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RELATIONSHIP BETWEEN SELECTED PHYSIOLOGICAL MEASURES AND FIELD TASK PERFORMANCE OF CANADIAN SOLDIERS

by

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ABSTRACT

One hundred and sixteen male Canadian military soldiers were subjected to a physical test battery of over 200 measurements in 1991 to develop combat readiness field test performance standards (Singh et al, 1991). The purpose of the present investigation was to further analyze the data base to determine the physiological factors related to best performance in the field tests. This information will be utilized in the development of fitness training programs for soldiers unable to meet the field test standards. The best (top 27%) and worst (bottom 27%) performers of each field test were identified and the physical test battery measurements of these groups were statistically analyzed to identify those measurements which significantly differentiated ($p \leq .05$) the two groups. In addition, the physical test battery results of the top three and bottom three field task performers were analyzed to determine if the group data supported their performances.

The results of the analysis indicated that the measurements that significantly differentiated between the best and worst performers were associated with anaerobic leg power, aerobic power, increased lean weight, trunk flexion and extension strength, and anaerobic arm power. The individual analysis moderately to strongly supported these results with the exception of the Ammunition Box Field Test. Training programs designed to improve the soldiers ability to meet the field task standards should focus on: lower body anaerobic training; aerobic power training; trunk flexion and extension strength training; and upper body / arms strength training. After the development of increased lean body mass there should be a conversion of the increased strength into power in all regions of the body.

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CHAPTER I. STATEMENT OF PROBLEM

A. Introduction

Many people view the military as a physical job. Commercials for the military ("There's No Life Like It"!) emphasize the physical aspect of the job. Movies and television consistently depict recruit training (Boot Camp) as physically challenging to prepare recruits for the inevitable harsh requirements of being a soldier. A common perception of soldiers is of warriors ready to be sent off to battle on a moments notice. However, in addition to their role as warriors, soldiers perform many other tasks, such as peace keeping and disaster assistance. To accomplish these roles, soldiers are trained in numerous skills and technologies. Over the years these changes have affected the role of physical fitness in the military.

In past years, advances in technology altered or reduced many of the physically demanding tasks traditionally performed by a soldier. Rather than the long march, the modern soldier may have used helicopters to reach the battle scene. Heavy equipment may have been moved in trucks and carriers rather than by soldier. As a result of these and other modernization's, the concept of physical fitness in the Canadian Army changed. Physical Fitness became based upon factors such as low body fat, aerobic fitness, and the ability to perform pushups, sit-ups, and/or chin-ups. These factors favored the lean slim marathon type physique over the stronger, heavier, more powerful body type (Marston et al., 1981; Lee, 1992). However, the present day physical demands a modern day soldier may face can be extreme.

A soldier must be prepared to fight in various conditions, terrain's, and environments. Today's soldier must carry into battle personal equipment, weaponry and surveillance/communication equipment that did not exist a few years ago. Advances in technology, such as night-vision goggles, make it a 24 hour battle day, with the accompanying reduction in sleep, rest, and nourishment. These considerations demonstrate that the need for physical fitness in the military today is as great as or greater than it has ever been (Jette et al., 1986).

The modern physical fitness requirements of a soldier in battle were revealed by the performance and post war analysis of British soldiers during the Falkland's war (Time magazine, 14 June 1982). The Falkland's war required a soldier to march up to 60 km carrying full combat load and still fight in a life or death battle the same day. In this war, soldiers of a fitness level similar to a typical marathon runner were less successful than those who had mesomorphic bodies with superior muscular strength and endurance.

This demonstration of the importance of muscular strength and endurance did not initially result in Canadian Forces appropriately altering their physical fitness requirements. Prior to 1987 in the Canadian Forces, there were no task-specific physical fitness performance standards for soldiers (Singh et al., 1991). The Canadian Forces fitness testing protocol at the time was the CF EXPRESS, an evaluation and prescription program which utilized handgrip, push-ups, sit-ups and a submaximal VO_2max measure to determine fitness. The CF EXPRESS did not relate well to the physical fitness requirements of a soldier identified as a result of Falkland's War analysis (Bell and Jacobs, 1986).

In 1978 the Canadian Human Rights Act was passed. Included in the Act was the Canadian Human Rights Commission Bona Fide Occupational Guidelines that required the demonstration of a relationship between occupational needs and physical fitness requirements (Singh et al., 1991). As a result of this Act, the Department of National Defense contracted the University of Alberta to assist them in improving and standardizing their physical fitness program to meet the guidelines of the Canadian Human Rights Act.

The primary purpose of the investigation carried out at the University of Alberta was to develop task-related minimum physical fitness performance standards for the Canadian Army. These standards were to ensure that the soldiers had the physical capabilities to meet the physical demands of their occupation. Some of the physiological components required by the soldiers were, aerobic fitness, anaerobic fitness, and muscular strength and endurance. In the initial stages of establishing these standards, Singh et al. took into consideration many factors, including test reliability, validity, safety, cost, and time constraints (Chahal, 1993).

Field task selection was from common tasks of an Infantry soldier. This was based upon the premise that all military personnel, including Armor, Artillery, Support Staff, etc., could at any time be called upon to carry out the duties of an Infantry soldier. In addition, it was agreed that the selected Infantry soldier tasks were the most demanding of the military and would serve as the best standard. Five field tasks, from potentially hundreds, were selected.

The five field tasks were:

- a simulated casualty evacuation;
- digging of a simulated slit trench;
- lifting, carrying and emptying of a full jerry can;
- lifting and lowering of a set number of ammunition boxes from a simulated truck bed;
- and a 16 km weight load march (Lee, 1992).

The University of Alberta research team then developed performance standards for the field tasks. To assist with the process, the research team utilized laboratory tests to assess and quantify the physical fitness of 116 male Canadian Military soldiers. Laboratory tests were used to measure the following fitness components: aerobic power, anaerobic power, muscular strength, muscular endurance and body composition. In total 220 different physiological measures were generated from the test battery. The test battery included: a treadmill aerobic power test; Wingate upper and lower body power tests; blood sampling and analysis; hydrostatic weighing; isotonic, isometric, and isokinetic strength testing; etc. (Lee, 1992; Chahal, 1993).

The result of the University of Alberta's study was the development of field tests and standards for the Canadian Forces. These standards allowed the military to quickly and simply determine if their soldiers or recruits possessed the physical fitness necessary to perform the various roles required of them. These field tests and standards have since been accepted and implemented by Canadian Forces. However, the acceptance of the field tests and minimal standards creates a potential problem for the military: what to do with soldiers who do not meet the standards. The military is faced with three options:

1. send an unfit soldier on assignment, which may include battle;
2. keep the unfit soldier home from assignment;
3. improve the soldiers physical fitness to a level where they will meet or pass the standards.

Sending the unfit soldier on assignment is a poor solution. An unfit soldier is a liability not only to themselves but to others who depend on them. In addition, it is counterproductive to have standards and not enforce them. Not sending the unfit soldier on assignment is a waste of valuable resources. Every soldier is a combination of many skills and abilities. The elimination of those skills from the assignment due to one component (physical fitness) is not the solution. The solution is to physically train the soldiers to a level where they are capable of meeting or exceeding the field test standards and performing the physical duties required of them.

A necessary prerequisite for the development of effective physical fitness training programs is the identification of the physiological factors required for successful performance of the field tests. Each field test was designed to challenge the soldier in a unique way. It is likely that the physiological requirements for each field tests were different. Therefore, at present, the field tests provide the military with the means to determine the physical readiness of their soldiers. However, until the physiological factors required for successful field test performance are identified, effective training programs to assist soldiers in meeting or exceeding the field test standards can not be properly developed.

B. Purpose of Study

As already stated, an earlier report by Singh et al (1991) established field tests and standards for the Canadian Military. A future report to the Canadian Military by Singh and associates will develop physical fitness training programs to prepare soldiers to meet or exceed the field test standards. This study acted as a bridge between these two reports by analyzing the data from the earlier study to identify the key physiological components necessary for successful field test performance. These identified components will form the basis of the military training programs of the future report.

The purpose of this study was to statistically analyze the physiological data base of 116 Canadian Forces male soldiers to determine the relationship between performance in the field tasks (Field Test Battery) and measured physiological components (Laboratory Test Battery). This analysis identified laboratory measurements which significantly differentiated top and bottom performers in each of the field tests. The identification of these measurements can be utilized in the development and design of military physical fitness training programs.

This purpose was accomplished by the following process:

1. Rank ordering the soldiers field test performances.
2. Identify the soldiers who were the best performers (top 27%) and worst performers (bottom 27%) in each field test.

3. Statistically analyze the best and worst field test performers laboratory results, and identify the laboratory measurements that significantly differentiated top and bottom field test performers.

4. Identify the three best performers (top three) and three worst performers (bottom three) in each field test.

5. Analyze the laboratory test results of the three best and worst performers in each field test to determine if their results agree or disagree with the conclusions drawn from the group analysis.

5. This analysis will help determine the physiological factors related to best performance of the field tests. This information may then be used in the design and development of a physical fitness training program for the Canadian Forces soldiers.

C. Significance of Study

Soldiers are a composite of many skills and abilities, all of which contribute to their value to the military. The proficiency of various soldiers in tactical analysis, communication, mechanical repair, etc., provide the backbone that allows the military to perform a wide variety of services under extreme circumstances. However, regardless of their skills and expertise, any soldier may be required to unload supply trucks, dig trenches, etc. in the line of duty. Therefore, this study will be significant for two reasons. First, it will improve the understanding of the physiological factors related to successful performance of the field tests. These physiological factors will be utilized in the development of proper physical training programs aimed at ensuring that soldiers posses the physical fitness they require to perform their many varied duties. Second, the field tests were developed in consultation with the military to represent the task specific physical requirements of a soldier. Therefore, the identification of the physiological factors necessary for successful field test performance will provide the military with an understanding of the required physiological profile of a soldier. This information will be valuable to the military in their training and recruitment of personnel.

D. Delimitations

1. This study was restricted to the data obtained from 116 healthy male subjects, 17-44 years of age with a mean age of 25.74 years (Singh et al., 1991).
2. All subjects were ar infantry personnel from the Canadian Forces Base, Calgary, Alberta, Canada.
3. The physiological laboratory measures were delimited to aerobic and anaerobic power, body composition, and muscular strength and endurance tests.
4. The field tests data analyzed consisted of the following common but essential military tasks:

- Maximal Dig

The soldiers were directed to scoop, lift and throw, as quickly as possible, 0.486 cubic meters of standardized gravel out of a slit trench simulator using an issue shovel. The purpose of the task was to simulate digging and building of defensive positions that provide protection to personnel against incoming enemy fire.

- Casualty Evacuation

The soldiers were directed to lift and carry (using the Fireman's Lift technique) a soldier of similar weight and height for a distance of 100 m. This simulated the evacuation of a wounded soldier in the shortest possible time in a battle situation.

- Ammunition Box Lift

The soldiers were directed to lift 48 ammunition boxes (weighing 20.9 kg each) from the ground to a table 1.3 m in height. This table height simulated the truck bed of a military truck. This task was completed at a submaximal effort (70% maximal aerobic power) due to the perceived risk of injury if soldiers attempted to lift the boxes rapidly.

- Weight Load March

The soldiers were directed to march for a distance of 16 kilometers in full fighting gear and backpack (total weight 24.5 kg). The pace was determined by discussion with the military and standardized at 88.9 m per minute. The march was conducted indoors to standardize environmental conditions (Chahal, 1993).

E. Limitations

1. Subject motivation level during field and laboratory measures could neither be fully controlled nor monitored.
2. No assessment of skill levels was made.

