12 km with a 46.12 kg load. More research is needed to further elucidate the role of upper body and lower body muscular endurance.

Fat Free Mass

Muscle tissue can be estimated to make up 50% of the fat free mass in man with greater cross sectional area of muscle being related to its maximal force potential [30]. Numerous studies have elucidated the relationship of fat free mass with military load carriage. Knapik et al. [22] observed a low but significant correlation of $r = -0.26$ when examining the relationship of fat free mass with a 20 km road march time using a 46 kg load. Lyons e al. [24] investigated the

influences of body composition upon the relative metabolic and cardiovascular demands of load carriage and found that lean body mass was one of the variables closely associated with cardiovascular demands of heavy load carriage task. Bilzon et al. [31] examined the hypothesis that individuals with greater body mass are more able to perform occupationally relevant load carrying tasks and found a moderately strong relationship between exercise time and body mass ($r = 0.69$, $p \leq 0.05$) and between exercise time and lean body mass ($r = 0.71$, $p \leq 0.05$), while having subjects run to volitional exhaustion at 9 km/h and while carrying an 18 kg load. Bilzon et al. concluded that heavier subjects were able to perform the load carriage task at a lower metabolic cost and for a longer duration, compared with the lighter subjects [31]. In agreement with Bilzon et al., Pandorf et al. [32] examined the correlates of load carriage among women with a 3.2 km loaded march, and found that with a 41 kg load, greater body size was associated with faster course time (body mass: $r = -0.59$, $p \leq 0.05$), suggesting that the performance of the larger subjects with greater muscle mass ($r = -0.56$, $p \leq 0.06$) were effected by the load to a lesser degree than the smaller lighter subjects. Koerhuis et. al. [28] identified lean body mass as the anthropometric parameter with the highest correlation to maximal load carriage capacity ($r = 0.81$), closely followed by body mass ($r = 0.76$). Overall these investigations elucidate the relationship between fat free mass and load carriage, showing that individuals with greater fat free mass perform faster and longer with heavier loads, and are effected to a lesser degree than individuals with less fat free mass in medium to long distance load carriage tasks.

The research reviewed above has primarily focused on identifying the physiological determinants of medium to long distance load carriage tasks. While certain combat operations may call for marching with heavy loads at medium to long distances, this remains to be a single aspect of combat occupations. Combat operations continue to evolve with each war, with the

varying terrain and the volatile tactics of the enemy, the battlefield can call for long patrols on foot, patrols in a vehicle, airborne operations and direct action raids. During training and combat operations, in addition to carrying heavy loads over medium to long distances, servicemen may be required to perform multiple, explosive, high intensity tasks while carrying heavy loads. Specifically this can be observed during direct action raids, where troops are transported via helicopter directly onto an objective and must quickly traverse the objective and perform anaerobic tasks like sprinting, lifting, pulling, crawling, and climbing, while still carrying significant loads. Further research examining the physiological determinants of load carriage during high intensity combat tasks is needed. The following sections will review the various investigations that have examined high intensity combat activities and the associated physiological variables involved in the tasks, as well as review the literature elucidating the effects of various loads during high intensity combat tasks.

PHYSIOLOGICAL DETERMINANTS OF HIGH INTENSITY COMBAT ACTIVITIES

In an attempt to identify the various fitness components involved in combat operations, a few investigations have provided some insight in this matter. In 1978, the Directorate of Military Occupational Structures began the process of identifying and quantifying the most physically demanding tasks within the Canadian Forces. With the use of questionnaires, interviews with experts, and on site evaluations, it was concluded that the majority of the strenuous tasks involve the physical handling of material and thereby require primarily upper body strength and muscular endurance [33]. Within the Canadian Forces manual [34], occupation specifications state that an infantryman must be able to participate in offensive and defensive operations including advances, attacks, crossing of obstacles, rescuing casualties,

constructing defenses and individual movements with a rifle, which are primarily anaerobic tasks.

In another study by Daniels et al. [35], which determined the association among aerobic power and dynamic lift capacity, with performance scores during five days of a sustained combat scenario among thirty three infantry soldiers and reported that muscular strength as measured by the incremental lift machine was significantly correlated with scores of operational performance ($r = 0.39$, $p \leq 0.05$). The five-day combat scenario consisted of offensive and defensive infantry maneuvers including; reacting to enemy fire, conducting raids, and evacuating wounded soldiers [35]. The highest correlation ($r = 0.46$) in this investigation was observed when aerobic power and the incremental lift scores were combined and compared to operational performance, showing that for sustained combat operations both muscular strength and aerobic power are key components to performance.

Knapik et al. [36] reported correlations between performance on a five-day simulated combat exercise and upper and lower body anaerobic power (as measured by Wingate test), and isokinetic endurance of the elbow flexors and knee extensors (as measured by isokinetic dynamometer). The combat scenario consisted of conducting ambushes, reconnaissance, offensive and defensive maneuvers, while carrying loads between 25-29 kg. Knapik et al. [36] found that upper body peak ($r = 0.46$, $p \leq 0.01$) and mean power ($r = 0.43$, $p \leq 0.01$) were significantly correlated with performance in field infantry tasks, concluding that anaerobic power appears to play an important role in the ability to sustain infantry combat activities over 5 days [35, 36]. It can be concluded from these investigations that in addition to aerobic power, muscular strength, muscular endurance, and anaerobic power have a positive impact in sustained

combat performance [33, 35, 36], showing the necessity of the warfighter to cultivate anaerobic capacities to optimize combat effectiveness.

While these investigations have examined some of the physical demands of sustained operations, further research that is more relevant to the anaerobic battlefield today, and that elucidates the roles of upper and lower body strength and power in high intensity military tasks under heavy loads, is warranted. The following sections will review the scientific literature regarding the various physiological determinants of short duration, high intensity military tasks.

Maximal Oxygen Consumption

Utilizing forty-three males and a course involving 19 obstacles, consisting of running, crawling, scaling, pulling, and lifting, Jette et al. [33, 37] compared the performance of an standardized obstacle course to laboratory measures of fitness recognized as important in performance of infantry tasks. Subjects completed the course as fast as possible wearing a minimal external load of a combat uniform, helmet, and rifle. Performance of the course was significantly and positively correlated to maximal aerobic power ($r = -0.69$, $p \leq 0.01$). Jette et al. [33] identified relative maximal aerobic power as the physiological variable which correlated highest with obstacle course performance ($r= -0.74$, $p \leq 0.01$). In the same study, Jette et al. [33] compared the average maximal aerobic power scores of the ten best course performers to the average maximal aerobic power scores of the ten lowest course performers and found a greater average value of 33% between the two groups.

In another investigation Bishop et al. [38] evaluated the physiological determinants of the performance of an 11-item military obstacle course, utilizing 47 male subjects and found lower significant correlations between course completion time and upper body ($r= -0.51$) and lower

body aerobic power (r= -0.53) as measured by open circuit spirometry, during a continuous incremental graded treadmill protocol, and an upper-body cycle ergometer, respectively. The relationship that $\dot{V}O_{2max}$ has with military tasks depends upon the task being performed, whether it is primarily anaerobic or aerobic (running, lifting, crawling, etc.), and may also depend on the overall duration of the course (19 stations vs. 11 stations), which may explain the lower correlations for aerobic power with the 11 station course, which took significantly less time to complete (~187 sec. $\pm$ 69 sec.) [38], when compared to the 19 station course (~333 sec. $\pm$ 60 sec.) [33]. The longer the duration of the course, the more aerobic the task becomes and the more $\dot{V}O_{2max}$ will play a role in determining performance of the course. It is also important to note that in both of these studies, the external load carried by the subjects was minimal (boots, uniform, rifle, helmet), which is not relevant to the modern battlefield [33, 38].

Upper and Lower Body Strength

Muscular strength has been identified as a fitness component that is related to the ability to complete routine infantry tasks and to sustain combat effectiveness [33]. Utilizing a 19 station obstacle course, Jette et al. used as a strength index the combination of grip strength, 1 rep maximum (1RM) for shoulder press and 1RM for seated leg press and found a significant correlation with obstacle course performance ($r = -0.51$, $p \leq 0.01$) [33]. Bishop et al. [38] observed that faster performers of the 11-item obstacle course, relative to body weight, averaged greater 1RM leg press, and 1 RM latissimus dorsi pull down, than slower performers. Rayson et al. [39] examined the relationship of physical performance and criterion military tasks in 379 trained soldiers. The military tasks included a single, maximum lift of an ammunition box, a carry of one 20 kg water jug in each hand on a 30 m course at 1.5 meters per second (test ceases

when not maintaining pace), a repetitive lift and carry task of a 44 kg ammunition box for 10 m onto a 1.45 m high platform (test ceases when not maintaining pace) and a timed loaded 12.8 km march. The physical performance tests included; static strength, upright pull, arm flexion strength, back extension strength, and dynamic strength and power. The resulting multiple regression models indicated that physical performance measures of absolute strength were predictive of the criterion military task performance [39].

From the studies reviewed [33, 38, 39], it can be concluded that upper and lower body strength are vital components of combat related performance, yet none of these studies have examined the role of strength during high intensity combat tasks with heavy load carriage. On the battlefield today, servicemen are regularly carrying mission essential equipment (body armor, ruck sacks, etc.) onto an objective and are required to perform high intensity, anaerobic tasks with an external load. More research examining this area is needed.

Upper and Lower Body Power

Maximal anaerobic power is related to the ability of muscle tissue to exert high force while contracting at a high speed, and can be assessed using short duration, maximal movement speed tests [40]. Bishop et al. [38] assessed anaerobic power of the upper and lower body using a Wingate test, with subjects attempting as many pedal revolutions as possible in 30 seconds. After assessing upper and lower body power, subjects performed an 11-item military obstacle course and concluded that, relative to body weight, the fastest one-third of the subjects ($n = 15$) who completed the course, averaged greater upper body anaerobic peak and mean power. Jette et al. [33] also found that performance of a 19-item obstacle course was significantly correlated to anaerobic lactic power ($r = -0.69$, $p \leq 0.01$), as measured by a cycle ergometer. Harman et al.

[41] ran forward stepwise multiple linear regression procedures, to determine the best linear equations to predict performance on the simulated military physical performance tests, using field expedient physical fitness scores (vertical and horizontal jump), and anthropometric measures as input. The vertical jump was found to be the most useful input variable, entering all predictive equations for simulated battlefield performance, reflecting the importance of explosive lower body power in high-intensity, short-duration combat activities [41].

Fat Free Mass

The more fat free mass an individual possesses, the ability to perform high intensity activities that require muscular power and strength increases. Harman [42] discussed the relationship of body size and composition to the performance of physically demanding military tasks and concluded that lean body mass tended to be positively associated with the ability to push, carry and exert torque. Kusano et al. [43] examined the impact of body size on women's military obstacle course performance and identified a trend ($p \leq 0.06$) in fat free mass influence on obstacle course time, whereas fat free mass increased, obstacle course time decreased. In the study done by Rayson et al. [39] it was reported that fat free mass was positively correlated with the performance of each physical performance test, and was the best predictor of criterion military task performance in four of the six criterion tasks. Pandorf et al. [32] identified correlates of load carriage and obstacle course performance among women and found that larger subjects with greater muscle mass were able to carry the heaviest load (41 kg) faster than smaller, less muscular subjects. These investigations elucidate the importance of developing and increasing fat free mass, which can be advantageous to the soldier when conducting high intensity tasks with loads.