F. Definition of Terms

1) Maximal oxygen uptake (VO_2max): Refers to the maximal volume of oxygen which is consumed per minute (litre/min (absolute) or ml/(kg.min)(relative)) during a progressive treadmill exercise test. The treadmill ergometer and Beckman Metabolic Measurement Cart were used to determine maximal oxygen uptake. The test protocol required the soldiers to march at a set speed of 88.9 meters per minute while wearing Full Fighting Order (standard army uniform plus helmet, rucksack, webbing, gas mask, and rifle). The total weight of this equipment was 24.5 kg. Each soldier was provided a five minute warm-up at zero grade, with the first two minutes at a speed slightly slower than testing speed followed by three minutes at testing speed. At the end of the warm-up the test began. With the soldier walking at testing speed the incline of the treadmill was increased 2% every two minutes until the soldier reached ventilatory threshold (determined by the Beckman Metabolic Measurement Cart "Convert" program). After ventilatory threshold, the incline of the treadmill was increased 2% every minute until VO_2max was reached, or the soldier could no longer continue due to fatigue (Lee, 1992).

2) Aerobic power: Synonymous with maximal oxygen uptake and refers to an individual's capability to diffuse oxygen across alveolar tissue, transport it in the blood and utilize in muscular tissue in order to perform maximum work.

3) Maximum heart rate: The maximal heart rate attained by a subject during a maximal oxygen uptake test.

4) Anaerobic power: Anaerobic power is the rate of energy utilized from sources other than the oxidative processes and is determined by the intensity and duration of the activity.

5) Wingate upper body power test: A 30 second supra-maximal arm ergometer test for determining upper body and arm power.

6) Wingate lower body power test: A 30 second supra-maximal leg ergometer test for determining lower body and leg power.

7) Wingate Force Setting: A relative setting in kiloponds determined by multiplying individual's body weight by 0.095 kg for the lower body power test and 0.062 kg for the upper body power test.

8) Wingate Peak Power Output (PPO): Measurement of power output for each five second interval of the 30 second test to determine the interval in which peak or highest power output occurred. This event usually occurs in the first five seconds of maximum exercise.

9) Wingate Maximal Power Output (MPO): The combination of maximal pedal frequency and resistance for an individual that elicits the highest possible [illegible]lative measure of mechanical work of a 30 s time frame. The power output f[illegible]ve second interval of the 30 s test was totaled and a mean value was calculated

10) Wingate PPO(R) and MPO(R): The resistance needed to elicit peak power output and maximal power output (for example, PPO[5] indicates that a resistance of 5 kp was needed to elicit peak power output).

11) Peak Lactic Acid: Blood sampled by finger puncture five minutes post-exercise, and analyzed for lactic acid.

12) Wingate Relative Power Output: Scores of power output transformed to compensate for body weight.

13) Wingate Absolute Power Output: Raw scores or power output without compensation for body weight.

14) Revolutions Per Minute (RPM): The number of pedal revolutions in each five second period extrapolated for one minute.

15) Anaerobic Threshold (AT): During the maximal treadmill test, a point where there is a nonlinear increase in Ve, VCO_2 and a sudden increase in RQ with a decline in expired CO_2 tension ($FECO_2$) and elevation of O_2.

16) Laboratory Tests: Tests of aerobic and anaerobic power, muscular strength, muscular endurance and body composition completed under controlled conditions. A detailed description of these tests is available in Chapter II.

17) Field tests: Selected common tasks representative of an infantry soldier's job requirement. These included: casualty evacuation, ammunition box lift, maximal dig and weight load march. A detailed description of these tests is available in Chapter II.

18) Muscular Strength: It is the maximum effective force or tension a group of muscles can exert in a single maximal voluntary contraction.

20) Isometric Strength: Maximum effective force or tension a group of muscles can exert in a single maximal voluntary contraction at a given angle.

21) Muscular Endurance: It is the ability of a muscle group either to contract repeatedly against a load or to sustain a contraction for an extended period of time.

22) Percentage of Body Fat: It is the percentage of body weight that is actually adipose tissue, estimated from Brozek's formula.

23) Fat Free Weight: The body weight less the weight of body fat.

24) Residual Volume: The amount of air that remains in the lungs after a maximum expiration.

CHAPTER II. REVIEW OF LITERATURE

A. Review of Military Physical Fitness Tests

Canadian Military

Up until 1971, the Canadian Forces used a common physical fitness test that measured muscular strength and endurance, cardiovascular fitness and agility. There were several problems identified with this test battery. First, the emphasis was placed on passing the test and not on development and/or maintenance of the soldiers physical fitness. Second, the commanders could not directly relate the test items to activities they foresaw their soldiers performing. Third, due to screening problems while administering the test, injuries and casualties occurred during or as a result of testing (Mayo, 1984).

To address these concerns, in 1972 the military adopted the 1.5 mile run as its fitness appraisal. This test was based on age and gender standards (Cooper 1977) and the Astrand nomogram (Astrand, 1954). Difficulties with the test arose. Many of the soldiers required to complete the test had inadequate training. In addition, in many sections of the military the program was poorly run or ignored. As a result of the manner in which the program was administered, the Surgeon General concluded the method carried an unacceptable risk for participants over 30 years of age. The Surgeon General further stated that the 1.5 mile run was an inappropriate test of general physical fitness. This was due to the fact the minimum standard could be achieved by a basically sedentary individual after a few weeks of training, or worse, no training at all. In addition, Mayo (1984) suggested the 1.5 mile run did an inadequate job of assessing the occupational requirements and demands of a Canadian soldier.

In 1983, the military adopted the CF EXPRESS (EXercise PREScription). The CF EXPRESS program was based upon the Canadian Standardized Test of Fitness (Fitness Canada, 1981). The CF EXPRESS consisted of a pretest screening, a fitness evaluation, exercise prescription, and a subsequent training program. The CF EXPRESS utilized: right and left hand maximal handgrip force (isometric) to determine muscular strength; one minute push-ups and sit-ups to measure muscular endurance; and a submaximal step-test to measure VO_2max. Stevenson et al. (1988) reported that the CF EXPRESS was a reasonable measure of gross physical fitness for large populations. However, Bell and Jacobs (1986) concluded that the test may lack the sensitivity to detect minor but significant changes in physical fitness due to training. The CF EXPRESS was designed to meet general physical fitness needs but did not meet the specific needs of the military. Lee (1992) stated of the CF EXPRESS that "combat forces clearly require a higher level of fitness than can be demonstrated by the CF EXPRESS program."

To address this problem, the military adopted two different programs to measure the physical fitness of their soldiers. The first was the Battle Efficiency Test (BET). The BET consisted of two 16 km marches in Full Fighting Order (standard army uniform plus helmet, rucksack, webbing, gas mask, and rifle) conducted on consecutive days. The first march included scaling a six foot (1.33 m) wall, jumping an eight foot (2.44 m) ditch and carrying a soldier for 200 m. This task had to be completed in 2 h and 45 min. The second march did not include the two jumps and carry but had to be completed in 2 h and

30 min (Jette et al., 1986). Although the test directly measured a military task, Myles et al. (1985) reported it was not a measure of aerobic power or endurance capacity and was hampered by terrain and weather conditions. In addition, there was a lack of standardization and rationalization of the norms (Jette et al., 1986). A more universal approach to the soldiers' requirements had to be considered when devising fitness tests, and these tests should be recognized and accepted by military commanders. Myles et al. (1985) reported:

> The test should result in a simple easily measured score...requiring nothing more than the ability to operate a stopwatch. Any test which stresses the appropriate fitness components, predicts some aspect of military performance and is simple to administer would be of great value to the field commander. It would allow him a quick and easy way to identify those men who are fit to fight.

The second fitness assessment program the military reviewed was the 19 item Indoor Standardized Obstacle Course (ISOC). Developed by Jette and Kimick (1986), this course required soldiers to perform activities that attempted to mimic tasks found in combat type conditions. In the development of the course, the soldiers were subjected to a series of laboratory tests. The laboratory results indicated the physiological requirements necessary to successful performance of the ISOC were valid components and important for a soldier in the military. These components were: aerobic and anaerobic power, muscular strength and endurance and body composition. As a result of their studies Jette and Kimick reported that although aerobic fitness was important to a soldier, greater emphasis should be placed on the development of upper body strength. Although

ISOC appeared to have been a step forward in military fitness testing, at present it requires further validation and acceptance by the Canadian Military (Singh et al., 1991).

International Overview of Military Performance Tests

The traditional military approach to the establishment of physical fitness standards has been "normative referencing": that is, standards based on the fitness test achievements of randomly selected military personnel. These normative standards were based upon a number of criteria, including: age, gender, and military units, such as combat, support, etc. (Lee, 1992). Following is a description of a number of international military physical fitness tests.

United States

The United States utilized the Army Physical Readiness Test (APRT). The APRT consisted of: maximum number of push-ups achieved in two minutes, maximum number of sit-ups achieved in two minutes, and timed two-mile run (Jette et al., 1986).

Australia

The Australian military utilized the Physical Training Test (PTT). The PTT consisted of a timed five kilometer run, maximum number of chin-ups, and maximum number of sit-ups (Rudzki, 1983). The implementation of the PTT resulted in most physical fitness training being geared towards achieving a passing PTT, and dissatisfaction with this method has been expressed. Rudski (1987) reported:

This reliance on PTT has led to a distortion of the relative value of other modes of conditioning such as swimming, cycling, rifle exercises, and most importantly walking. In practice, I see soldiers who have difficulty passing their PTT's and yet are described by their commanders as being excellent in the field. This would indicate that the PTT is not the most appropriate method to test the fitness of a field force soldier.

Great Britain

Great Britain utilized two standardized methods to measure the physical fitness of their soldiers. The first, the Army Personal Fitness Assessment Test, was used as a diagnostic tool to provide the basis for future fitness testing. It consists of pull-ups, trunk curls, dips on the parallel bars, and a step-test. The standards were all age and gender specific. The second test, the Basic Fitness Test (BFT), was conducted twice a year and is dependent upon age. If the soldier was under 40 years of age, they were required to walk and run 2.5 km as a group (in combat uniform) in 15 minutes, followed by a walk-run of the same distance in their best time. If a soldier was over 40 years of age, they had the choice of performing the same test protocol as soldiers under 40 years of age, or a 4.8 km walk/run in under 29 or 30 minutes, depending on age. Again, the standards for the BFT were age and gender specific (Jette et al., 1986).

Israel

The Israeli Defense Force (IDF) chose to utilize weight load walking instead of traditional methods (running, calisthenics, etc.) as their primary method of testing and conditioning their troops. Israeli research in weigh-load walking showed some meaningful benefits. First, weight load walking was effective in improving objective measures of fitness. Second, it resulted in fewer training injuries than other programs. Third, the method was well received by the soldiers and resulted in a positive attitude towards training. The basic requirement for the Israeli soldier was a five kilometer march in full battle order, with each soldier carrying approximately 30 kg, in a one hour time limit (Bar-Khama, 1980; Rudski, 1987).

Sweden

The Swedish military utilized a laboratory approach with their soldier's fitness testing. Soldiers underwent testing to measure Physical Working Capacity (testing on a cycle ergometer) and muscular power (weighted sum of three isometric tests). These tests measured: hand grip, knee extension, and elbow flexion (Jette et al., 1986).

Summary of Review

This review, although limited to a few countries, was considered representative of the methods utilized by different countries around the world (Lee, 1992). However, a recurrent theme was that these training programs lacked an essential element.

> Physical training requirements and physical fitness standards have traditionally been based on experience and subjective judgment rather than objectively determined requirements for successful performance... There is a paucity of information indicating actual requirements for physical fitness (exercise capacity) for operational units in the army which deal in situations such as sustained combat. This information is needed not only to establish actual combat needs, but also to develop more appropriate and efficient physical training programs (Murphy et al., 1984).

B. Development of Task Related Physical Performance Standards

In 1978 the Canadian Human Rights Act was passed. This Act dramatically altered the approach the Canadian Armed Forces needed to use to establish physical fitness standards for their soldiers. Included in the 1978 Act was the Canadian Human Rights Commission Bona Fide Occupational Guidelines that required the demonstration of a relationship between occupational task and physical fitness requirements.