Muscular Endurance

Muscular endurance involves the ability to perform submaximal muscle actions, extended over a large number of repetitions with little recovery [40]. Jette et al. [37] measured upper body muscular endurance with submaximal bench presses and found a significant correlation with the performance of a 19-station obstacle course ($r = -0.49$, $p \leq 0.01$). Pandorf et al. [32] measured the maximum number of sit ups completed in 2 minutes and push ups completed in 2 minutes, and found the muscular endurance scores to be correlated with the performance of certain segments of an obstacle course. Push-up scores were related to low-crawl performance ($r = -0.59$, $p \leq 0.1$), and a suspended pipe shimmy ($r = 0.58$, $p \leq 0.1$), while carrying a 14kg load. Sit-up scores were also related to low crawl performance ($r = -.60$, $p \leq 0.1$) while carrying a 14 kg load, and a 27 kg load ($r = -0.55$, $p \leq 0.1$), and were also significantly correlated to the completion of the suspended pipe shimmy ($r = 0.64$, $p \leq 0.05$) under a 14 kg load. Harman et al. [41] utilized the Army Physical Fitness Test (APFT) to measure upper body muscular endurance using 2 minutes of maximal push-ups and 2 minutes of maximal sit-ups, to predict simulated battlefield physical performance with five 30 m sprints, a 400 m run, a casualty drag, and an 8-station obstacle course. Harman et al. [41] found significant correlations with push-up scores and the 400 m run ($r = -0.51$, $p \leq 0.01$), 30 m sprints ($r = -0.38$, $p \leq 0.05$), obstacle course performance ($r = -0.43$, $p \leq 0.05$) and also found significant correlations with sit-up scores and the 30 m sprints ($r = -0.37$, $p \leq 0.05$) and obstacle course completion time ($r = -0.57$, $p \leq 0.01$). These investigations provide insight in how developing upper body muscular endurance may prove to be beneficial in improving high intensity military task performance.

THE EFFECTS OF LOADS DURING HIGH INTENSITY COMBAT ACTIVITIES

During combat operations servicemen carry equipment that are essential to the completion of the mission, including body armor, weapons, ammunition, food and water, which can burden the servicemen with loads ranging from 21.6 kg to 75 kg [4, 14]. While carrying the heavy loads, troops must be able to effectively perform basic combat related tasks including reacting to contact, pushing and pulling objects, and maneuvering around obstacles. Derrick et al. [44] examined the influence of body armor and weight, ranging from 22 to 35 lbs, on the performance of the Marine while performing simulated combat-type tasks, including a mile foot march, a simulated raid, a casualty rescue, a grenade throw, an obstacle course, and a combat crawl. Derrick et al. found significant decreases in performance between the subjects wearing body armor, versus those not wearing any armor, attributing the performance decrement to the extra weight of the armor [44]. Nelson and Martin [45] examined the effects of load on combative movement performance in men and women, using 5 different load conditions for women ranging from .59 kg to 36 kg, and 6 different load conditions for men ranging from .77 kg to 43.53 kg and assessed their performance during ten and twenty five yard sprints, an agility run, a standing long jump, reaction movement tests, and a ladder climb.

Nelson and Martin concluded that for most of the performance tests, a systematic increase in load produced a systematic decrease in performance, with the 36 kg load resulting in a performance decrement of approximately 25% in all of the performance tests, showing that an increase in load resulted in significantly poorer performance for both the men and women. Pandorf et al. [32] examined load carriage and obstacle course performance among women, utilizing a 14 kg and 27 kg load and a six-station obstacle course and reported a performance decrement of 12% to 26% for the subjects to traverse hurdles, a zig-zag run, and straight sprint

events with the 27 kg load than with the 14 kg load. Pandorf et al. also observed the greatest difference with the low crawl obstacle, which took more than twice as long to complete with the 27 kg load (25.3 sec. $\pm$ 6.3 sec) than the 14 kg load (12.2 sec. $\pm$ 2.3 sec) [32].

Treloar et al. [46] elucidated the effects of load carriage (21.6 kg fighting load comprising webbing, weapon, helmet, and body armor) on five 30 meter timed sprints and found that when subjects were loaded, there was a significant increase in the mean 30 m sprint time (8.2 $\pm$ 1.4 sec, $p \leq 0.01$) compared to when subjects were unloaded (6.2 $\pm$ 0.8 sec, $p \leq 0.01$). Treloar et al. also identified that 51.7% of the total increase in sprint time occurred within the first 5 meters, when subjects were expected to rise from the prone position to begin sprinting, highlighting the importance of upper and lower body power during fire-and-movement activities [46]. In this investigation it was concluded that a fighting load of 21.6 kg significantly affected soldier mobility when conducting explosive, anaerobic military tasks [46].

Larsen et al. [47] examined the effects of the weight of body armor (~17 kg) during a circuit of high intensity combat related tasks and found that participants' circuit time to completion was 7.3 $\pm$ 1.0 seconds slower when wearing armor ($p \leq 0.01$), and shooting, vaulting, and crawling were also slower when wearing armor (0.8 $\pm$ 0.2, 0.4 $\pm$ 0.2, and 1.0 $\pm$ 0.4 seconds, respectively, all $p \leq 0.05$). The major finding of this investigation was that participants' circuit time to completion was 10% slower during the armored trial, concluding that wearing armor impairs repeated high-intensity military task performance [47].

It can be concluded from the above investigations that external loads on servicemen have a degrading impact on the performance of high intensity combat related tasks. More research examining the role of strength and power and the effects of heavy loads greater than 30 kg, on high intensity combat relevant tasks are needed. To ameliorate the performance decrement that

occurs with an external load during high intensity combat related tasks, servicemen can utilize a proper physical training program to strengthen the specific fitness components that are required to perform high intensity tasks while carrying an external load. The following sections will discuss the different training programs utilized in various investigations that have shown to improve the performance of high intensity combat related tasks.

TRAINING TO IMPROVE PERFORMANCE OF HIGH INTENSITY COMBAT TASKS WHILE CARRYING HEAVY LOADS

The Effects of Different Training Programs on Performance of High Intensity Military Tasks

In 1987 Kraemer et al. [29] examined the effects of four different 12-week physical training programs on short duration, high intensity load bearing performance, carrying a total load of 44.67 kg for 2 miles. 35 soldiers were randomly assigned to one of four training groups: An upper and lower body resistance training and high intensity endurance training (HIET) group, which included interval training, an upper body resistance training and HIET group, a resistance training only group (upper and lower body), and a HIET only group. It was found that only the physical training programs that combined resistance training and HIET made significant improvements ($p \leq 0.05$) in the loaded 2-mile load carriage task, suggesting that a combination of resistance training and running is necessary to improve high intensity load bearing performance [29].

Harman et al. [48] examined the effects of a 24-week concurrent physical training program on a loaded (34 kg) 2-mile load carriage task and maximal and repetitive box lifting performance of 46 female soldiers and found maximal box lifting performance improve by 47%

after 24 weeks of concurrent training. Harman et al. also reported after 24 weeks of concurrent training, subjects improved their 2-mile load carriage performance by 32.5% to 4.4 mph, which is considerable faster than what is stated in the Army field manual as the normal rate of march (2.5 mph) on a road [48, 49]. In 2001 Kraemer et al. [50] examined the effect of resistance training on women's strength/power and occupational performances and found that after 6-months of upper and total-body strength training, there was an improvement in the 2-mile loaded-run performance ($p \leq 0.068$) while carrying a 34.1 kg load, but 6-months of aerobic training alone did not improve the loaded-run performance, which is typical of traditional military training today. This indicates that a combination of strength/power and aerobic endurance is vital for significant improvements in this military task [50].

Harman et al. [51] investigated the effects of two different 8-week training programs on military physical performance, with one group utilizing a combined weight based and aerobic endurance training program (WBT), and the other group utilizing the Army Standardized Physical Training Program (SPT), which is predominately a calisthenics and aerobic endurance training program. The subjects trained for 5 days a week for 8 weeks and at the end of the 8 weeks, statistically significant improvements for both groups were reported for all military tasks, and physical tests. In the 400 m run with an 18 kg load, the weight based training group reduced their time by 16%, while the SPT group reduced its time by 11% ($p \leq 0.05$). In the 3.2 km load carriage task with 32 kg, the SPT group reduced its time by 14%, whereas the WBT group reduced its time by 15%. The WBT group reduced its obstacle course time by 10%, while the SPT group reduced its time by 16%. In all of the military testing, there were statistically significant improvements for both training groups ($p \leq 0.05$). The lack of any significant difference in training effect between both training groups may be due to the similarity of the

training programs, the lack of volume with the WBT program (2 sessions a week), and the emphasis of the WBT program being designed to improve speed, agility and endurance, rather than on the development of strength, power, and hypertrophy [51]. Even though the training effect for both programs may not have been statistically different over an 8-week time span, there is no question that a properly designed WBT program would be the premier option to develop the anaerobic capacities of servicemen over a longer time span.

Santtila et al. [52] elucidated the extent of the changes in maximal and explosive strength elicited by an 8-week endurance-based military training period within 72 recruits and reported that when strength training was added to the 8-week basic training regimen, maximal bilateral isometric force of the arm extensors improved significantly by 11.8% ($p \leq 0.001$) compared to the normal basic training group which improved by 7.8% ($p \leq 0.05$). Maximal rate of force development of the upper extremities increased significantly by 28.1% ($p \leq 0.05$) only in the strength training group and maximal leg extension strength increased by 12.9% ($p \leq 0.01$) compared to the normal basic training group where no significant change occurred (5.2%, $p = 0.45$). This investigation shows that normal endurance-based basic training may be inadequate to elicit significant changes in upper and lower body maximal and explosive strength, and a proper resistance training program must be supplemented to the normal basic training regimen, in order to have any significant changes in maximal and explosive strength [52].

Hendrickson et al. [53] utilized 56 recreationally trained women to investigate 3 different physical training programs and their effect on tactical occupational tasks, including a 3.2 km load carriage task, an obstacle course, and a 61.4 kg mannequin drag and found that 8 weeks of non-linear, periodized combined strength and aerobic endurance training resulted in increases in maximal strength and peak power that were not significantly different from strength training

alone. Hendrickson et al. reported improved performance in tactical occupational tasks, with combined strength and aerobic endurance training resulting in the largest percent improvement for each of the tactical occupational tasks tested with a -9.8% decrease in mannequin drag time, a -13.1 % decrease in the 3.2 km load carriage time, and a -5.3% decrease in obstacle performance time [53]. From the literature reviewed, it can be concluded that a properly designed concurrent strength and aerobic endurance training program may be the premier program to improve high intensity, tactical occupational tasks.

Optimizing Training to Improve Performance of High Intensity Military Tasks Under Load Carriage

Before designing and implementing a physical training program to improve battlefield performance, it is of utmost importance to first conduct a "needs analysis" of the modern battlefield and of the servicemen [54]. This process involves a thorough evaluation of the characteristics and demands of combat activities and also profiles the needs of the servicemen by assessing training status, and determining the primary goal of training, thus providing an individualized training program to meet the needs of the battlefield [40, 55]. In a review by Kraemer and Szivak [54] on optimizing strength training for the warfighter, the modern battlefield today was referred to as an "anaerobic battlefield", with anaerobic demands, requiring servicemen to possess muscle size, strength and power, with only needed cardiovascular support. This can be observed with the recent wars in Afghanistan and Iraq, where many combat operations that were conducted consisted of direct action raids, which would transport the troops directly onto or near an objective by ground or air. Due to different battlefield terrain, along with the risk of Improvised Explosive Devices (IED's), and with a view of maintaining combat

effectiveness throughout an operation, it was rare to march long distances to reach an objective (>10 km), which is very typical of traditional military training today.