The guidelines consisted of the following four steps:

1. Identify tasks, based on operational requirements
2. Identify the physical capability required to complete the tasks
3. Develop the appropriate tests which predict the capability to complete the tasks
4. Set minimum preference standards based on the tests

Singh et al. (1991) used the Bona Fide Occupational Guidelines to establish task related (field) fitness tests and standards for the Canadian Military. Following is a detailed explanation of the process utilized in each of the four steps.

Identify Tasks Based On Operational Requirements

From the hundreds of physical tasks and activities Canadian soldiers were required to perform, a series of representative common tasks were selected as the field tasks. Field task selection was from common tasks of an Infantry soldier. This was based upon the premise that all military personnel, including Armour, Artillery, Service, etc., could at any time be called upon to carry out the duties of an Infantry soldier. In addition, it was agreed the infantry's tasks were the most demanding of the military and would serve as the common denominator for task related physical performance standards (Lee, 1992). The selection of the tasks was based upon:

1. A comprehensive review of the scientific and national & international military literature data bases;
2. Interviews and field observations with subject matter experts in the field at Canadian Force Base (CFB) Wainwright, Alberta; and, at the headquarters of Combat Brigade Group in Calgary, Alberta; and
3. Interview, special meetings and briefs at Forces Mobile Command (FMC) Headquarters in Montreal, Quebec (Lee 1992);
4. These selected tasks then received approval of senior Canadian Military administration.

The tasks that were identified as common field tests were: the Maximum Dig, the Weight Load March, the Casualty Evacuation, and the Ammunition Box Lift. All field tests were performed in standard military uniform (boots, khaki pants and shirt, etc.) unless otherwise stated. Following is a detailed description of each field test (Lee, 1992).

Maximum Dig

The Maximum Dig field task was used to simulate the digging of a slit trench (Figure 1). The purpose of a slit trench is to establish a soldier's defensive position and provide protection against incoming enemy fire. A metal box with the dimensions of 1.8 m in length x 0.6 m width x 0.45 m depth was used to simulate the digging trench task. The box was filled with a volume of standard gravel of 0.486 cubic meters. The gravel was of consistent size at less than one centimeter in diameter. In addition, the gravel was dampened with water to reduce dust suspension and alleviate breathing discomfort. Less than one-half liter of water was utilized for this purpose and did not add significantly to the weight of the gravel. A soldier's task was to scoop lift and throw all the gravel out of the simulated slit trench in the shortest time possible using an issue shovel. Soldiers were instructed to dig at the maximum rate possible. The time required for completion was recorded (Chahal, 1993; Lee, 1992).

Figure 1. Soldier Performing the Maximal Dig Field Test.

Note. Subject is digging from the box they are within to the adjacent box.

Weight Load March

The Weight Load March simulated a 16 km march in full fighting order, which included standard army uniform plus rucksack, helmet, webbing, gas mask and rifle (including basic ammunition load) (Figure 2). The total weight of the full fighting order was 24.5 kg. The soldiers marched in a gymnasium at CFB (Canadian Forces Base) Calgary, Alberta. The marching speed was standardized at 88.9 m per minute (equivalent to 5.33 km/h) and an electronic timer pulsed every 34 s to assist the soldiers at pace maintenance. Sport Tester heart rate monitors were used to measure the work intensity for each soldier. A heart rate/VO_2 relationship was previously established for each soldier based on their laboratory treadmill test. For every soldier, heart rate and Borg scale of perceived exertion score were established and recorded every 500 m (Chahal, 1993; Lee, 1992).

Figure 2. Soldier Performing the Weight Load March Field Test.

Casualty Evacuation

The Casualty Evacuation simulated the evacuation of a wounded soldier. Soldier evacuation may be required in situations where the lives of both soldiers, the soldier evacuating and the soldier being evacuated, are at risk, and speed is of the essence.

Therefore the field test was performed at maximal voluntary effort. The soldiers were dressed in Light Fighting Order which included standard army uniform, with helmet and webbing (Figure 3). The soldiers were required to lift and carry (using the Fireman's Carry) another soldier of approximately the same weight for a distance of 100 m. The time required for completion was recorded (Chahal, 1993; Lee, 1992).

Figure 3. Soldier Performing the Casualty Evacuation Field Test.

Ammunition Box Lift

The Ammunition Box Lift simulated the unassisted lifting of ammunition boxes to the bed of a military truck (Figure 4). The Ammunition Box Lift required a soldier to lift an ammunition box (20.9 kg) from the floor to a table top of a height of 1.3 m (simulated height of truck bed). The subjects were required to lift 48 ammunition boxes in total. Each soldier performed at a submaximal rate of 70% of his maximal aerobic power. A maximal effort was not asked of the subjects due to the increased risk of injury if the boxes were moved too quickly (Chahal, 1993; Lee, 1992).

Figure 4. Soldier Performing the Ammunition Box Field Test (Chahal, 1993).

Identify The Physical Capability Required To Complete The Tasks

In an attempt to understand the factors involved in soldiers common tasks, research was performed on a number of physiological tasks including: lifting; digging; and marching with load.

Physiological Factors Involved in Lifting

Lifting is a complex motion that integrates different muscle groups and contraction types. Pytel and Kamon (1981) reported:

> Lifting requires two types of contractions, static and dynamic. The initial part of the lift closely resembles isometric exercise, as the postural muscles and the muscles needed to overcome the inertia of the load all apply force without changing length. When the force applied is greater than the load, the lift becomes dynamic as a result of change in the length of the muscles involved.

Singh et al. (1991) utilized laboratory tests that measured both static and dynamic strength. Isometric tests included: handgrip strength and endurance, arm flexion strength and endurance, and trunk flexion and extension strength. Dynamic tests included: arm flexion strength, and trunk flexion and extension strength, knee flexion and extension torque, leg extension strength, trapezius lift strength and endurance, and bench press strength.

Much of the literature reported upper body involvement in the lifting process. The abdominals perform the role of increasing intra-abdominal pressure, therefore relieving the load on the spine (Bartelink, 1967; Cailliet, 1981; Morris et al., 1961). When the trunk is in the flexed position, pressure in the abdominal area increases. This assists in reducing the lumbar curvature and decreasing the angle between vertebra (Singh et al., 1991). Abdominal muscles may provide between 30-40% of the force necessary for support of the spinal column (Alexander, 1985). Thorstensson (1994) reported greater inter-abdominal pressure during the lifting process than lowering and speculated that the increase was primarily a result of activation of the transverse abdominis. Thorstensson reported on the involvement of the transverse abdominis during lifting:

> Producing IAP (inter-abdominal pressure) during lifting and lowering would be mechanically advantageous since the pressure could be increased without adding to the spinal compressive force that would be the case if extensive use was made of muscles which run either parallel (rectus abdominis) or partially parallel (external oblique, internal oblique) to the spine. Thus a possible unloading of the spine is offered by the increase in IAP.

Abdominal muscle strength has been demonstrated to be less than half that of trunk extensors and more susceptible to fatigue (Hasue et al., 1980; Smidt et al., 1983).

Although abdominal strength may be more susceptible to fatigue, Wheeler (1993) stated that lumbar extensors are generally considered the limiting factor in lifting capacity.

This was supported by Hagen et al. (1993) who reported lumbar extensors demonstrated higher activation levels than the quadriceps or biceps during the lifting process. Potvin and Norman (1993), working with subjects lifting in a strictly controlled upright position utilizing a similar resistance (19 kg) to Singh et al. (1991) (20.9 kg), measured fatigue to the lumbar and thoracic erector spina muscles and found a significant decrease in strength and endurance only with the lumbar muscles.

Lifting height is another factor effecting lifting capability. As the height of a lift increases, the amount a person is able to lift decreases. As the height exceeds shoulder level, this inverse relationship increases dramatically (Chaffin, 1975; Snook and Irvine, 1966). Genaidy and Asfour (1989), working with loads similar to the ones used by Singh et al. (1991), recorded average lifting endurance times of 27 minutes. Subjects in Genaidy's study were lifting from the ground to a height of 0.76 m whereas soldiers in Singh et al.'s study lifted to a height of 1.3 m. Utilizing a lifting height of 1.3 m may have resulted in shorter lifting endurance times in Genaidy and Asfour's study.

Energy expenditure in the lifting process is influenced by technique, frequency, load, and height. Some factors increasing energy expenditure during submaximal lifting are: increased rate of lifting loads of the same mass; increased mass of load at the same frequency; and increased lifting height (Hagen et al., 1993). Body position during the lift also affects energy expenditure. Hagen et al. (1993) reported an increase in energy expenditure utilizing the squat technique (bent knees and back erect) as compared to the stoop technique (straight legs and bent back).

Limited research on lifting exists. There is little known about the precise muscular involvement. Singh et al. (1991) stated, "Lifting objects from ground level requires whole body involvement: i.e., back, legs, abdominal region and arms, and for most people lifting capacity is limited by upper body strength." However, the specifics have not yet been identified.

Physiological Factors Involved in Digging

Digging played a major role in one of the selected field tasks, Maximal Dig, which simulated the shoveling out of an individual slit trench. Physiological requirements have been primarily reported in terms of submaximal aerobic power. During the digging process, energy was reported to be expended at a constant submaximal rate of approximately 70% of aerobic power. The involvement of muscular strength and endurance is not well understood or investigated. However, for optimal digging performance muscular strength and endurance of the arms, trunk and legs are necessary (Chakraborty et al., 1974; Stevenson et al., 1987,1988).

Physiological Factors Involved in Marching with Load

As with digging, marching has generally been examined in terms of aerobic involvement. Maximal aerobic capacity was believed to be a primary physiological factor involved in marching (Chahal, 1993). However, little research has been carried out in marching with a ruck pack the size and weight used in Singh et al.'s (1991) study.

Injury research in marching was revealing. Wells et al. (1983), working with postal workers carrying lighter loads (11-16 kg) than those utilized by Singh et al. (20.9

kg) found fatigue in the neck and shoulder regions to be of concern to the subjects involved. Other researchers focused specifically on injuries to soldiers performing marching training (Knapik et al. 1992; Jordaan and Schwellnus, 1994). The majority of the injuries in the marching studies involved the lower extremities and lower back. Jordaan and Schwellnus (1994) reported, "...injuries to the knee, lower leg, and ankle accounted for more than 80% of all injuries." Strength training in these areas can reduce the risk of injury (Arnheim, 1985). Therefore, strength in the lower extremities and lower back may be required in marching. This was supported by Dziados et al. (1987), who reported hamstring strength to be the only predictor of marching time in a study with soldiers in full combat gear.

Summary of Lifting, Digging and Marching with Load

Some information on the physiological requirements of lifting was available. However, few studies have been performed on digging and marching with load. It appeared that no study collected the detailed and comprehensive data of these tasks to the same extent as Singh et al. (1991). Therefore, this study's further analysis of the data will increase the understanding of the physiological requirements of these activities.

Development of the Appropriate Laboratory Tests to Predict Field Task Capability

After reviewing the physiological factors involved in lifting, marching and digging, Singh et al. (1991) developed a test battery to measure the physiological factors identified. Laboratory tests were conducted in the following areas: aerobic power, anaerobic power, muscular strength, muscular endurance, and body composition. In all, 18 different laboratory tests were used to measure 220 different physiological variables. Following is a brief description of these tests.

Aerobic Power Test

The treadmill ergometer and Beckman Metabolic Measurement Cart were used to determine maximal oxygen uptake. The test protocol required the soldiers to march at a set speed of 88.9 m per minute while wearing Full Fighting Order (standard army uniform along with helmet, rucksack, webbing, gas mask, and rifle). The total weight of this equipment was 24.5 kg. Each soldier was provided a five minute warm-up at zero grade, with the first two minutes at a speed slightly slower than testing speed followed by three minutes at testing speed. At the end of the warm-up the test began. With the soldier walking at testing speed the incline of the treadmill was increased 2% every two minutes until the soldier reached ventilatory threshold (determined by the Beckman Metabolic Measurement Cart "Convert" program). After ventilatory threshold, the incline of the treadmill was increased 2% every minute until VO_2max was reached or the soldier could no longer continue due to fatigue (Lee, 1992). Blood lactate levels were measured five minutes post-test. Blood lactate results were not utilized in this study.