While on an objective, servicemen are expected to conduct anaerobic tasks like sprinting, climbing, jumping, pulling and pushing while carrying significant loads. Physiologically, these combat activities reveal the necessity of lower body and upper body strength and power, and also aerobic endurance, in order to effectively conduct and complete missions. Muscle hypertrophy may also be advantageous for the warfighter to conduct high intensity combat activities, since greater muscle cross-sectional area increases the muscle's ability to produce force [40, 54]. In order to optimally develop upper and lower body muscle hypertrophy, strength and power, while maintaining aerobic capacity, a proper physical training program founded on the principles of specificity, progressive overload, and periodization must be designed [40].

CONCLUSION

After comprehensive review of the literature, there is still much to be investigated regarding high intensity combat relevant tasks and load carriage performance. The focus of many studies and reviews have elucidated the physiological determinants of medium to long distance marching under various loads and the influence of different physical training programs on load carriage performance at medium to long distances. Studies have also examined the effects of load carriage on the performance of high intensity combat tasks, however studies examining the physiological determinants of high intensity combat tasks under heavy load carriage, along with the proper training required to improve performance in these types of tasks is warranted. Further research determining the physiological requirements of heavy load carriage and the performance

of high intensity tasks encountered on the battlefield today must be conducted. Further investigation elucidating the physiological underpinnings of high intensity tasks under heavy load carriage, allows the appropriate exercise prescription to be designed, which leads to the optimal development of the physical capacities of the servicemen to meet the demands of today's "anaerobic battlefield".

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CHAPTER 3

METHODS

Subjects

18 recreationally active men (age, 21.8 ± 2.4 yr, height, 172.9 ± 6.4 cm, weight, 80.7 ± 13 kg) participated in this investigation. All of the subjects were required to complete a medical questionnaire and were screened by a physician for any orthopedic, cardiovascular, or other medical problems that may prevent a subject from safely completing the study and confound the results of this investigation. 12 subjects were recruited for this study from the Army Reserve Officer Training Corps (ROTC) unit out of the university population, and 6 subjects were civilian students from the university population. Participants were briefed on the risks and benefits of the investigation and afterwards completed a written informed consent form to participate in the study. This investigation was approved by the Institutional Review Board for use of human subjects at the University of Connecticut. Subject characteristics are presented in Table 3.1.

Subject number	Ht. (cm)	Wt. (kg)	Age (Year)	AVG Peak Pow. (W)	1RM SQ. (kg)	1RM BCP (kg)	2 Miile Run (sec.)	Push-ups (2 min.)	Sit-ups (2 min.)	Course time Loaded (sec.)	Course time Unloaded (sec.)
1	178	86.1	22	4346.3	113.6	113.6	853	72	76	37.4	28.1
2	168	81.1	21	2982.8	70.5	79.5	943	64	79	36.2	28.1
3	173.5	58.9	21	2625.8	68.2	56.8	823	48	64	45.1	29.2
4	162	61.4	22	2949.3	79.5	79.5	868	77	73	44.8	34.1
5	173	78	19	3968.7	86.4	95.5	763	92	90	29.8	25.2
6	165	66.6	21	3336.4	65.9	63.6	979	60	73	41.6	27.8
7	179.5	80	22	3845.5	127.3	88.6	900	71	78	31.1	25.3
8	169.5	98.8	21	4590.0	152.3	102.3	1024	60	48	30.8	24.4
9	176.25	104.9	30	6571.6	275	188.6	1259	106	64	28.8	23.3
10	173.5	84.7	24	4806.8	143.2	118.2	933	53	55	39.4	28.4
11	162	69.7	20	3580.7	84.1	81.8	896	62	70	38.0	28.5
12	187	103.6	23	6198.1	213.6	156.8	1025	53	53	29.4	23.5
13	173.5	88.6	22	4660.4	156.8	118.2	963	75	35	33.4	26.5
14	177	72.1	21	3870.6	111.4	84.1	901	76	78	35.8	28.5
15	177	74.9	20	3859.0	95.5	70.5	872	75	69	36.5	27.7
16	175	78.3	20	3464.3	102.3	88.6	842	63	65	31.2	25.4
17	167	77.9	21	3911.1	163.6	120.5	874	80	74	34.8	25.1
18	176	86.4	22	5168.1	122.7	113.6	945	60	71	31.8	23.9
Mean	172.9	80.7	21.8	4152.0	124.0	101.1	925.7	69.3	67.5	35.3	26.8
SD ±	6.4	13.0	2.4	1055.7	54.5	32.8	107.4	14.4	13.0	5.1	2.6

Table 3.1 Subject Characteristics

Experimental Controls

To reduce variance caused by differences in age, and to be able to generalize our findings to a military population, subjects that were recruited for the study were men between the ages of 18-35. Also, since physical fitness tests are regularly administered twice a year to ensure the maintenance of a base level of physical fitness essential to every military occupation, active combat units physically train at least three times a week to maintain a level of fitness and combat readiness [1, 2]. Subjects in this study were recreationally trained men who exercised at least three times a week for 60 minutes each day.

To control for any extraneous variables in the participant's diet and activity, subjects were asked to record their diet and activity for 48 hours prior to their first performance of the military course. Participants were also encouraged to continue their normal exercise routines, but refrain from strenuous exercise during the 48 hours prior to the first visit. After the first performance of the military task course, subjects replicated their diet and activity logs for another 48 hours prior to their final performance of the military tasks course, ensuring that subjects would be in a similar physiological state during both visits.

Subjects also performed both of the visits at the same time of day, reducing the influence of diurnal hormone variations. All of the military task visits were conducted at night, since the majority of direct action raids and combat operations take place in the evening. Lastly to reduce inter-tester variability, the same tester recorded the timing of the military course for each subject.

Experimental Design

A within-group, randomized, counterbalanced design was utilized for this investigation. To minimize learning effects related to the unfamiliarity of the different protocols in the study,

prior to any data collection, participants underwent a familiarization session, which exposed the subjects to the experimental conditions of the performance testing protocol, the Army Physical Fitness Test (APFT) protocol, and the military course protocol. In addition, anthropometric measurements were also performed, and subjects were familiarized with a standardized dynamic warm up protocol that would be used before all experimental visits. The standardized warm–up consisted of 5 minutes on a cycle ergometer at a resistance level of 5, with a speed maintained under 60 rpm, followed by dynamic stretches, including forward and lateral lunges, knee hugs, quadriceps stretches, straight leg marches, and body weight squats [3]. Furthermore, to reduce any stress related to the military load, subjects were also fitted for the Interceptor Body Armor (IBA) and MOLLE rucksack and were instructed on proper wear technique.

Performance Testing Protocol

Following the familiarization session, participants completed a countermovement jump protocol, a 1 repetition max (1RM) squat protocol and a 1RM bench press protocol in the same visit. After performing the standardized warm-up, countermovement vertical jump power was assessed using a force plate and associate software (Fitness Technology, Australia, Ballistic Measurement System Software, Australia). Lower body power testing, and 1RM testing were assessed using previously described methods [4]. Subjects were asked to perform three consecutive maximal jumps with their hands on their hips. Participants performed two sets of the countermovement jumps, with at least 2 minutes of rest between sets. The highest power for each set was recorded. Subsequently after the countermovement jump testing, lower body strength was assessed by a 1RM squat protocol using a Smith machine, and upper body strength was assessed with the use of a 1 RM free-weight bench press protocol. For each 1RM test,

subjects performed 8-10 repetitions at ~50% of estimated 1-RM, followed by another set of 3-5 repetitions at 85% of 1-RM. Up to four maximal trials separated by 2-3 minutes of rest were used to determine individual 1-RM's for the squat and bench press exercise [4].

Army Physical Fitness Testing

Following the performance testing protocol, subjects were given at least 24-hours of rest before performing the Army Physical Fitness Test (APFT). After the completing the standardized warm-up, subjects performed the APFT according to Army Field Manual 21-20 [1], which consists of 2 minutes of maximal push-ups, 2 minutes of maximal sit-ups, and a timed 2-mile run. A rest of 3-5 minutes was allotted between each test. The ROTC cadets in this investigation performed the APFT one week prior to participation in this study, fulfilling a requirement for enrollment in the Army ROTC program. APFT scores were utilized from this testing session and were deemed reliable, since test administration was given by experienced Army personnel and according to FM 21-20.

Military Course Protocol

Following a minimum of 48-hours of rest, subjects completed a visit in randomized order, which was either unloaded (combat uniform, and boots [~3.2 kg]) or loaded (combat uniform, boots, IBA [6.9, 8.1, or 9.1 kg depending on size] and MOLLE rucksack [30 kg]), carrying a total weight of ~ 42 kg. The remaining visit was then completed 48 hours later. For each visit, after performing a standardized warm-up, subjects were reminded of the test protocols for the military course. The military course consisted of three consecutive military relevant tasks and began from the prone position, leading into a 30 m sprint, followed by a ~27 m zig-zag run,

and concluding with a 10 m, 79.5 kg casualty drag, which is the approximate weight of a U.S infantryman with a combat load [5]. Timing for the course began with the first upward movement from the prone position, and finished at the end of the casualty drag apparatus when the subject passed the 10 m mark. Times were hand recorded by the same timer using a stopwatch (Fisher scientific, Waltham, MA). Three trials were performed to increase the reliability of recorded performance times [6], and a five-minute rest was given in between each trial to ensure adequate recovery.

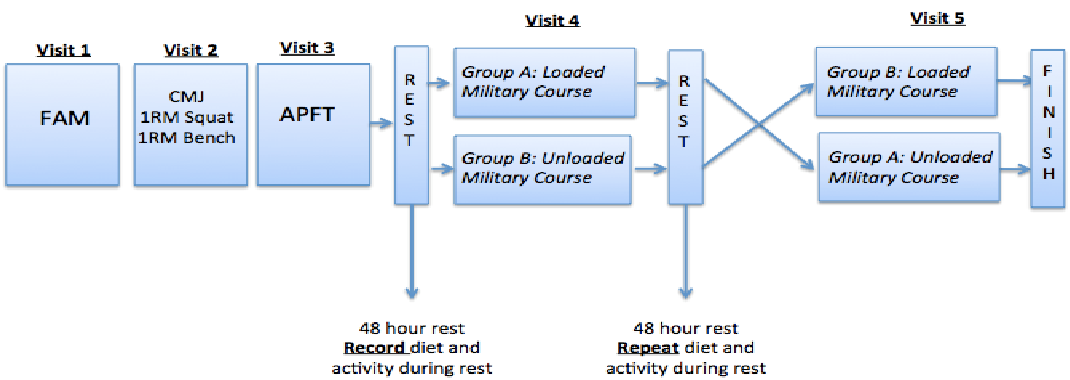

Figure 3:1. Sequence of the investigation

Familiarization	Performance Test	APFT	Military course (unloaded or loaded)
Anthropometrics taken	Standardized warm-up	Standardized warm-up	Standardized warm-up
Standardized warm-up -Countermovement jump protocol -1 RM squat protocol -1 RM bench press protocol -APFT protocol -Fitting for IBA and MOLLE -Military course protocol	Countermovement Jumps -Two sets of 3 consecutive maximal jumps.	2 minutes of maximal push-ups	Start from prone position, leading into 30 m sprint, followed by 27 m zig-zag running, concluding with 10 m casualty drag.
	1 RM squat -1 set of 8-10 reps at 50% estimated 1RM -1 set of 3-5 reps at at 85% estimated 1RM -Up to 4 maximal 1 RM trials	2 minutes of maximal sit-ups	3 Trials, with 5 minutes rest in between each trial.
	1 RM Benchpress -1 set of 8-10 reps at 50% estimated 1RM -1 set of 3-5 reps at at 85% estimated 1RM -Up to 4 maximal 1 RM trials	2-mile run	48-hour rest and repeat military course protocol with opposite experimental condition

Figure 3.2 Details of each visit in the experiment

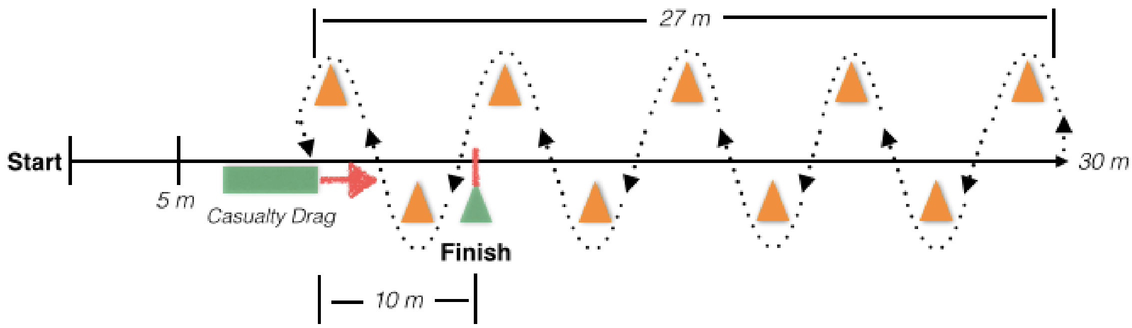

Figure 3.3. Overall military course

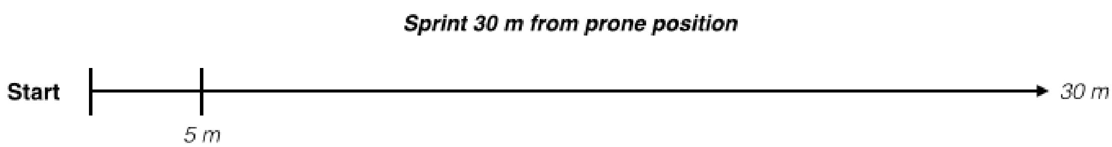

Figure 3.4. Task 1 of military course

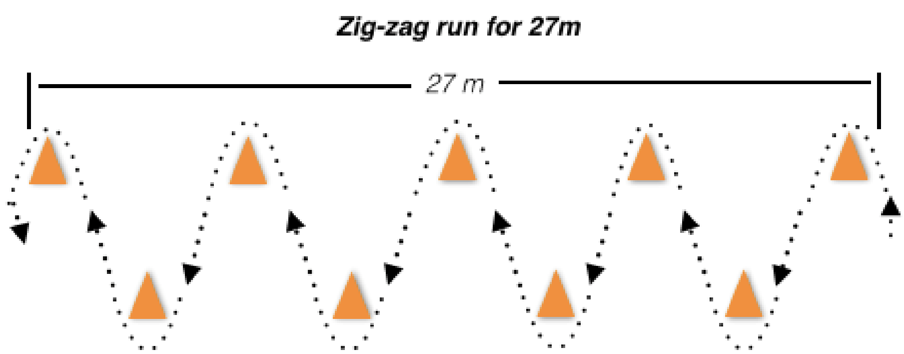

Figure 3.5. Task 2 of military course

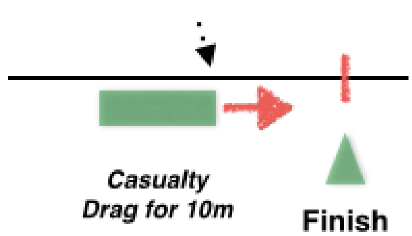

Figure 3.6. Task 3 of military course

Statistical Analysis

It was determined that an n-size of 18 would be sufficient to defend the 0.05 alpha level of significance with a Cohen probability of ≥ 0.80 for each dependent variable (nQuery Advisor software, Statistical Solutions, Saugus, MA). Subjects were separated into two different groups based on their primary modality of training for the past year (Resistance trained [RT] and Traditional Army trained [AT]). A 2 (RT v. AT) by 2 (loaded trial v. unloaded trial) by 5 (total time, 5m time, 30 m time, agility time, causality drag time) mixed methods analysis of variance (ANOVA) was used to detect significant mean differences (SPSS Version 21). When significant differences were observed, a Fisher's LSD post-hoc analysis was used to make pairwise comparisons. A Pearson product moment correlation was utilized to determine the relationship between potential anthropometric and performance predictors and military task performance. We also used independent t-tests to compare mean values for these potential predictors in the two groups. All values are presented as means and standard deviations, and significance was set at $p \leq 0.05$.

CHAPTER 4

RESULTS

Overall Unloaded and Loaded Times for RT and AT Groups

Subjects were separated into two different groups based on their primary modality of training for the past year (Resistance trained [RT] and Traditional Army trained [AT]). Subject characteristics for the RT and AT group can be observed in table 4.1.

RT			AT		
Age (yr)	HT (cm)	WT (kg)	Age (yr)	HT (cm)	WT (kg)
22	178	86.1	21	168	81.1
22	179.5	80	21	173.5	58.9
21	169.5	98.8	22	162	61.4
30	176.25	104.9	21	165	66.6
24	173.5	84.7	20	162	69.7
23	187	103.6	20	177	74.9
22	173.5	88.6	20	175	78.3
21	167	77.9	21	177	72.1
22	176	86.4			
19	173	78			
22.6 ± 2.9	175.3 ± 5.6	*88.9 ± 10.1	20.8 ± .7	169.9 ± 6.5	*70.4 ± 7.8

Table 4.1 Subject characteristics for RT and AT group (Mean ± SD). * Significant difference ($p \leq 0.05$)

In the AT group, significant differences were found between the unloaded (28.7 ± 2.5 sec) and loaded (38.7 ± 4.8 sec) conditions, with the loaded condition eliciting a significant 35% increase in overall course time when compared to the unloaded time (10.0 ± 3.4 sec, $p \leq 0.05$). Significant differences were also found within the RT group between the unloaded (25.4 ±1.8 sec) and loaded (32.7 ± 3.6 sec) conditions, with the loaded condition eliciting a significant 29% increase in overall course time when compared to the unloaded time (7.3 ± 2.1 sec, $p \leq 0.05$). The AT group took significantly longer to complete the military course under a load when

compared to RT group (RT 7.3 ± 2.1 sec, 29% increase vs. AT 10.0 ± 3.4 sec, 35% increase, $p \leq 0.05$). The means and standard deviations of the unloaded military course time and the loaded military course time for the RT and AT group can be seen in figure 4.1.

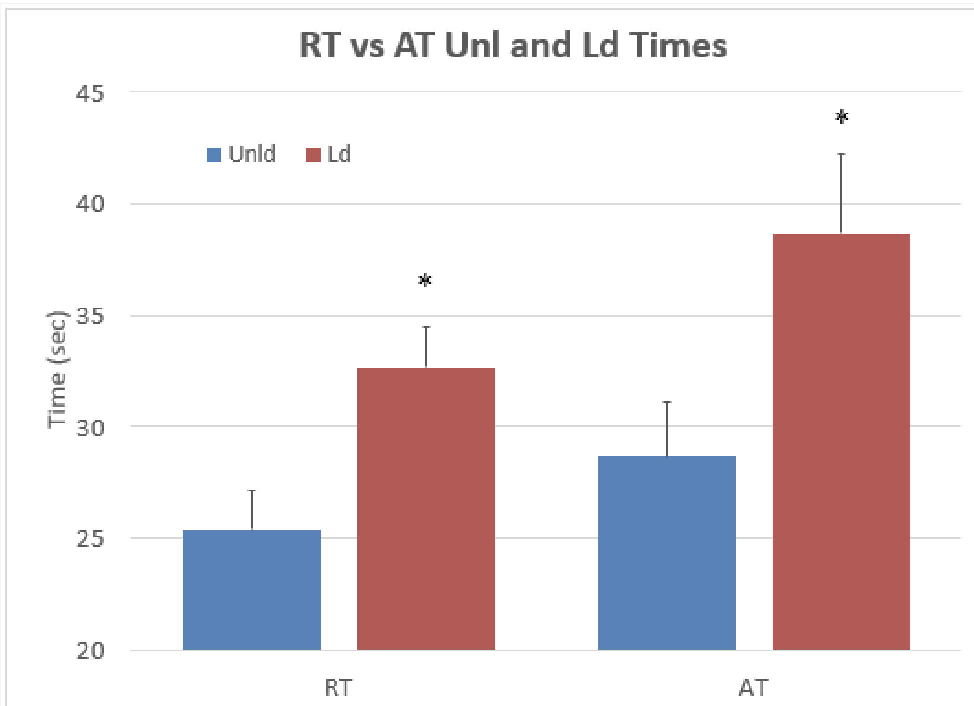

Figure 4.1. Mean differences in military course times under the unloaded and loaded condition for RT and AT groups. Error bars designate standard deviations. * Significant difference.

Overall Loaded Course Time with Components

Average time to complete the total course under a load and each component within the course can be seen in Figure 4.2. In the loaded condition the RT group performed the entire military course significantly faster ($p \leq 0.05$) than the AT group. Within the course, the RT group performed significantly faster when rising from the prone to the first 5m, and performing the casualty drag ($p \leq 0.05$).

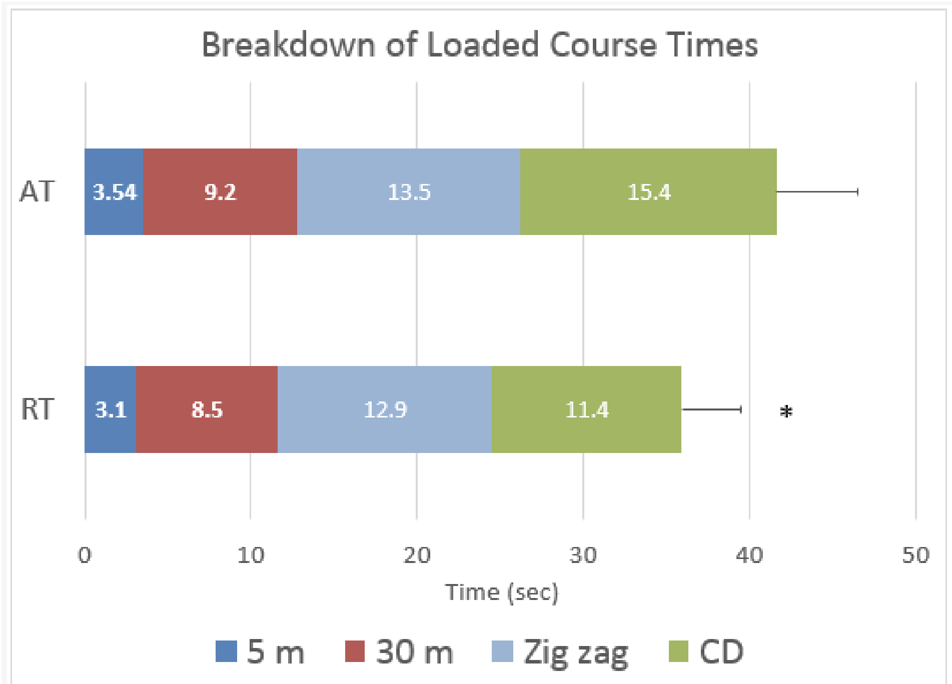

Figure 4.2. Mean differences for RT and AT groups in overall loaded military course times and each component within the course. Error bars designate standard deviations. * Significant difference.

Completion Times for Overall Course and Components

The means and standard deviations of the overall military course time and each component within the course for the RT and AT groups in the loaded and unloaded condition can be seen in Table 4.2.