Anaerobic Power Tests

Soldiers performed lower and upper body Wingate power tests. The duration of each test was 30 seconds. Tests were completed on Monarch cycle and arm ergometers modified to interface with computers that calculated and provided the resistance and data based on the soldiers' body weight. Computer programs calculated: test resistance, repetitions per minute, peak power output, and mean power output. Warm-up consisted of 3-5 minutes at 30-40 percent of predicted kilopond setting.

For the cycle ergometer the seat was adjusted to allow a slight bend in the knee (approximately 15 degrees) and toe clips were utilized. With the arm ergometer, a seat belt was utilized around the soldiers waist to secure his hips throughout the test. The subjects remained seated throughout both tests with the rate of cranking/peddling being determined by the soldier. Warm-up ended if the subjects reached a heart rate of 150 bpm after three minutes. If not, the soldiers continued to warm-up until they reached a heart rate of 150 bpm or a maximum of 5 minutes of warm-up was used.

Three seconds before the start of the test, soldiers were instructed to increase peddle/cranking speed to a maximum, at which time the appropriate resistance was applied and the soldier performed the 30 second test. During the last 5 seconds the time was counted down for the soldier and verbal encouragement was given. At the termination of the test the resistance was quickly reduced to a minimum. Soldiers continued to slowly peddle/crank for 2-3 minutes or until their heart rate decreased to below 120 bpm. Blood lactate samples were taken from the soldiers upon completion of the tests. Trained technicians utilized Sigma Lactic Acid analysis kits for all blood samples (Lee, 1992).

Muscular Strength and Endurance Testing Equipment

a. Isotonic Electronic Free-Weight Dynamometer

This testing apparatus was built and designed to measure the concentric phase and eliminate the eccentric phase of an isotonic exercise. When the soldier performed more than one repetition, the dynamometer automatically returned the weighted ba: back to the original position at a set speed. When the bar returned the soldier would again perform the concentric phase of the exercise. This cycle was continued until the test was completed (Chahal, 1993).

b. Isokinetic Electric Trunk and Leg Dynamometer

This testing dynamometer measured isokinetic-concentric and isometric maximal strength. Isokinetic tests included: concentric leg extension, trunk extension and trunk flexion tests. Isometric tests included: trunk extension and trunk flexion. The dynamometer set up consisted of an electric motor connected to a chain and a load cell. Connected to the chain and load cell was a cable that passed over ball bearing pulleys and emerged through a platform (on which the soldier was standing). The positioning of the soldier relative to this cable was determined by the test (Figure 5).

Figure 5. Isometric Trunk Extension Strength Test on Electric Trunk and Leg Dynamometer.

For testing leg extension, a webbed belt with an attached steel bar was secured around the soldier's waist, and the cable, emerging from the platform between the soldier's feet, was attached to this belt. The belt was easily adjusted comfortably and securely around the soldier's waist. To test trunk extension, a bar was connected to the cable allowing the soldier to stand and perform the back-lifting motion. To test trunk flexion, the cable was connected to two pulleys located on the posterior aspect of the back board and the cable was connected to a shoulder harness through a back board (Chahal, 1991).

Prior to testing, the electric dynamometer and load cells were calibrated. As jerking movements could have resulted in artificial increases in peak force output, soldiers were instructed not to produce bouncing, jerky movements during the test. Load cell output was connected to a computer to record, plot and store data (Chahal, 1993).

Muscular Strength Tests

a. Isometric Strength Tests

These tests were conducted at joint angles relevant to the appropriate field tests. The test battery consisted of: arm flexion, trunk flexion and extension, and handgrip. The soldiers performed a warm-up contraction of 50-60% maximal voluntary effort prior to testing. Testing consisted of the soldiers performing two maximal voluntary contractions of five seconds duration each with a rest period of three minutes between contractions. Maximal force generated was recorded and used for data analysis. Subjects were instructed to breathe normally, and the soldiers were verbally encouraged during testing (Chahal, 1993). Following are descriptions of the various isometric strength tests.

Isometric handgrip strength test

Utilizing a handgrip dynamometer (Carolina Biological Supply Company, Burlington, North Carolina, U.S.A.), maximum grip strength was recorded for each hand. Testing procedures were identical to those described by Stevenson et al. (1988).

Isometric arm flexion strength test

Testing was conducted at the elbow angle of 105 degrees with the soldier grasping the bar with hands shoulder width apart. Elbow angle and hand width were representative of a soldier's arm position while carrying ammunition boxes (Chahal, 1993).

Isometric trunk flexion strength test

To test isometric trunk flexion strength, the Isokinetic Electric Trunk and Leg Dynamometer was set up so the cable came up behind the soldier, passing through two pulley's on the back board and attaching to a hook on an upper back harness worn by the soldier (Figure 6). The harness hook, on the soldier's upper back, was standardized at a height parallel to the inferior border of the upper arms at armpit level. The upper pulley was adjusted to the height parallel to the hook elevation while the soldier was standing and a chain was used to adjust the cable length according to the soldier's height. The feet were positioned with the lateral borders shoulder width apart (Figure 7). Soldiers were tested at a hip angle of 160 degrees (Chahal, 1993).

Isometric trunk extension strength test

This test was performed at a hip angle of 160 degrees, which was measured with a manual goniometer before testing during the submaximal warm-up contraction. The bar-attached-to-the-cable set-up was used with an over and under handgrip to perform the test. For safety reasons, soldiers were instructed to keep their upper back straight while performing the test. The foot positioning was the same as for the trunk flexion strength test (Chahal, 1993).

Figure 6. Harness Used for Testing on Isokinetic Electric Trunk and Leg Dynamometer.

Figure 7. Soldier Performing Isometric Trunk Flexion Strength Test.

b. Isokinetic-Concentric Strength Tests

The isokinetic-concentric strength test battery consisted of the following tests: arm flexion, leg extension, trapezius lift, bench press, trunk flexion, trunk extension, and knee flexion and extension. The following tests: arm flexion, leg extension, trapezius lift and bench press, were conducted at a cable velocity of 13 cm/s (corresponding to an angular velocity of 30 degrees/s). The trunk flexion and trunk extension tests were conducted at a cable velocity of 6.5 cm/s (angular velocity 15 degrees/s). These velocities were based on the knowledge that trunk movements tend to occur at slower velocities than peripheral joint movements (Singh et al., 1991). Knee extension and flexion tests were conducted at an angular velocity of 180 degrees/s. This speed was specific to the angular knee velocity utilized by soldier during weight load marching (Dziados et al., 1987). Warm-up for the soldiers consisted of six contractions at 50-60 % of maximal effort. Testing consisted of two sets of two maximal voluntary contractions with a three minute rest interval given between each set of contractions. Maximal force was recorded and used for data analysis (Chahal, 1993).

Isokinetic-concentric arm flexion strength test

The arm flexion contraction was performed from approximately 180 degrees to 40 degrees of elbow flexion. Grasping the bar with hands shoulder width apart a soldier exerted a maximal contraction, lifting the bar upwards. After full flexion, the cable was automatically lowered by the dynamometer to the starting position for another repetition (Chahal, 1993).

Isokinetic-concentric leg extension strength test

Prior to the test a soldier stood on the dynamometer platform to allow adjustment of the cable to waist height and connection to the waist testing belt. To provide stability, the soldier was instructed to grasp each end of the bar attached to the belt (Figure 8). Testing was conducted from a starting knee flexion angle of 90 degrees to a finish angle of 180 degrees (full extension). The cable was released by the dynamometer at a preset speed. When standing height was reached, the soldier reassumed the knee flex angle of 90 degrees and prepared to repeat another maximal contraction (Chahal, 1993).

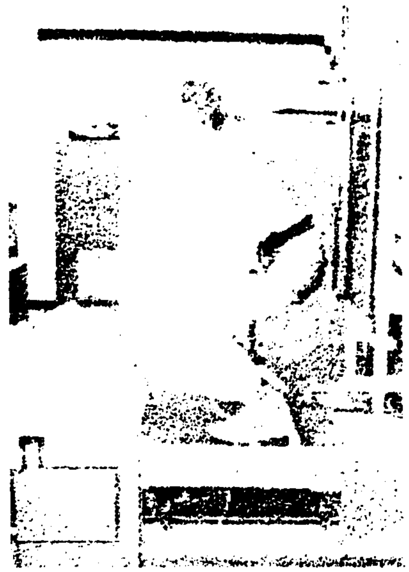

Figure 8. Soldier Performing Isokinetic-Concentric Leg Extension Strength Test.

Isokinetic-concentric trapezius lift strength test

A soldier was tested in a standing position with feet shoulder width apart. The weight bar was equipped with special handles to simulate handles of the standard ammunition box (handles 38.5 cm apart). The test started with arms at full extension. The bar was then lifted upward until the top part of the grip handles reached a height parallel to the soldier's clavicle height (sternal end)(Figure 9). At this point the subject relaxed, maintained their grip on the handles, and the dynamometer returned the bar to the starting position for the soldier to perform another contraction (Chahal, 1993).

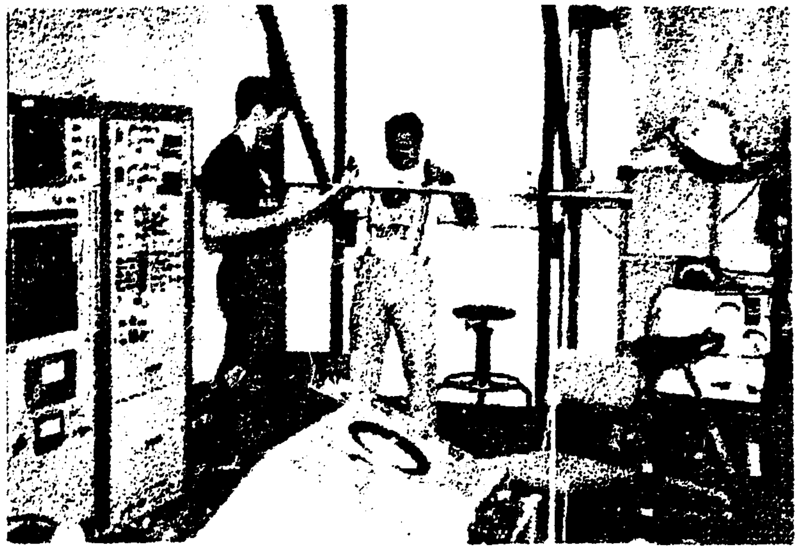

Figure 9. Soldier Performing Isokinetic-Concentric Trapezius Lift Strength Test (Chahal, 1993).

Isokinetic-concentric knee flexion and extension torque tests

These tests were performed on a Cybex Dynamometer (Cybex, 1983; Moffroid et al., 1969) within a range of 90 to 180 degrees knee flexion. At the "start" command the soldier maximally extended the knee, then maximally flexed it. Only one repetition was utilized and the test was conducted on both legs.

Isokinetic-concentric trunk flexion strength test

The test was conducted through a hip angle range of 150-170 degrees. Body positioning and handgrip were identical to that used for the isometric trunk flexion strength test. Keeping the legs and back straight a soldier pulled forward and downward while the cable was released at a preset speed. When a hip angle of 150 degrees was reached, the soldier stopped pulling and again assumed the starting position to perform another maximal contraction (Chahal, 1993).

Isokinetic-concentric trunk extension strength test

The test was conducted through a hip angle range of 150-170 degrees. Body positioning and handgrip were identical to that used for the isometric trunk extension strength test. Keeping the legs and back straight a soldier pulled up on the bar while the cable released at a preset speed. When a hip angle of 170 degrees was reached, the soldier stopped pulling and again assumed the starting position to perform another maximal contraction (Chahal, 1993).