Mil. Test Components	RT Loaded	RT Unloaded	AT Loaded	AT Unloaded
5 m	3.09 ± .4 sec	1.68 ± .1 sec	3.56 ± .5 sec	1.7 ± .13 sec
30 m	8.48 ± .9 sec	5.78 ± .3 sec	9.27 ± 1.1 sec	5.94 ± .2 sec
Zig-Zag	12.8 ± 1.1 sec	10.4 ± .7 sec	13.7 ± .9 sec	10.5 ± .5 sec
Casualty Drag	11.2 ± 2 sec	9.2 ± 1.3 sec	16.1 ± 3.7 sec	12 ± 2.5 sec
Total Time	32.7 ± 3.6 sec	25.4 ± 1.8 sec	38.7 ± 4.8 sec	28.7 ± 2.5 sec

Table 4.2. Times for each component within the military course and total time for the RT and AT groups under both conditions. Mean ± SD.

Relationship Between Loaded Military Course Time and Power

A Pearson's correlation of individual scores for the loaded military course time versus power output is provided in Figure 4.3. There was a strong negative correlation between total loaded time and peak power ($r = -0.67$, $p \leq 0.05$), with peak power explaining 45% ($r^2 = .45$) of the variation in total loaded time.

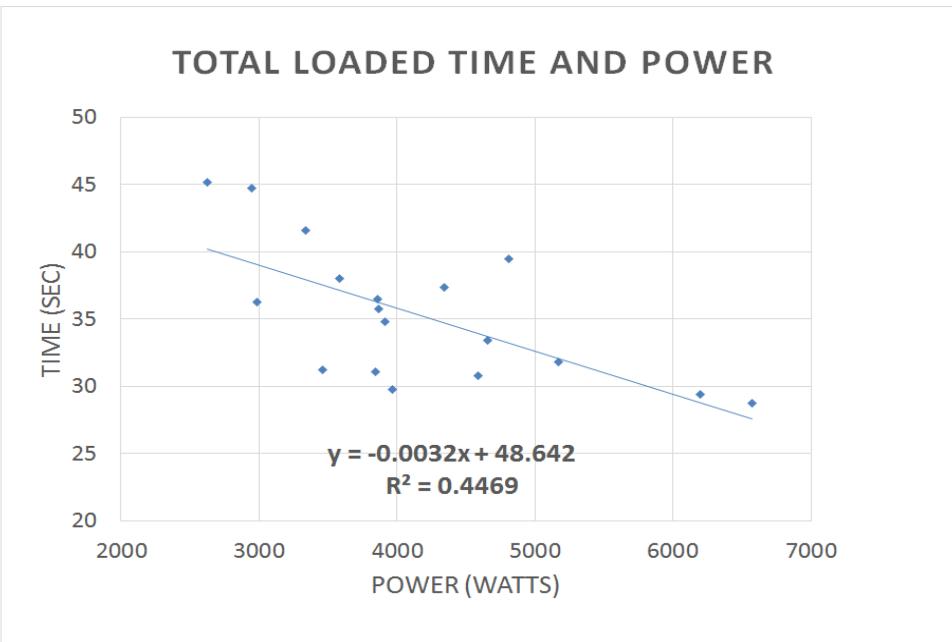

Figure 4.3. Scatterplot representing individual scores (data points) of each subject for military load times (sec) and power output (W). Linear trend line is shown along with r^2 value.

Relationship Between Loaded Military Course Time and Lower Body Strength

The correlation of individual scores for the loaded military course time and squat 1RM can be observed in Figure 4.4. There was a strong negative correlation between total loaded time and squat 1 RM (kg) ($r = -0.62$, $p \leq 0.05$), with squat 1 RM explaining 39% ($r^2 = .39$) of the variation in total loaded time.

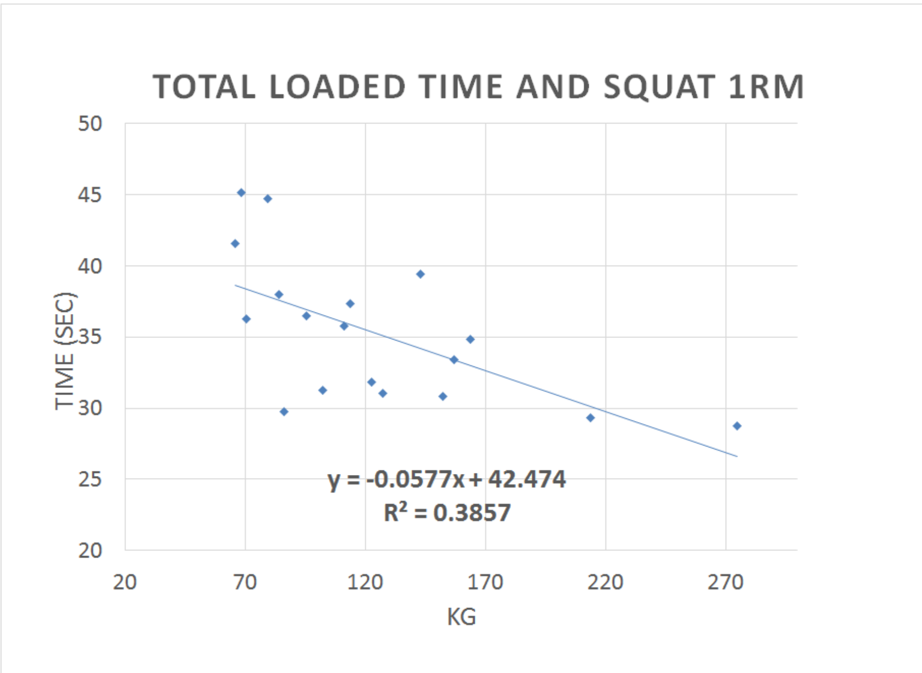

Figure 4.4. Scatterplot representing individual scores (data points) of each subject for military load times (sec) and squat 1RM (kg) scores. Linear trend line is shown along with r^2 value.

Relationship Between Loaded Military Course Time and Upper Body Strength

The correlation of individual scores for the loaded military course time and upper body strength can be observed in Figure 4.5. There was a strong negative correlation found between total loaded time and bench press 1 RM (kg) ($r = -0.62$, $p \leq 0.05$), with bench press 1 RM explaining 39% ($r^2 = .39$) of the variation in total loaded time.

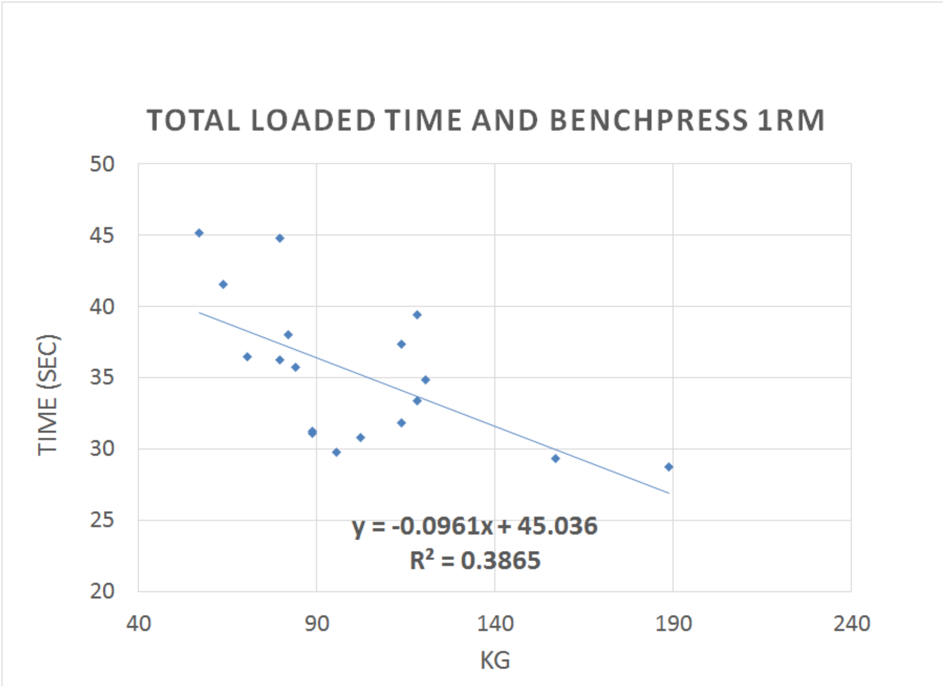

Figure 4.5. Scatterplot representing individual scores for overall military load time (sec) and bench press 1RM (kg). Linear trend line is shown along with r^2 value.

Relating Performance Test Variables to Loaded Military Course Performance

The correlation of all the performance testing variables with the loaded military course time and its three components can be observed in Table 4.3. Strong correlations can be observed for the strength and power measures with the overall military loaded task, and the majority of the components within the course. There was only one significant correlation between a component of the APFT (number of push-ups) and performance on the loaded military course (total time).

	Total Loaded	Loaded 5 m	Loaded 30 m	Loaded zig-zag	Loaded casualty drag
Peak Power	-0.67 **	-0.66 **	-0.60**	-0.39	-0.64**
Squat 1 RM	-0.62**	-0.70 **	-0.58*	-0.48*	-0.57*
Bench press 1 RM	-0.62**	-0.65 **	-0.54*	-0.44	-0.59**
Push-ups	-0.38*	-0.507	-0.428	-0.254	-0.34
Sit-ups	0.113	0.104	-0.069	0.095	0.138
2 mile run time	-0.374	-0.112	-0.285	0.043	0.036

Table 4.3. Correlation matrix of all performance testing variables with overall loaded military course time and the three different components of the military test. ** significant at $p \leq 0.01$ level. * significant at $p \leq 0.05$ level.

Group-Specific Differences in Military Course Performance Predictors

The means and standard deviations of peak power for RT and AT groups can be seen in figure 4.6. The two groups differed significantly, with the RT group averaging 44% greater peak power than the AT group (RT = 4806.7 ± 936.3 W; AT = 3333.6 ± 449.5). Squat 1RM means and standard deviations for the RT and AT groups can be seen in figure 4.7. Significant differences were found between the RT (155.5 ± 54 kg) and AT groups (84.7 ± 16.9 kg), with the RT group averaging 83% greater lower body strength.

The means and standard deviations of bench press 1 RM can be seen in figure 4.8 for the RT and AT group. Significant differences ($p \leq 0.05$) were found between the RT (121.6 ± 29.9 kg) and AT groups (75.6 ± 10.9 kg), with the RT group averaging 61 % greater bench press 1 RM than the AT group. Significant differences were not found for any of the APFT variables between the RT and AT group. The means and standard deviations of the APFT variables between the two groups can be seen in table 4.4.

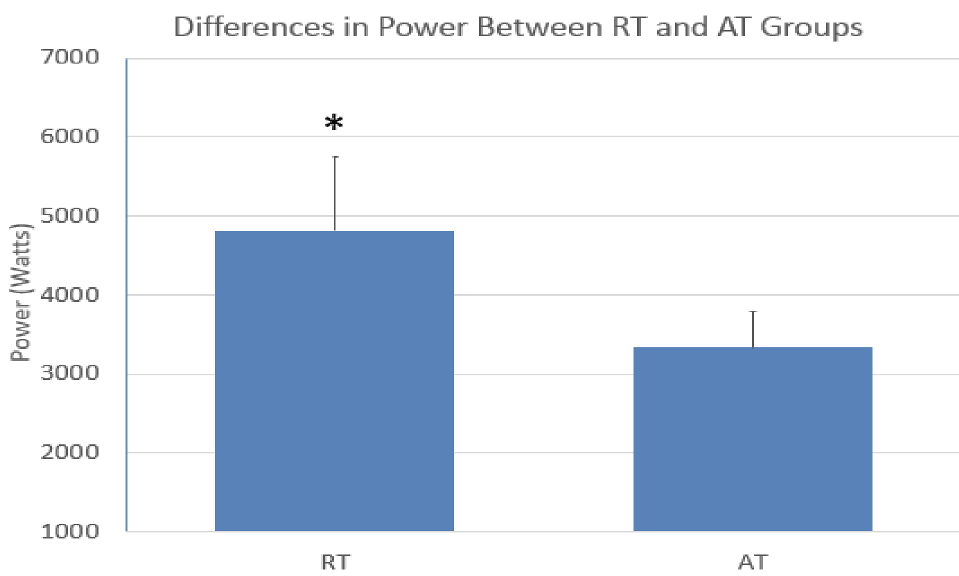

Figure 4.6. Mean differences in peak power (W) for the RT and AT group. Error bars designate standard deviations. * Significant difference at $p \leq 0.05$ level.

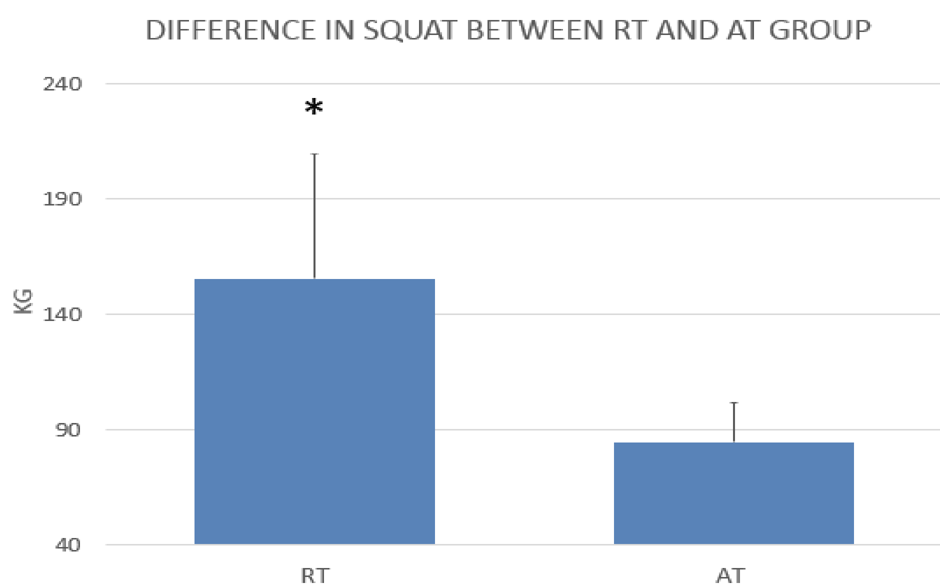

Figure 4.7. Mean differences in squat 1 RM (kg) for the RT and AT group. Error bars designate standard deviations. * Significant difference at $p \leq 0.05$ level.

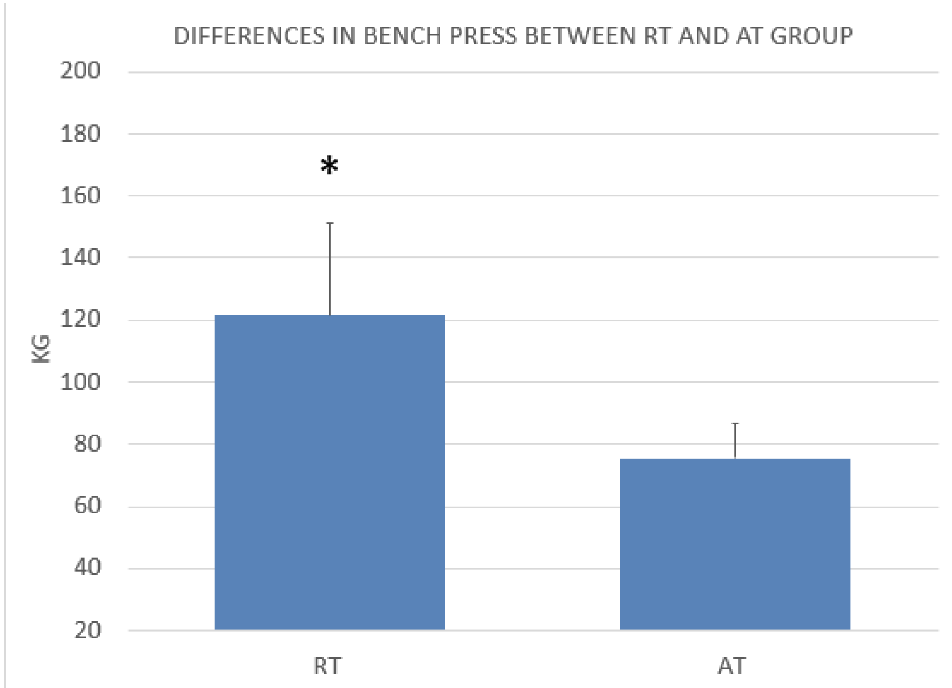

Figure 4.8. Mean differences in bench press 1 RM (kg) for the RT and AT group. Error bars designate standard deviations. * Significant difference at $p \leq 0.05$ level.

A.P.F.T Components	RT (mean ± SD)	AT (mean ± SD)
2 min. Push-ups	72 ± 17	66 ± 10
2 min. Sit-ups	64 ± 17	71 ± 5
2 mile run (sec)	954 ± 133	891 ± 51

Table 4.4. Mean scores of the APFT testing components for the RT and AT group. No statistically significant differences were observed between the RT and AT group in any testing component ($p \leq 0.05$).

CHAPTER 5

DISCUSSION

The purpose of this study was to determine the role of strength and power on short duration, high intensity military tasks incorporating heavy load carriage. Most studies that have examined strength and power in military tasks have not utilized significant loads, or assessed strength and power in conjunction with performance outcomes on high intensity tasks with significant loads. This investigation utilized only three military relevant tasks (prone position into 30 m sprint, 27m zig-zag run, 10 m casualty drag) vs the multi-station (8-19) obstacle courses frequently used in other investigations, since direct action raids mostly involve short distance sprinting around obstacles and to points of cover. The first 5 m of the 30 m sprint began from the prone position because it was here that Treloar et al. [7] observed the greatest decrement in 30 m loaded sprint times. A short distance casualty drag was included to simulate a battlefield scenario where a serviceman would quickly transfer the casualty behind a point of cover to administer first aid. Also, the overall load utilized in this investigation (~42 kg) is typical of a U.S. infantryman during modern combat operations [5].

There were strong negative correlations between upper body strength, lower body strength, lower body power, and overall loaded military course time, highlighting the role of strength and power during high intensity combat-relevant tasks (see Table 4.3). It is important to mention that the negative correlations indicate that greater strength and power were associated with shorter course completion times. These findings coincide with Jette et al. [8], Bishop et al. [9] and Treloar et al. who found significant correlations between strength and power and military obstacle course performance. Strength and power being highly correlated to high intensity

military tasks is also congruent with the findings of Harman et al. [10] who found that lower body power could predict simulated battlefield performance on a course that included a 30 m run and a 27 m zig-zag run with an 18 kg combat load. In the present investigation, lower body strength was the only variable that had a consistently strong correlation with overall loaded course time, as well as every component of the course (prone position to 5m, 30 m sprint, 27 m zig-zag run, 10 m casualty drag).

Another important observation is the lack of a significant relationship between push-ups, sit-ups, and 2-mile run time with respect to overall time on the loaded military course (see Table 4.1). This coincides with previous findings by Pandorf et al. [11] who observed that APFT scores did not correlate with performance on a loaded military obstacle course. The only significant correlation between any APFT variable and military course time was the association between number of push-ups and time to rise from prone and sprint 5 m. This coincides with previous findings, which suggested that push up ability is related to the performance of fire and movement techniques [7, 10]. The lack of correlation between push-ups, sit-ups, and 2-mile run time with respect to high intensity combat tasks is highly relevant: the majority of the military continues to use calisthenics and aerobic training as the primary methods of preparation for combat deployment. Yet, the physical demands of deployment more closely mirror the conditions of the loaded military course used in the present investigation. Given the observed strength of correlations between strength/power and performance on the high intensity combat task, it is likely that a strength and conditioning program that focuses on the development of strength and power will better prepare our servicemen to meet the demands of the battlefield [12-14]. Such a program could incorporate training that would develop aerobic capacity concurrently.

To further elucidate differences between resistance training and traditional Army training in terms of the performance on high intensity combat tasks, groups were dichotomized based on training history over the previous year, resulting in placement into a resistance trained (RT) or traditional Army trained (AT) group. Significant differences between the groups were found for lower body power, squat 1 RM, bench press 1 RM, and most importantly, performance on the loaded military course. It is important to note that while RT out-performed AT on the overall loaded military course (by 5.99 sec on average ($p \leq 0.05$); 4.95 sec (82%) of the time difference was attributed to performance on the casualty drag component. This is not surprising, as it was the most heavily loaded component of the course, and was therefore likely to be most sensitive to differences in upper and lower body strength. As measured by the squat 1RM, the RT group had substantially more lower body strength when compared to the AT group (155.5 ± 54 kg vs. 84.6 ± 16.9 kg, $p \leq 0.05$). Significant differences were also found for bench press 1RM (RT: 121.6 ± 29.9 kg, AT: 75.5 ± 10.9 kg, $p \leq 0.05$). In light of these differences, it is no surprise that the RT group performed significantly better in the casualty drag, since this military task involves the same muscle groups in the upper and lower body as the squat and bench press.

The two groups also differed on the time to complete the first 5 m of the course, where subjects rose from the prone position to sprint 30 m. On average, this segment accounted for 10% of the difference in total course time (.5 sec), with RT outperforming AT. The action of rising from the prone position with a load into a sprint requires significant upper and lower body strength, which is also reinforced with the strong correlations of the bench press 1 RM and the squat 1 RM with the prone to 5 m task ($r = -0.65$, $r = -0.70$, respectively, $p \leq 0.05$). There were no significant differences between the RT group and the AT group for the loaded 30 m sprint time, and the loaded 27 m zig-zag run time, which coincides with Harman et al. [15], who

observed no significant differences between 8-weeks of Army training and weight training in terms of timed 30 m rushes with fighting loads.

The observed effect of loading on military course performance was expected and corresponds with previous research. Overall, performance on the military course decreased 31% when loaded (26.8 ± 2.7 sec vs 35.3 ± 5.0 sec, $p \leq 0.05$). This is similar to the findings of Treloar et al. [7] who observed a 29% increase in time when a 21.6 kg load was added to 30 m sprints. The larger performance decrements observed in this study may be explained by the use of a heavier loading scheme. The increase of the weight of body armor has also been shown to significantly impair repeated high-intensity military tasks, with time to completion being 10% slower during armored trials. When examining overall performance decrements during loaded trials in the RT and AT groups, the AT group had a 35% increase in course time versus the RT group, where a 29% increase in course time was observed. The significant difference in performance between the RT and AT groups can be attributed to the significant difference ($p \leq 0.05$) in RT group body mass (88.9 ± 10.1 kg vs. 70.4 ± 7.8 kg). This finding is in line with previous investigations, which have shown that larger, more muscular individuals perform better and are less affected by heavier loads than smaller, less muscular individuals [11, 16].

The lack of a significant difference between the RT and the AT group in the loaded 30 m sprint time and the 27 m zig-zag run time may be due to the familiarity of the AT group with military loads and equipment. Even though each subject was familiarized with the course and the load, the AT may have had an advantage due to prior training exposure. The AT group consisted of ROTC cadets, while the RT group was mainly comprised of civilians who had no experience wearing military loads. Thus even larger differences might have been evident if the groups had similar overall exposure to military load carriage. Furthermore, a significant

difference in weight was observed between the RT and the AT groups (88.9 ± 10 kg vs. 70.4 ± 7.8 kg, $p \leq 0.05$), which may help explain the lack of difference in the 30 m and 27 m zig-zag run time. Individuals with more body weight carry their own weight, in addition to the external load, with the heavier subjects carrying a greater overall load, which may place the heavier subject at a disadvantage during the 30 m sprint and 27 m zig-zag run. Despite the significant differences in weight, 30 m sprint time (8.5 ± .9 sec vs. 9.3 ± 1.1 sec) and 27 m zig-zag run times (12.8 ± 1.1 sec vs. 13.7 ± .9 sec) were not statistically different between the RT and AT groups. This may be explained by the RT group possessing a significantly greater amount of lower body power, offsetting the detrimental effects of extra weight, reinforcing the importance of lower body power.