Isokinetic-concentric bench press strength test

Soldiers performed this test in a supine position on a bench utilizing the Isokinetic Electric Dynamometer (Figure 10). Bar height was preset at two inches above the chest (mid-sternal level) with the soldier grasping the bar with hands shoulder width apart. At the start, the soldier pushed up on the bar until full extension of the elbow joints was reached. The soldier then relaxed and the dynamometer returned the cable to the starting position where they again performed another maximal contraction (Chahal, 1993).

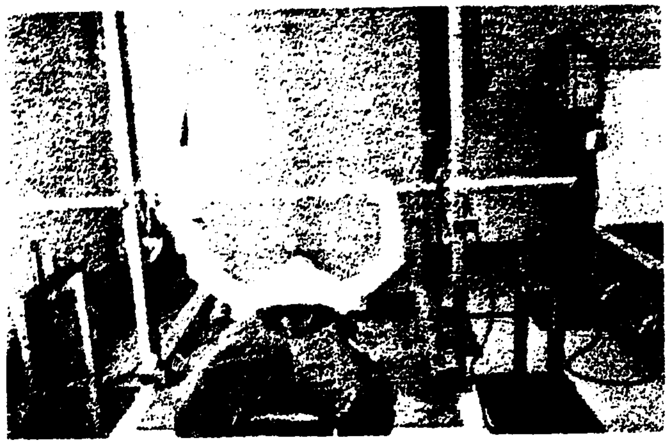

Figure 10. Soldier performing Isokinetic-Concentric Bench Press Strength Test.

c. Muscular Endurance Tests

Isometric handgrip endurance tests

This test was conducted on the handgrip dynamometer. Grip endurance was measured for both the right and left hands. Soldiers attempted to maintain the force output needle at 205.8 N for as long as possible. Instruction was given when the force needle deviated from 205.8 N. Test termination criteria was the inability of the subject to maintain the required force for a two-second time span. Data for endurance scores were recorded in seconds (Chahal, 1993).

Isometric arm flexion endurance test

Testing was conducted at an elbow angle of 105 degrees, as this angle represented the elbow angle soldiers would utilize while carrying ammunition boxes. A free weight bar (20.9 kg) was used to simulate the ammunition box, and elbow angle was kept constant by using a goniometer. The subject held the bar with hands at shoulder width.

Soldiers were provided continuous feedback during the test as to their elbow angle and test termination occurred when they failed to maintain the testing elbow angle for two seconds. Time sustained with the elbows at the testing angle was recorded in seconds (Chahal, 1993).

Isotonic-concentric trapezius lift endurance test

Body positioning and lifting technique utilized in this test were similar to the isokinetic-concentric trapezius lift strength test. Rationale for using the free-weights over isokinetic procedures was that when lifting the ammunition boxes the soldier would be required to lift the same weight regardless of joint angle. Soldiers performed 10 contractions per minute with a 21 kg bar (three second lift followed by a three second rest interval). After each lift, the soldier relaxed and the bar automatically returned to the starting position. Pace was set using a metronome and the test was terminated when a soldier was unable to keep up to the metronome pace or completed 100 repetitions. The number of completed repetitions was then recorded (Chahal, 1993).

d. Body Composition Test

Hydrostatic weighing

The hydrostatic weighing tank's dimensions were 6 feet in height x 4 feet in width x 10 feet in length. An aluminum chair suspended from a load cell was connected to a computer. Soldiers were weighed (to the nearest tenth of a kg) in a bathing suit prior to each test. In the chair a 9.45 kg divers belt was placed across the soldier's thigh, close to their waist, and vital capacity was measured. Residual volume was estimated as a 24% of vital capacity. At this point the hydrostatic weight was determined using the following procedure:

1. Air bubbles were dislodged from the soldiers suit, hair and body.
2. The soldier maximally inhaled and closed their nasal passages. The soldier was instructed to remain as motionless as possible.
3. The subject was slowly lowered into the water, and once a motionless state was achieved a six second underwater weighing reading was recorded. At this time the chair was lifted by the tester to such a point that the soldier's head and neck rose from the water.
4. The percent body fat (based on Bozek et al.'s (1963) formula) and fat free body weight were then calculated.

This procedure was repeated until the computer recorded two readings within a half percent of body fat to each other (Mottola, M.F.).

Determination Of Acceptable Level For The Performance Standards.

The process for determining the performance standards was as follows. Recommended performance standards for the field tasks were based on: (a) cutoff performances suggested by the panel of subject matter experts and the researcher; (b) soldiers physiological capabilities to meet job requirements. A panel of expert judges was asked to classify all individuals into pass and fail groups. Then a discriminate analysis was used to determine the linear combination of field tests that maximally discriminated between the two groups and the resultant classification was used to determine percentage of correct classifications. The discriminate analysis results did not support or refute any of the cutoff performances suggested by the expert judges or the researcher (Chahal, 1993).

Based on this process Singh et al. (1991) set the performance standards for the field tests as follows:

- a 13 km Weight Load March at standard military pace (5.33 km/h);
- the Maximum Dig Field Test in 360 s or less;
- the Casualty Evacuation Field Test in 60 s or less;
- the Ammunition Box Field Test in 300 s or less (Chahal, 1993).

C. Relationship Between Field and Laboratory Test Results

Chahal (1993) and Lee (1992) statistically explored the relationship between the laboratory tests and the field tests by first computing Pearson Product Moment Correlation's between the laboratory tests and field tests. Correlation results ranged from -.02 to -.49. The negative coefficients indicate that as laboratory performance scores increased time to complete the field tests decreased (Lee, 1992). Lee (1992) stated that for the most part the correlation's were low and that the homogeneity of the subjects may have been partially responsible for the low correlation's.

Lee (1992) and Chahal (1993) then explored the possibility that several laboratory variables would combine to produce a predictive model for the field tests. Stepwise multiple regression was used for this procedure. The laboratory tests which had the highest Pearson Product Moment Correlation coefficients with the field tests and ideally low correlation among other laboratory tests were selected for the analysis (Lee, 1992).

The results of their analysis was as follows. Lee (1992), analyzing the results of aerobic and anaerobic power tests against field test performance reported the following. For the Casualty Evacuation the multiple correlation coefficient was 0.49. The corresponding multiple correlation and regression equation for predictive purposes used only one laboratory measurement: leg peak power output. For the Ammunition Box Lift the multiple correlation coefficient was 0.49. For predictive purposes, only leg peak power output and aerobic power relative were significant. For the Maximal Dig, the multiple correlation coefficient was 0.62. The two significant variables were again leg peak power output and aerobic power relative. Finally, the Weight Load March did not reveal significant correlation with the aerobic and anaerobic power laboratory variables for multiple correlation.

Chahal (1993), analyzing the results of muscular strength, muscular endurance and body composition tests against field test performance reported the following. For the Casualty Evacuation the multiple correlation coefficient was 0.49. The corresponding multiple correlation and regression equation for predictive purposes used only two laboratory variables: static trunk flexion strength and percentage of body fat. For the Ammunition Box Lift the multiple correlation coefficient was 0.43. For predictive purposes, only static trunk flexion strength and percentage of body fat were significant. For the Maximal Dig, the multiple correlation coefficient was 0.58. The two significant variables were dynamic leg extension strength and trapezius lift endurance. Finally, for the

Weight Load March the multiple correlation coefficient was 0.29, and was not significant with any laboratory test (Chahal, 1993).

Lee (1992) and Chahal (1993) then computed canonical correlation coefficients between selected laboratory tests and field tests. The resulting coefficient provided an overall relationship with the selected laboratory tests and field tests. The canonical correlation coefficient achieved was 0.73, indicating a good relationship between the laboratory and field tests (Lee, 1992; Chahal, 1993).

The present study was undertaken to reexamine the data collected from Singh et al.'s (1991) research. Although the correlation's obtained utilizing the Pearson Product Moment Correlation Coefficients were relatively low, it was felt that additional statistical exploration of the data base would reveal valuable information about the relationship between the laboratory and field tests. The logical next step to Singh et al.'s (1991) research project would be the development of exercise programs to improve the soldiers performance in the field tests. Therefore, it seemed necessary and lucrative to examine the association between laboratory and field tests results as thoroughly as possible.

To this end, a review of literature dealing with field and laboratory tests results was performed. Some studies reported a strong relationship between field and laboratory tests (Brettoni et al., 1989; Buono et al., 1991; Fohrenbach et al., 1987). Other studies noted a weak relationship (Watson and Sargeant, 1986; Woods et al., 1992). Several variables that impacted this relationship were identified.

The Effect of Modality on Laboratory and Field Test Relationship

One factor that affected the relationship between laboratory and field tests was the modality of the tests. Brettoni (1989), working with cyclist and runners, reported anaerobic threshold (AT) values obtained by ventilatory methods (on treadmill for runners and cycloergometer for cyclist) were significantly correlated to AT values obtained with a field test using track running and cycling. He postulated that when the laboratory tests mimic, as closely as possible, the field tests, they were good predictors. Buono (1991 found a similar relationship. He reported a strong relationship between a timed distance run (field test) and a treadmill VO_2max laboratory test. A weaker relationship was found with field tests of more dissimilar modality (the step test or submaximal cycle ergometer VO_2max predictive tests).

Singh et al., (1991) addressed the issue of modality between laboratory and field tests. Singh's et al.'s laboratory tests were specifically adapted to duplicate, as closely as possible, the actions that occurred in the field tests. For example, soldiers performed the Treadmill Aerobic Power test while wearing the same clothing (Full Fighting Order) and marching at the same speed (8.9 m per minute) as was utilized in the Weight Load March Field Test. In addition, many of the muscular strength and endurance tests utilized specific resistance's or were performed at specific joint angles that mimicked those found in the field tests.

Diversity of Factors Affecting the Relationship Between Laboratory and Field Tests

Woods (1992) and Elliot et al. (1990) discussed the need to consider diverse physiological factors when analyzing the relationship between field and laboratory tests. Woods (1992), in a study measuring upper body muscular strength and endurance, found low correlation's between accepted laboratory tests (isotonic contractions on a set resistance) and field tests (pull-ups, pushups, etc.). However, body fat percentage and height both had a significant relationship with the laboratory tests. Elliot (1990) also found a relationship between diverse laboratory and field tests, with body composition being a significant [illegible] when comparing skilled tennis players.

Analysis of laboratory and field tests should not be restricted to what may seem to be a dominant fitness component, but should be based on as many factors as possible. This will assist in not only determining <u>if</u> a relationship exists, but <u>where</u>. In Singh et al.'s study there was not only a diverse set of laboratory tests but a diverse set of field tests. In total 18 different laboratory tests provided 220 physiological variables for aerobic power, anaerobic power, muscular strength, muscular endurance and body composition. Field Tests pushed the soldiers to full out effort for time frames ranging from 60 seconds (Casualty Evacuation) to over 2 hours (Weight Load March), and taxed physiological factors necessary for lifting, carrying, digging and marching.

Validity and Reliability of Tests

Cogan and Costill (1984) estimated that 10-30% of inter-test (ergometer) variability was technological. Establishing the reliability of tests is imperative in comparing laboratory and field tests. Singh et al. (1991) recognized the need to establish reliability for the newly developed and untested laboratory and field tests. A pre-test was utilized by Singh et al. to determine the reliability of all field tests and laboratory tests that did not have literature reported values. The results of the pre-test showed reliability for all tests ranged from 0.83 to 0.99.

Validity is also imperative. Steininger (1987) questioned the validity of laboratory tests for research in some sports:

> The value of a laboratory test is incontestable for sports involving simple, rhythmic movements like cycling, rowing or running. These tests fail in sports characterized by complicated, non-rhythmic movements in which quickness, rapid force development and fast reactions are required.

The field tests developed by Singh et al. are of the simple, rhythmic movement category that Steininger supports. Therefore the use of laboratory tests to analyze the field test results would also seem to be supported.

For the results of the statistical analysis to be inferred to a greater population, construct validity of the field tests must also be established. Construct validity of the field tests was established by Singh et al. utilizing a multi-phase process that included identification of tasks and the subcomponents of being a military soldier. The procedure used for identifying these aspects included survey questionnaires, interviews, observation and physical measurements. Consultation was used with subject matter experts and received the approval of senior administrators (Singh et al., 1991). Chahal stated this process "...allows greater face validity of the selected tasks and also ensures acceptability of the set standards within an organization (Chahal, 1993)."

Heterogeneity of Subjects

In some studies comparing laboratory and field tests, the heterogeneity of the subjects had an effect on the results. Paliczka et al. (1987), studying recreational runners, commented on the effect of heterogeneity on correlation, "The high correlation shown in this study, whilst undoubtedly influenced by the heterogeneous nature of the sample..." Lehmann et al. (1983), reporting on past studies involving runners, stated, "These previously described, highly significant correlation's may be favored by nonhomogenous groups."

However, some studies (Fohrenback, 1987; Lehmann, 1983) still obtained significant relationships between laboratory and field test while utilizing homogeneous groups. Lehmann (1983) obtained significant results from a homogeneous sample of marathoners utilized a laboratory test (treadmill with no grade) that closely resembled the field test (running speed in marathon). Fohrenbach (1987) reported on a similar study with marathoners utilizing field (running outdoors on asphalt track) and laboratory (running a marathon) tests of similar modalities. He noted a significant relationship between test results while utilizing a homogeneous sample.

The effect of homogeneity must be considered with the soldiers in Singh et al.'s study, as combat soldiers would likely have had similar physical attributes and abilities. However, as discussed earlier, the modality of the laboratory and field tests in Singh's study was similar and, as with Lehmann and Fohrenbach, a significant relationship may still be found. Indeed, the homogeneity of the soldiers may prove beneficial. If a significant relationship can be determined between the laboratory and field tests, the validity of the results will be strengthened by having the results come from a homogeneous group.

D. Summary Of Literature Review

Over the years the Canadian Military has altered their protocols in response to research in fitness. However, the 1978 Canadian Human Rights Act forced the military to develop fitness standards based upon their own requirements rather than utilize standards from other aspects of society. The Canadian Military contracted Singh et al. (1991) to develop field tests that would meet these needs. The field tests and standards Singh et al. developed provided the military with a means of assessing the physical fitness of their soldiers. However, the military still had to address the issue of soldiers who failed the standard or wished to improve their performance.

Research in the areas of lifting, digging and marching, was not thorough enough to answer the question. Singh et al.'s (1991) extensive laboratory and field test results on the 116 soldiers provided an opportunity to further explore this area. Other research into the relationship between laboratory and field tests has indicated a number of areas of concern which Singh et al.'s data appears to address. Therefore, the need and the means to address the question appear to be present.

CHAPTER III. METHODOLOGY

A. Subjects

The subjects were 116 male military Army Infantry personnel from Canadian Forces Base, Calgary, Alberta, who had volunteered to participate in the project. The age range of the subjects was 17 - 44 years, with a mean age of 25.74 year (Lee, 1992).

The soldiers filled out health hazard appraisal forms, Par-Q, Consent Forms for laboratory and field tests, had their resting blood pressure and heart rate monitored. In addition, they underwent medical screening prior to being included in the study. The soldiers were asked to refrain from vigorous exercise for 24 hours preceding testing, and abstain from smoking, alcohol, caffeine and excessive eating prior to and during the testing period. (Lee, 1992).

B. Laboratory Test Battery

A detailed description of all laboratory tests utilized in Singh et al.'s (1991) study has been provided earlier. Tables 1, 2, 3, 4 and 5 list the laboratory test battery and the resulting laboratory measurements utilized in this study.

Table 1. List of Aerobic Laboratory Test Battery and Resulting Laboratory Measurements Utilized in this Study

Aerobic Laboratory Test	Laboratory Test Battery	Resulting Laboratory Measurement
VO_2max Test	Treadmill Ergometer	• absolute aerobic power • relative aerobic power • absolute anaerobic threshold • relative anaerobic threshold

Table 2. List of Muscular Strength Laboratory Test Battery and Resulting Laboratory Measurements Utilized in this Study

Muscular Strength Laboratory Tests	Laboratory Test Battery	Resulting Laboratory Measurement
Isometric Strength Tests	Handgrip Test	• left handgrip strength • right handgrip strength
	Arm Flexion Test	• static arm flexion mean • static arm flexion maximal
	Trunk Flexion Test	• static trunk flexion mean • static trunk flexion maximal
	Trunk Extension Test	• static trunk extension mean • static trunk extension maximal
Isokinetic-Concentric Strength Tests	Arm Flexion Test	• dynamic arm flexion mean • dynamic arm flexion maximal
	Leg Extension Test	• dynamic leg extension mean • dynamic leg extension maximal
	Trapezius Lift Test	• dynamic trapezius lift mean • dynamic trapezius lift maximal
	Knee Flexion and Extension Torque Tests	• left knee flexion • left knee extension • right knee flexion • right knee extension
	Trunk Flexion Test	• dynamic trunk flexion mean • dynamic trunk flexion maximal
	Trunk Extension Test	• dynamic trunk extension mean • dynamic trunk extension maximal
	Bench Press Test	• bench press mean • bench press maximal

Table 3. List of Muscular Power Laboratory Test Battery and Resulting Laboratory Measurements Utilized in this Study

Muscular Power Laboratory Tests	**Laboratory Test Battery**	**Resulting Laboratory Measurement**
Upper Body Power Test	Upper Body Wingate Test	• arm peak power output • arm mean power output • arm relative power output - ppo (peak power output) • arm relative power output - mpo (mean power output)
Lower Body Power Test	Lower Body Wingate Test	• leg peak power output • leg mean power output • leg relative power output - ppo (peak power output) • leg relative power output - mpo (mean power output)

Table 4. List of Muscular Endurance Laboratory Test Battery and Resulting Laboratory Measurements Utilized in this Study

Muscular Endurance Laboratory Tests	**Laboratory Test Battery**	**Resulting Laboratory Measurement**
Isometric Muscular Endurance Tests	Handgrip Test	• left handgrip endurance • right handgrip endurance
	Arm Flexion Test	• arm flexion endurance
Isotonic-Concentric Muscular Endurance Tests	Trapezius Lift Test	• trapezius lift endurance

Table 5. List of Body Composition Laboratory Test Battery and Resulting Laboratory Measurements Utilized in this Study.

Body Composition Laboratory Test	**Laboratory Test Battery**	**Resulting Laboratory Measurement**
Body Composition Test	Hydrostatic Weighing	• weight • body density • body fat percentage • lean weight

C. Field Test Battery

The field test battery consisted of the following four task-specific events.

Maximal Dig Field Test

The soldiers scooped, lifted, and threw, as quickly as possible, 0.486 cubic meters of standardized gravel out of a slit trench simulator using an issue shovel. The purpose of the task was to simulate digging and the building of defensive positions to provide protection to personnel against incoming enemy fire.

Casualty Evacuation Field Test

The soldiers lifted and carried (using the Fireman's Lift technique) another soldier of their own weight and height for a distance of 100 m. This simulated the evacuation of a wounded soldier in the shortest possible time in a battle situation.

Ammunition Box Field Test

The soldiers lifted 48 ammunition boxes (weighing 20.9 kg each) from the ground to a table 1.3 m in height. This table height simulated the bed of a military truck. This task was completed at a submaximal effort (70% maximal aerobic power) because of the perceived risk of injury if soldiers attempted to lift the boxes as quickly as possible.

Weight Load March Field Test

The soldiers marched for a distance of 16 kilometers in full fighting gear and backpack (total weight 24.5 kg). The pace was determined by discussion with the military and standardized at 88.9 m per minute. The march was conducted indoors to standardize environmental conditions such as terrain, humidity, temperature, and accuracy of speed (Chahal, 1993).

D. Statistical Analysis Of The Collected Data

Statistical analysis of the data base collected by Singh et al. (1991) had previously been performed by Lee (1992) and Chahal (1993). The statistical procedures they utilized were as follows:

1. Identify any multivariate outliers from data and remove them from analysis.
2. Mean, standard deviations, and range of scores for each variable (laboratory and field tests) were determined.
3. Pearson Product Moment Correlation's amongst all field and laboratory tests were calculated.
4. Multiple Stepwise Correlation's and Regression equations were formulated for each field task.
5. Canonical Correlation between laboratory and field test variables

The goal of Chahal and Lee's research was to attempt to predict performance of the field tests from the results of laboratory tests. They attempted to establish the best prediction with the most efficiency.

The process Lee and Chahal utilized to develop the predictive regression equations resulted in variables being excluded that, on their own, would be related to a field test, but in conjunction with other variables did not add any additional information. When analyzing their data, their process chose laboratory test variables that correlated highly with the field task but not with other laboratory tests. For example, even though the laboratory test aerobic-power-absolute may have had a higher correlation to the Ammunition Box Field Test than leg-mean-power-output, leg-mean-power-output may have been chosen for the equation. The reasoning being that although leg-mean-power-output was only moderately related to the field test, it did not show much relationship to other variables. Aerobic-power-absolute, on the other hand, was not chosen as it was correlated with many other laboratory test variables. Thus, Lee and Chahal's statistical analysis resulted in only a few laboratory tests being included in the regression equation. This occurred because in the context of their goal, which was prediction, they did not require the information from other laboratory tests (Stevens, 1992).

The purpose of the present study was not to predict field test performance but to explore the data to determine the physiological factors involved in the performance of the individual field tests. The logical next step to Singh et al.'s research project would be the development of physical fitness training programs to improve the soldiers performance in the field tests. Therefore, it was a necessary and lucrative endeavor to examine the data as thoroughly as possible to best enable the development of the physical fitness programs. To this end, it was felt a reexamination of the data would expose and clarify any relationships that had been missed by the correlation statistical method. To accomplish this, statistical analysis of both group and individual data was performed.

Analysis of Group Data

To analyze the group data, soldier's performances in each field test were rank ordered (ordinal scale) from #1 to #116. Rank was based on performance time for three of the four field tests: Casualty Evacuation, Ammunition Box, and Maximum Dig. For example, the soldier who performed the Casualty Evacuation Field Test the fastest was given the rank #1. The second fastest was given rank #2, etc. For the fourth field test, the Weight Load March, rank was based upon a finishing heart rate/maximal heart rate ratio. A detailed description of the ranking method used for the Weight Load March is provided in Chapter IV.

As a result of this ranking, the soldiers in each field test were divided into three groups. The first group contained soldiers whose performance in the particular field test ranked in the top 27%. The second group contained soldiers whose performance in the field test ranked in the bottom 27%. The third group contained soldiers whose performance in the field test ranked in the middle 46%. As this study attempted to identify which physiological factors contributed to success or failure in the field tests, only the first (top 27%) and second (bottom 27%) groups were utilized.

The top 27% will hereafter be referred to as Group A. The bottom 27% will hereafter be referred to as Group B. This method provided a simple, sensitive and stable item discrimination to be applied to the data. An item discrimination provides a means to discriminate or differentiate between examines who were relatively high on a criterion of interest and those who are relatively low. Therefore, this method provided a means to differentiate soldier's performance in the field tests (Crocker and Algina, 1986).

Independent t-tests were performed on Group A and B to determine if there was a statistically significant performance difference between the two groups for each field test. Groups A and B were the independent variables and the field test results were the dependent variables. The results for all four field tests were significant values of .000 indicating a significant difference in performance between Groups A and B for all four field tests.

For the statistical analysis, Groups A and B were the independent variables and the results of the laboratory measurements were the dependent variables. As the independent variable was composed of only two groups (Group A and Group B), the t-test for independent groups statistical method was utilized. For every field test, all laboratory measurements were statistically analyzed to determine if there was a significant difference in the performance by Groups A and B soldiers. The null hypothesis of the study applied to each t-test performed. The null hypothesis stated that the difference between the means of Group A and Group B's performance on a specific laboratory measurement was due to random sampling from populations where the means were equal. For example, using the Casualty Evacuation Field Test, and the laboratory measurement absolute aerobic power, the null hypothesis would state: performance in the Casualty Evacuation Field Test (as identified by Group A and Group B) had no effect on the performance of the laboratory measurement absolute aerobic power, and the difference between the means of Group A and Group B's absolute aerobic power results was due to random sampling from populations with equal means. Statistical variables calculated were: mean, statistical deviation, and 2-tail significance.

This process resulted in a significance value being determined for all laboratory tests for each field test. The interpretation of the significance level was in the context of the confidence in whether the two populations (Group A and Group B) came from populations where the difference between the two groups in the test being examined was zero. The greater the significance value (for example, .99) the increase in confidence that the difference between the two populations was zero. These significance values for all the laboratory measurements were recorded and analyzed according to the significant value (Stevens, 1992).

Utilizing numerous t-tests increased Type 1 error probability. To address this, some studies utilizing numerous t-tests set alpha at 0.01. However, this was an exploratory study with the intent of analyzing all laboratory measurements for the purpose of best understanding the physiological requirements of each field test. Therefore, in this study there was a greater concern of Type II error, and as a result alpha was set at 0.05 (Stevens, 1992).

Analysis of Individual Data

The results of this study will be utilized in the development of future military training programs. Therefore, the determination of the key physiological factors necessary for successful field test performance must be as precise as possible. As already stated, analysis was performed on group data using the t-test statistical method. The t-test method represented a common approach to data analysis. However, it was felt further exploration of the data would provide additional depth and clarity to the findings.

Additional exploration consisted of analyzing the laboratory test results of the three best (first, second, and third place finishers) and three worst (last, second last and third last finishers) individual performances for each field test. This analysis was used to determine if the individual performances supported or opposed the results obtained utilizing t-test group analysis. For example, if the group data analysis indicated that leg power absolute was a significant factor in the top performance of the Casualty Evacuation Field Test, did the analysis of the best and worst three performers support this? Did the best three performers significantly outperform the worst three performers in leg power absolute? If the best individuals finished considerably better than the worst individuals in tests that significantly differentiated Group A (top 27%) and Group B (bottom 27%), this would have supported the group data analysis. If this situation did not occur, it would challenge the group data analysis.

In addition, the individual analysis provided unique information on the interplay between physiological components and performance. The t-test analysis provided a broad understanding of this interplay by identifying that, for example, physiological factors 1,2, and 3 were significantly related to best performance of field test X. The individual analysis, however, provided a different and unique view of the situation. For example, soldier A may have been successful with high scores in physiological factors 1 and 3, yet a poor score in factor 2. Contrarily, soldier B may have been successful with a high score in factor 2, yet poor scores in factors 1 and 3. Therefore, the individual analysis provided additional information and an interesting and rarely utilized view of the data that assisted in determining the importance of the physiological factors to field test performance.

The process used for the individual analysis for the four field tests was as follows.

- The three best and three worst performers were identified.
- Laboratory measurement results for all 116 soldiers were rank ordered (ordinal scale) according to performance, with #1 being assigned to best performance and #116 being assigned to the worst performance.
- The individual rankings for all best three and worst three performers in all field tests were determined and plotted on a graph. This graph was constructed with rank order on the Y axis and the laboratory measurements on the X axis.

This study used these group and individual analysis methods to determine the relationship between the laboratory measurements and field test performance.

CHAPTER IV. RESULTS AND DISCUSSION

A. Analysis of the Casualty Evacuation Field Test

In a battle situation, a soldier may be required to evacuate an injured or wounded soldier from a hazardous position to a safe one. The speed and effectiveness with which this is accomplished could be the difference between life and death. As a result of the importance of this task, the Casualty Evacuation Field Test was included in the field tasks recommended by Singh et al. (1991) to the Canadian Military. To perform the field test a soldier was required to carry another soldier of equivalent height and weight at a maximal effort for a distance of 100 m. The recommended performance standard for the test was 60 s (Chahal, 1993).

Analysis of Group Data

In the performance of the Casualty Evacuation Field Test the following protocol was utilized. Two soldiers (soldier A and B) were involved: the soldier being timed for their performance (soldier A) and the soldier being carried (soldier B). Soldier A, using the Fireman's Carry technique, lifted soldier B onto his shoulder and steadied himself before the timed test began. Soldier A used his non-dominant arm and hand to stabilize soldier B. Soldier A's other arm was free to move (Figure 3).

Theoretical Analysis of Casualty Evacuation Field Test

To analyze the field test from a performance perspective, the activity was divided into the following components.

- the involvement of the lower body
- the involvement of the trunk region
- the involvement of the upper body/arm
- the energy system utilized

a. Involvement of Lower Body

The involvement of the lower body would likely have been significant in the performance of the field test. The propulsion of soldier A was derived mainly from muscular power and strength of the lower body. As a considerable weight was being carried and the event was timed, leg [illegible] was an important factor. Force, when walking, was generated by hip and knee ext[illegible]sion and planter flexion (Tortora, 1989). The stress on the involved joints [illegible]ased due to the extra weight carried and the speed at which soldier A traveled. The laboratory measurements that addressed these factors were: leg power, dynamic leg extension and knee extension.

b. Involvement of the Trunk Region

In the Casualty Evacuation Field Test the soldier being carried (soldier B) was of equal weight (or as close as possible) to the soldier performing the carry (soldier A). This constituted a noteworthy weight having been carried on soldier A's shoulders. The stabilization of soldiers A's trunk region was necessary to carry this weight for 100 m.

The stabilization of the trunk required the involvement of the back extensors and abdominal muscles. The laboratory measurements that addressed these factors were static and dynamic trunk flexion and extension tests.

c. Involvement of the Upper Body/Arm

With the upper body/arm region there were three likely areas of involvement. First, in the performance of the activity, the dominant arm was free to move. Its movement would ha[illegible]buted to forward propulsion of soldier A by having produced a counter force to the tru[illegible]otation created by the leg movements. Arm power laboratory measurements addressed this involvement. Second, the muscles of the shoulder area of soldier A were used in supporting soldier B. The laboratory measures addressing this involvement were the trapezius strength and endurance tests. Third, soldier B was stabilized on soldier A's shoulders to reduce disruptive forces and movements during the carry. Soldier B was stabilized primarily with soldier A's non-dominant arm and hand. The laboratory measurements for arm strength and power, and handgrip strength and endurance would have addressed this involvement.

d. Energy Systems

Fox, Bowers and Foss (1988) stated that events lasting 45 seconds have an approximate percentage energy contribution of 80% anaerobic and 20% aerobic. The mean time for completion of the Casualty Evacuation Field Test was 46.9 seconds. Therefore, most of the energy production required from the Casualty Evacuation Field Test was likely derived from anaerobic sources.

Analysis of t-test Results

With this performance breakdown in mind, a statistical analysis of the 116 soldier's Casualty Evacuation Field Test performances was undertaken. The statistical analysis was conducted to identify the physiological factors that were responsible for best and worst performances. To accomplish this, the following process was used.

1. Casualty Evacuation Field Test results for all 116 soldiers were rank ordered.
2. Two groups were identified. A group of the best performers (first 27% of the rank ordered) and a group of the worst performers (last 27% of the rank ordered).
3. Statistical t-tests were then performed using the best and worst groups as independent variables and the laboratory tests as the dependent variable (Crocker and Algina, 1986).

This process identified two groups, the best performers and the worst performers of the Casualty Evacuation Field Test, and performed a statistical analysis of their performance on every laboratory measurement. The purpose of this process was to attempt to understand the physiological factors that contributed to top performance of the field test. By better understanding the physiological factors involved, it is more likely that an effective, efficient fitness training program can be designed for military personnel.

The t-test statistical analysis produced a significance value for every laboratory measurement. This value was interpreted in the context of confidence in whether the two samples came from populations where the difference between the means of the two populations is zero (Stevens, 1992). For example, if the significant value for a particular laboratory measurement was 0.99, it would have indicated 99% confidence in predicting the difference between the two populations was zero. However, if the significant value was .01, it would have indicated only a 1% confidence in predicting population difference at zero, and therefore a strong confidence that the two groups came from different populations. All t-test results which produced significant values of less than .05 were manually checked to insure that the differentiation in the groups was due to a superior performance of the best group and not vice versa.

The results of the t-test analysis are shown in Table 6. Table 6 lists the laboratory measurements that differentiated the performance of the best and worst groups for the Casualty Evacuation Field Test to a significant value of .05 or less. The laboratory measurements were listed in order of level of significance. A complete list of all laboratory measurements and their related significant values is available in Appendix B1.

Table 6 was analyzed in reference to the four performance components stated earlier: the involvement of the lower body; the trunk region; the upper body/arm region; and the energy system utilized.

Table 6. Casualty Evacuation Field Test T-Test Results for Laboratory Tests With Significant Values of .05 or Less.

Laboratory Tests	Significant Values
leg mean power output	.000 **
leg peak power output	.001 **
leg relative power output mpo	.001 **
dynamic trunk flexion mean	.001 **
static trunk flexion maximal	.003 **
right knee extension	.004 **
static trunk flexion mean	.005 **
dynamic trunk flexion maximal	.010 **
lean weight	.011 *
leg relative power output ppo	.013 *
dynamic trunk extension mean	.014 *
dynamic trunk extension maximal	.017 *
dynamic leg extension maximal	.020 *
absolute aerobic power	.021 *
static trunk extension mean	.021 *
dynamic leg extension mean	.023 *
left knee extension	.026 *
right knee flexion	.033 *
arm mean power output	.039 *
arm peak power output	.041 *

* $p \leq .05$ ** $p \leq .01$

a. Lower Body

A number of leg power and strength measurements had significant values of .05 or less. Three leg power measurements had the most significant values: leg mean power output (.000), leg peak power output (.001) and leg relative power output - mean power output (mpo) (.001). All three measurements were significant to less than .01. Leg relative power output - peak power output (ppo), the fourth leg power measurement, was significant to .013. The components of the field test: short duration, timed, and heavy resistance, supported the importance of power. The importance of leg power measurements was further supported by Lee's (1992) multiple correlational analysis which indicated the importance of leg peak power output for Casualty Evacuation Field Test performance.

Soldier A carried a resistance equal to their own weight and not a standard weight, such as a 70 kg sack. Therefore, it seems reasonable absolute and relative leg power would both have been important, which they were. However, there may have been a benefit to absolute power. This was supported by the significance of lean weight (.011) as the best performers group (mean lean weight of 66.1 kg) had a greater mean lean weight than the worst performers group (mean lean weight of 60.7 kg).

One leg strength laboratory measurement was significant to less than .01: right knee extension (.004). This may have indicated the importance of the right leg quadricep muscles in providing strength and balance to soldier A as he struggled with the extra weight. No other leg strength measurements were significant to less than .01. However, most were significant to less than .05. Left knee extension (.026), dynamic leg extension maximal (.020), dynamic leg extension mean (.023), and right knee flexion (.033) were all significant to less than .05. The only leg strength laboratory measurement not significant to less than .05, although it was close, was left knee flexion (.055).

These results indicated the importance of leg strength in the performance of the Casualty Evacuation Field Test and supported the theoretical analysis assumption that lower body power and strength were important components to the performance of the field test.

b. Trunk Region

Almost all the laboratory measurements for trunk flexion strength and trunk extension strength were significant to less than .05. All four trunk flexion laboratory measurements were significant to .01 or less: dynamic trunk flexion mean (.001), static trunk flexion maximal (.003), static trunk flexion mean (.005), and dynamic trunk flexion maximal (.010). The importance of trunk flexion measurements was supported by Chahal's (1993) research which identified static trunk flexion as the only strength and endurance measurement included in the regression equation for the Casualty Evacuation [illegible] Test.