Subjects were also placed in the RT and AT groups on the basis of their training history (at least 3x a week for the past year in one modality) with no information on the specific variables of their training programs (power, hypertrophy, strength, intensity, etc.). Greater differences may be observed if strictly power or strength trained subjects are compared with traditional army trained subjects. There is a need for further investigation concerning the effects of different training programs (strength, power, hypertrophy, calisthenics, etc.) on the performance of short duration, high intensity military load carriage tasks.

Conclusions

This investigation examined the role of upper and lower body strength and power on performance in short duration, high intensity, combat relevant tasks, under conditions of heavy load carriage. While we used distinct combat task length (3 tasks vs 8-19 tasks in other studies), the current findings support the observations of previous studies. The physiological

underpinnings of the modern battlefield remain to be fully elucidated; yet this investigation has underscored the overriding importance of strength and power in today's "anaerobic battlefield". The findings from this investigation may be utilized as a basis to develop optimal training regimens that include strength, power, and hypertrophy training. For combat occupations, these approaches would likely improve combat effectiveness by helping servicemen meet the demands of the battlefield, and more safely complete the mission.

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Consent Form for Participation in a Research Study

University of Connecticut

Principal Investigator: Dr. William Kraemer
Study Title: The role of strength and power during the performance of anaerobic military relevant tasks under heavy load carriage.

Introduction

The purpose of this study is to examine the relationship between strength and power and anaerobic military relevant tasks. Specifically, we will be examining the relationship of upper and lower body strength and power between the performance of anaerobic military relevant tasks while carrying a military ruck sack, with a heavy load.

This consent form will give you the information you will need to understand why this study is being done and why you are being invited to participate. It will also describe what you will need to do to participate and any known risks, inconveniences or discomforts that you may have while participating.

We encourage you to take some time to think this over and to discuss it with your family, friends and doctor. We also encourage you to ask questions now and at any time. If you decide to participate, you will be asked to sign this form and it will be a record of your agreement to participate. You will be given a copy of this form.

Why is this study being done?

Training within the military has primarily been focused on aerobic endurance training, yet many of the demands of today's battlefield require anaerobic strength and power. The ability to carry heavy loads over long distances, in the fastest time, are essential aspects of soldiering, but the anaerobic aspect of soldiering has nearly been neglected. In addition to the need to be able to carry loads over long distances, Soldiers also need to be able to move in explosive ways during firefights and ambushes. The majority of existing research today has been focused on the many aspects of load carriage over long distances, but there is little research on the aspects of load carriage during short, anaerobic, explosive tasks. We hypothesize that there will be a significant relationship between strength and power and the performance of anaerobic military tasks under heavy load carriage. This will have beneficial implications for individuals wishing to join the armed services, and current Soldiers within the military, enabling them to focus their training regimens to meet the demands of today's battlefield.

What are the study procedures? What will I be asked to do?

Before you can be approved for participation, you must complete a medical history questionnaire to ensure that you meet all of the inclusion and none of the exclusion criteria for this study. You must also sign this consent form.

Upon review of your medical history form by our medical monitor (Jeffrey Anderson, M.D.), you will not be allowed to participate in this study if you have a pre-existing medical condition that may put you at risk while performing the testing sessions or that might influence the outcomes of this study. Such conditions may include, but may not be limited to, heart conditions or anomalies, respiratory conditions, blood pressure problems, or neurological disorders.

Inclusion Criteria:

You will be a potential study subject if you are a healthy male or female 18-35 years of age at the start of the study and who has consistently performed resistance exercise 2-3x/week for at least 6 months prior to the study. You also must be trained in the squat and bench press exercise.

You will be medically screened from the study if you have ever:

1. Diagnosed with hypertension, diabetes, or cardiovascular disease by a physician.
2. Musculoskeletal injuries or physical limitations affecting ability to exercise, or increasing risk of injury or discomfort during exercise. This includes back injuries or disk problems.
3. Use of anti-inflammatory medications (aspirin, Non Steroidal Anti-Inflammatory Drugs, i.e. Ibuprofen) either on an ongoing basis or for 60 hours prior to each visit.
4. Use of hormonal substances, including testosterone, anabolic steroids, growth hormones, or spironalactone (Aldactone®) (a common drug with opposing actions to testosterone).
5. Any autoimmune condition that is uncontrolled. Individuals taking medications for controlled endocrine conditions may be admitted if the physician deems it will not impact the variables of the study. An unacceptable condition would be a recent onset of new medication where the dosage has not yet been stabilized.
6. Contraindications for participation based on health history by the study physician.

If you are eligible for this study, you will be asked to complete 5 total visits to the University of Connecticut Human Performance Laboratory, Gampel Pavilion, Storrs, CT.

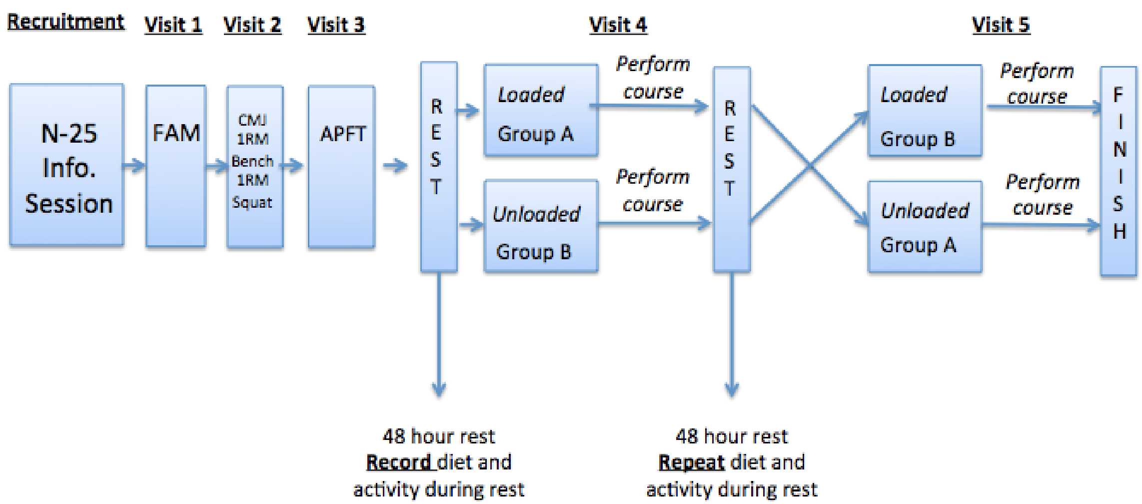
Overview of study design:

Prior to beginning the main investigation, you will attend a familiarization session, which will provide you the opportunity to become familiar with all the testing protocols and techniques of the testing. During the familiarization session, you will be familiarized with the test protocols for the countermovement jumps, 1 rep max (1RM) squat, 1RM bench press and the Army Physical Fitness Test (APFT). The APFT consists of a 2 minute maximal push up test, a 2 minute maximal sit up test, and a two-mile run. You will also be fitted for the Interceptor Body Armor (IBA), and will have the opportunity to be perform the military relevant course with and without the IBA and the 30 kg load in the ruck sack. Anthropometrics will also be recorded during the familiarization session.

Following the familiarization visit, you will come in for your next visit and will undergo performance testing, which consists of the counter movement jumps, 1RM bench press and 1RM squat. Following this visit, you will perform the Army Physical Fitness Test (APFT). After performing the APFT, you will have 48 hours of rest. During this 48-hour rest, you will be asked to refrain from strenuous activity, and to record your activity and diet during the 48 hours.

After the 48-hour rest period, you will come in for your next visit which will consist of performing the military relevant course (sprint, agility, casualty drag) either loaded or unloaded due to your random assignment. Following this visit, you will rest for another 48-hours, and will repeat your diet and activity log during your previous 48 hour rest. Following this 48-hour rest, you will perform the course again loaded or unloaded based upon your random assignment. You will have the opportunity to perform the course in an unloaded and loaded condition. This design is summarized in Figure 1.

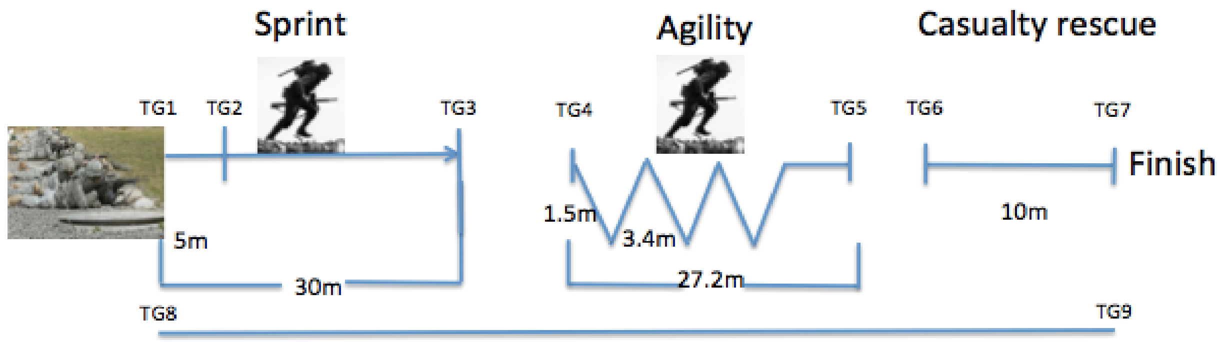
FIGURE 1



Legend:
FAM: Familiarization of protocol and anthropometrics
CMJ: Counter movement jumps
Bench: Bench press
APFT: Army Physical Fitness Test
Loaded: With rucksack and body armor
Unloaded: Without rucksack or body armor
Perform Course: Sprint, agility, casualty rescue

The breakdown of testing visits can be seen in the following illustration:

Figure 2



*TG=Timing gate

Breakdown of testing visits:

Familiarization (~1.5 hours):

During this visit we will familiarize you with all study procedures to be used. You will then be taught the standard warm-up protocol (described below), which you will perform prior to any testing. You will also learn and will demonstrate the correct technique for performing the squat exercise and the bench press exercise using a Smith machine. The counter movement jumps will also be taught and you will have the opportunity to practice the jumps. You will also learn the proper technique of the push-up and sit-up and will be able to demonstrate the proper technique. Furthermore the protocols of the APFT will be explained to you.

You will be taught all the procedures for performing the military relevant tasks in the course. You will be able to walk through each task within the course and will also have the opportunity to carry the 30 kg load, and wear the Interceptor Body Armor that will be used in the study during the military tasks, In addition to further describing and practicing all study procedures, anthropometric data (including height and weight) will be recorded at this time using a stadiometer and an electronic scale.

We will review the proper lifting technique on the squat to confirm your training status. We will then test your 1RM for the squat exercise, which is the most amount of weight that you can lift for 1 repetition of a smith machine squat with correct technique. After learning the standard warm-up (which you will complete prior to all visits), you will perform 6-8 repetitions of the back squat exercise with light resistance. Next, you will perform 2-5 repetitions of the back squat at a moderate intensity. Finally, you will perform progressively heavier lifts, one at a time, until you reach the maximal amount of weight you can lift using correct technique. Between each attempt you will rest for approximately 3 minutes. A maximum of 6 sets will be performed. During this period, if you appear unable to safety complete a squat, the testing will be stopped.