Although no trunk extension factors were significant to less than .01, three of the four were significant to less than .05: dynamic trunk extension mean (.014), dynamic trunk extension maximal (.017), and static trunk extension mean (.021). The fourth trunk extension test, static trunk extension maximal (.062) was significant to slightly over .05.

c. Upper Body/Arm

In the performance of the Casualty Evacuation Field Test, soldier A stabilized soldier B with their non-dominant arm. There were no arm/upper body measurement that were significant to .01 or less, and only two, arm mean power output (.039) and arm peak power output (.041), that were significant to .05 or less (Table 6). None of the other 12 upper body/arm strength or endurance measurements were significant to .05 or less. In addition, none of the four handgrip strength and endurance measurements were significant to .05 or less.

The theoretical analysis speculated the upper body /arm region would have been involved in: contributing to forward propulsion of soldier A; and the stabilization of soldier B with soldier A's shoulder, arm and hand musculature. The t-test results indicated that absolute arm power measurements were the only significant upper body power, strength or endurance measurements. Arm power may have been significant for its involvement in the forward propulsion of the body. The pumping of the free arm, although limited, may have provided a slight counter balance to the twisting motion developed by the legs.

Although no arm power laboratory measurements were significant to .01 or less, the two absolute arm power measures were significant to .05 or less. The two relative arm power relative measurements were considerably less significant: arm relative power output - peak power output (.141) and arm relative power output - mean power output (.271).

The non-significance of all laboratory measurements related to arm or handgrip strength or endurance would seem to suggest the relative lack of importance of these factors to the performance of the field test. The non-significance of all laboratory measurements related to shoulder stability (dynamic trapezius lift mean, dynamic trapezius lift maximal, trapezius lift endurance) would also seem to suggest their lack of importance to field test performance.

d. Energy Systems

When the measurements discussed are removed from Table 6, only one measurement remained: absolute aerobic power. The mean performance time for the 116 soldiers in the casualty evacuation was 46.9 s. Fox et al. (1988) stated two or three minutes of exercise are needed to accelerate oxygen consumption to the required level for oxygen utilization and energy production. They further stated that events lasting 45 s would derive 80 % of their energy from the anaerobic systems and only 20% from the aerobic system. It was therefore unlikely the absolute aerobic power measurement was significant due to its requirements as an energy source for the Casualty Evacuation Field Test. However, it may have been significant because of its association with increased lean weight. If two equal volumes of muscle have the same relative aerobic power, and the volume of one muscle mass is doubled, the result will be identical aerobic power relative scores for both, but a doubled aerobic power absolute for the larger muscle mass. This association with increased lean mass may explain the significance of absolute aerobic power. This was supported by the non-significance of the measurement for relative aerobic power (.319). The significance of absolute aerobic power provides further evidence of the importance of absolute factors over relative ones to the performance of the Casualty Evacuation Field Test .

Analysis of Individual Data

Further analysis was conducted on the laboratory results of the best (top three finishers) and worst (bottom three finishers) performers in the Casualty Evacuation Field

Test. This examination was conducted to determine if the conclusions arrived at in the Analysis of Group Data section would be supported by the analysis of the best and worst three individual performances. For example, the group data analysis indicated that absolute leg power was significant at differentiating best and worst performances of the Casualty Evacuation Field Test. However, when individual performances were reviewed, did the best performers have significantly better absolute leg power than the worst performers? If the best individuals finished considerably better than the worst individuals in measurements that significantly differentiated the best and worst groups, this would support the group analysis conclusions. If this situation did not occur, it would challenge the group analysis conclusions.

To accomplish the analysis of the best and worst three performers the following process was used:

- All 116 soldier's Casualty Evacuation Field Test performances were rank ordered according to time.
- The best three (three fastest times) and worst three (three slowest times) performers were identified.
- For each laboratory measurement, the performances of all 116 soldiers were rank ordered (1 to 116). The process ranked the soldier with the best performance in the laboratory test as #1 and the soldier with the worst performance as #116.
- The laboratory measurement rankings of the three best and worst performers were identified.

- These rankings of the three best and worst performers were analyzed.

To enhance the comparative process, best performers (first, second and third place finishers) were analyzed against worst performers (last, second last and third last finishers). The first place finisher's rankings were analyzed against the last place finisher's rankings. Second place was analyzed against second last place, and the third place against third last place.

To improve the visual interpretation of these results, the rankings were plotted on graphs. Figure 11 demonstrates this process, as it displays the first place finisher's rankings of soldier #107 (sol #107) graphed against the last place finisher's rankings of soldier #58 (sol #58). Figure 11 displays rankings (from 1-116) on the Y axis, and the appropriate laboratory measurements on the X axis. The measurements were positioned on the graph according to the statistical t-test results from the Analysis of Group Data section. In the Analysis of Group Data section, Table 6 identified the leg mean power output laboratory measurement as having had the lowest significance level at .000. Therefore, on the graphs utilized for the Casualty Evacuation Field Test analysis, the leg mean power output abbreviation (LP-E) was the first (from left to right) on the X axis. A complete listing of the order of all laboratory measurements, and their abbreviation, on the X axis is available in Appendix B1.

To assist in the analysis, vertical lines were positioned on the graphs to identify the point at which the significance level of the laboratory measurement became greater than .01. In Table 6 dynamic trunk flexion maximal (abbreviation: DTF-M) had a significance level of .010 and lean weight (abbreviation: LEAN-WT) had one of .011. Therefore on

Figure 11 there was a vertical line positioned between these two measurements with .01 on the top. This line denoted when the significant value exceeded .01.

To further assist in the analysis, a rating system was devised based upon rank. This system separated the rankings from #1 to #116 into five equal sections. The rating system was as follows:

- ranking 01 - 23 = EXCELLENT
- ranking 24 - 46 = ABOVE AVERAGE
- ranking 47 - 69 = AVERAGE
- ranking 70 - 92 = BELOW AVERAGE
- ranking 93 - 116 = POOR

Analysis of First and Last Place Finishers

Figure 11 displayed the rankings of the best and worst performers in the Casualty Evacuation Field Test on laboratory measurements significant to .05 or less. Table 20 in Appendix B2 lists all laboratory measurement raw scores and resulting rankings for these soldiers.

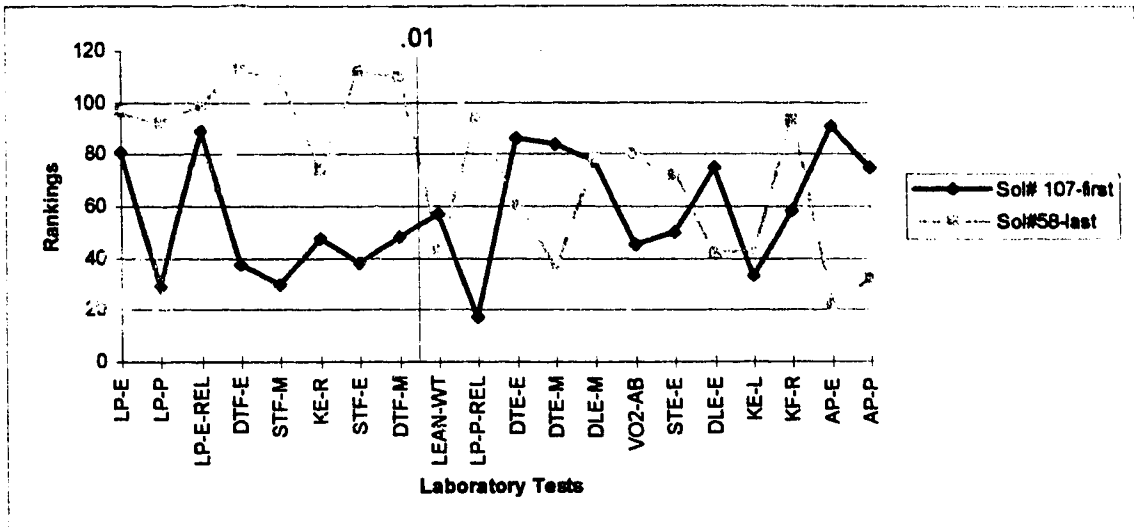

Figure 11. Rankings of First and Last Place Finishers in the Casualty Evacuation Field Test for Laboratory Measurements with Significant Values of .05 or Less ($p \leq .05$)

Note. The abbreviations for the Figure are: LP-E, lean mean power output; LP-P, lean peak power output; LP-E-REL, leg relative power output mpo; DTF-E, dynamic trunk flexion mean; STF-M, static trunk flexion maximal; KE-R, right knee extension; STF-E, static trunk flexion mean; DTF-M, dynamic trunk flexion maximal; LEAN-WT, lean weight; LP-P-REL, leg relative power output ppo; DTE-E, dynamic trunk extension mean; DTE-M, dynamic trunk extension maximal; DLE-M, dynamic leg extension maximal; VO2-AB, absolute aerobic power; STE-E, static trunk extension mean; DLE-E, dynamic leg extension mean; KE-L, left knee extension; KF-R, right knee flexion; AP-E, arm mean power output; AP-P, arm peak power output

Soldier #107 (first place) ranked consistently well on the laboratory measurements significant to .01 or less. In leg power rankings soldier #107 had a discrepancy between mean and peak power results. On leg peak power tests the subject achieved an above average ranking on the absolute power test (LP-P), and an excellent ranking on the relative power test (LP-P-REL). However, the soldier ranked below average on the two mean leg power tests, leg mean power output (LP-E), and leg relative power output - mean power output (LP-E-REL). With the discrepancy between the mean and peak scores it was difficult to state the importance of leg power to the soldiers first place finish. However, the peak leg power scores were two of the highest rankings soldier #107 achieved, with the relative peak power ranking (LP-P-REL) having been the highest ranking the soldier achieved on measures significant to .05 or less. Indeed, this measure was the only top twenty ranking this first place finisher achieved. This supported the importance of peak leg power to his performance.

In trunk flexion measurements soldier #107 performed well. Three of soldier #107's rankings on the trunk flexion results were above average: dynamic trunk flexion mean (DTF-E), static trunk flexion maximal (STF-M) and static trunk flexion mean (STF-E). One test, dynamic trunk flexion maximal (DTF-M), was average. For right knee extension (KE-R), soldier #107 ranked above average.

Soldier #107's rankings on laboratory measurements significant to .01 or less were among his best rankings. There was one additional area in measurements significant to between .01 and .05 where soldier #107 achieved a reasonable ranking: left knee extension (KE-L). In the group data analysis right knee extension (KE-R) was significant to less than .01 and left knee extension was not (.026). However, no documentation was kept on the soldiers to determine if they were left or right side dominant (left or right handed, etc.). Considering the predominance of right side dominant people in society, it is difficult to determine if the significance of right knee extension established the importance of right knee extension or knee extension on the dominant side of the body.

Soldier #107's left knee extension ranking (33) was better than his right knee extension ranking (47.5). It was possible that soldier #107 was left side dominant and these rankings further reflected the importance of dominant knee extension to the performance of Casualty Evacuation Field Test. Supporting this assumption was the soldiers knee flexion results in which he achieved a better ranking for the left side (53) than the right side (58). Contradicting this assumption was the soldiers handgrip strength and endurance scores for which he ranked higher for the right hand on all tests. Knowing right side or left side dominance may have assisted in the interpretation of the data and further studies in this area may consider recording it.

Soldier #58, the last place finisher in the Casualty Evacuation Field Test, performed poorly on laboratory measurements significant to .01 or less with six poor and two below average rankings in the eight tests. The subject achieved two poor rankings (LP-E, LP-E-REL) and one below average ranking (LP-P) on leg power measurements. However, most indicative of the last place finish may have been the four poor rankings on the four trunk flexion static and dynamic measurements (DTF-E, STF-M, DTF-M, and STF-E). Thes[illegible]gs on measurements significant to less than .01 were the only poor [illegible]ht knee flexion (KF-R), soldier #58 achieved on all the measu[illegible]

[illegible]