Finally, we will familiarize you with all the exercise protocols to be used, including the AHRET, isometric squat tests, and vertical jump test.

Standard warm-up:

At the beginning of all visits, you will perform a standardized warm-up consisting of 5 minutes of moderate exertion cycling (Level 5 at 60-65 rpm) on a recumbent cycle ergometer. This is immediately followed by dynamic stretching exercises. It will be completed at the beginning of any visit that includes physical testing.

Performance Testing: 1RM bench press, 1RM squat, countermovement jumps. (~45 min.)

You will perform the standard warm-up and following the warm-up you will perform 3 counter movement jumps on a force plate. You will perform 3 maximal, consecutive jumps, with hands on your hips during the jumps.

Following the counter movement jumps, you will perform the 1RM squat exercise. Your first set will be 8-10 repetitions at ~50% of your estimated 1RM followed by another set of 2-5 repetitions at ~85% of 1RM. Subsequently, 4-5 maximal trials will be used to determine your 1RM. The use of a Smith machine and two trained spotters helps to ensure your safety during the exercise.

Following the 1RM protocol of the squat, you will perform the 1RM bench press exercise. Your first set will be for 8-10 repetitions at ~50% of estimated 1RM followed by another set of 2-5 repetitions at ~85% of 1RM. Subsequently, 4-5 maximal trials will be used to determine your 1RM. The use of a Smith machine and two trained spotters helps to ensure your safety during the exercise.

Army Physical Fitness Test (APFT): (~45 min.)

After your performance testing visit, you will conduct the Army Physical Fitness Test which will be administered according to Army Field Manual 21-20 (1998). You will first perform the standard warm-up protocol before any testing. Once the warm up is complete, you will be reminded of the standards of the APFT and will perform the push up test first. You will perform as many push-ups as possible in two minutes. Test administrators will score and time the test and will only count the push-ups that were done with the proper technique. The test will be terminated when the time has elapsed or when you are unable to perform a push-up with proper technique.

Following the push up test, you will perform the sit up test. You will be reminded of the standards of the sit-up test prior to the start of the test and will perform as many sit-ups as possible in two minutes. Scorers will only count the sit-ups that were completed with the proper technique. The test will be terminated when the time has elapsed or when the subjects are unable to perform a sit-up with the proper technique.

Following the sit up test, you will perform the 2 mile run test on a track. You will attempt to run 2 miles as fast as possible. The test will be terminated when you have finished running 2

miles, or if you are physically unable to complete the run. The time at the end of the 2 mile run will then be recorded.

The raw scores of the test will be converted into point scores according to FM-21-20, which will be given to you at the end of the study.

Rest: 48 hours, Diet and Activity Log

You will be asked to refrain from vigorous activity for 48 hours, and will accurately record your diet and activity for 48 hours with the activity and diet log that you have received from the Human Performance Laboratory.

Military relevant tasks: (~1 hour)

After your 48-hour rest your next visit will be the performance of the military relevant tasks. At the beginning of this visit you will perform the standard warm-up protocol before performing the course. You will then perform the course either with a load or without a load, according to the random assignment. During the unloaded trial you will be wearing a military uniforms, and boots, which will be issued to you at the beginning of the study. During the loaded trial, in addition to wearing the military uniform, and boots, you will be carrying a 30 kg military rucksack and will be wearing the Interceptor Body Armor, which weighs 14 kg. The total amount of weight during the loaded trial will be ~44kg. You will run through the course a total of 3 times, with up to a 5 minute rest in between each bout. The overall course will be timed using electronic timing gates. In addition each individual task will be timed using the electronic timing gates.

Task 1: You will start in the prone position and the timing will begin with your first movement. You will come up out of the prone position and begin to sprint until you reach the end of the sprint station and will immediately continue to the agility station.

Task 2: Immediately following the sprint, you will perform an agility drill that consists of 9 cones that are staggered such that adjacent cones are 1.5 m apart laterally and 3.4 m apart along the length of the course. You will maneuver around every cone as fast as possible until you reach the end of the agility station and will immediately continue to the casualty rescue.

Task 3: Immediately following the agility station, you will perform a casualty rescue by dragging an 81kg dummy 10 m. This is the final station of the course. The course is summarized in Figure 2.

Rest: 48 hours, Replicate Diet and Activity Log

You will accurately replicate your diet and activity from the previous 48-hour rest period by referring to your diet and activity log given to you by the Human Performance Laboratory.

Military relevant tasks: (~1 hour.)

After this 48-hour rest period your next visit will be the performance of the military relevant tasks for the second time. At the beginning of this visit you will perform the standard warm-up protocol before performing the course. You will then perform the course either with a load or without a load, according to the random assignment. If you performed the course with a load the first time through the course, during this visit you will be performing the course without a load and vice versa. During the unloaded trial you will be wearing a military uniforms, and boots, which will be issued to you at the beginning of the study. During the loaded trial, in addition to wearing the military uniform, and boots, you will be carrying a 30 kg military rucksack and will be wearing the Interceptor Body Armor, which weighs 14 kg. The total amount of weight during the loaded trial will be ~44kg. You will run through the course a total of 3 times, with up to a 5-minute rest in between each bout. The overall course will be timed using electronic timing gates. In addition each individual task will be timed using the electronic timing gates.

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>
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What are the risks or inconveniences of the study?

1 RM bench press, 1RM squat, and performing the military relevant tasks with a load:

The performance of muscular exercise and physical effort exposes you to the potential risk of injury associated with overexertion and/or accident. This study has been planned in a manner which will minimize risk of injury to the musculoskeletal system. The possibility of cardiopulmonary overexertion is slight, and will be minimized by screening, selection and monitoring procedures that are designed to anticipate and exclude you, if it is deemed that exercise might be harmful to you.

When correctly performed, resistance exercise and carrying a load during different tasks is a low-risk activity in healthy individuals. However, it poses some inherent risks. Transient physical symptoms such as fatigue, soreness, dizziness, lightheadedness, fainting, nausea, and vomiting may occur. Additional risks associated with resistance exercise, strength and power tests, and performing loaded military relevant tasks, involve the possibility of muscle strains or pulls of the involved musculature, delayed muscle soreness 24 to 48 hours after exercise, muscle spasm, muscle strains, and in extremely rare instances, muscle tears, ligament and/or tendon damage, or injury to the discs in the lower back. Every effort will be made to make this investigation safe for your participation through screening, familiarization, experienced testing

personnel, warm-up and cool-down (i.e., stretching and low intensity activity-specific exercise), technique instruction and practice, supervision, monitoring and individualized exercise testing.

All of the laboratory research assistants are CPR and AED certified, there is an AED immediately accessible in the laboratory, and the laboratory has documented emergency protocols in place should an emergency arise. The study physician is Jeffrey Anderson, M.D.

Various Inconveniences:

The total time requirement of this study is approximately 4.5 hours (see chart below). We may choose to contact you again at a later date, either regarding this study specifically or for a follow up study. We will contact you via telephone or e-mail. You will be given the option to decline and this will not affect your participation in the study.

The **total time commitment** for this study is outlined in the following table:

Description	Time	Times completed	Total time
Information Session	30 min.	1	.5
Familiarization	1.5 hours	1	1.5
Performance test	45 min.	1	.75
APFT	45 min.	1	.75
Military tasks	30 min.	2	1
Total Time commitment:			~4 hours 30 min

What are the benefits of the study?

By participating in this study, you will obtain your one-repetition maximum in the squat exercise. You may enhance your existing knowledge of resistance exercise that you can use in your personal exercise regimen. If you are a member in the military community or are a future recruit or cadet, you can benefit from the anticipated results of this study. We hypothesize that the stronger more powerful individuals will perform better during anaerobic military relevant tasks while carrying a load. If the results of this study confirm our hypothesis then this will help guide you to train appropriately to improve your performance on the battlefield. The results of this study can help guide leaders within the military community to include within their physical training regimens a strength and power aspect that can increase combat effectiveness and soldier survivability.

Will I receive payment for participation? Are there costs to participate?

There are no costs and you will not be compensated for this study.

How will my personal information be protected?

The following procedures will be used to protect the confidentiality of your data:

Your identity:

Your data will remain confidential. For research purposes, your name will be number-coded. In routine data entry and statistical analyses, you will not be identified by name (except on a need-to-know basis). At the conclusion of this study, the researchers may publish their findings. Information will be presented in summary format and you will not be identified in any publications or presentations. You will not be referred to by name in any publication without your written consent. Data that is shared with others will be coded (as described above) to help protect your identity.

Security of your personal information:

Your data, medical and other information will be kept in locked file cabinets. A master key that links names and number codes will be maintained in a separate and secure location. This master key will be destroyed in three years. All electronic files (e.g., database, spreadsheet, etc.) related to this study will be password protected. Any computer hosting such files will also have password protection to prevent access by unauthorized users. Only investigators and research assistants directly involved with this study (and approved by the University for this study) will have access to the data and/or passwords. Analyzed data will be kept in "aggregate" form, meaning, there will be no way for anyone outside of direct study personnel to know who you are.

You may be asked if you would consent to having your picture taken during the study. We ask you because it is often helpful during scientific presentations or research publications to have these pictures. For example, students who present posters at conferences on research findings may benefit by having a picture to include. You do not have to have your picture taken to participate in this study. You can indicate your decision to allow your images to be taken by initialing (yes or no) at the end of this form.

The IRB and ORC

You should also know that the UConn Institutional Review Board (IRB) and the Office of Research Compliance may inspect study records as part of its auditing program, but these reviews will only focus on the researchers and not on your responses or involvement. The IRB is a group of people who review research studies to protect the rights and welfare of research participants.

What happens if I am injured or sick because I took part in the study?

In the event you become sick or injured during the course of the research study, you should immediately notify the principal investigator of the study, Dr. William Kraemer (office 860-486-6892), or the study physician, Dr. Jeff Anderson (860-486-0404 ext 0). In the event that a serious medical condition arises, Dr. Anderson will evaluate the condition and, if indicated, will direct you to seek medical care at a hospital.

If you have a medical emergency, the local emergency medical services will be called immediately. On-site medical care is limited to emergency stabilization pending evacuation to a

hospital. If you require medical care for such sickness or injury, your care will be billed to you or to your insurance company in the same manner as your other medical needs are addressed.

However, if you believe that your illness or injury directly resulted from the research procedures of this study, you may be eligible to file a claim with the State of Connecticut Office of Claims Commissioner. For a description of this process, contact the Office of Research Compliance at the University of Connecticut at 860-486-8802.

Can I stop being in the study and what are my rights?

You do not have to be in this study if you do not want to. If you agree to be in the study, but later change your mind, you may drop out at any time. There are no penalties or consequences of any kind if you decide that you do not want to participate.

Whom do I contact if I have questions about the study?

Take as long as you like before you make a decision. We will be happy to answer any questions you have about this study. If you have further questions about this project or if you have a research-related problem, you may contact the principal investigator, Dr. William Kraemer, at 860-486-6892, or a student researcher.

Documentation of Consent:

I have read this form and decided that I will participate in the project described above. Its general purposes, the particulars of involvement and possible risks and inconveniences have been explained to my satisfaction. I understand that I can withdraw at any time. My signature also indicates that I have received a copy of this consent form.

Please put your **initials** below. You may withdraw this consent in writing at any time.

I ____ do ____ do not consent to have my full photographic and videographic images taken/used.

I ____ do ____ do not wish to be contacted for follow-up studies or for future studies.

______________________	______________________	___________
Participant Signature:	Print Name:	Date:
______________________	______________________	___________
Signature of Person Obtaining Consent	Print Name:	Date: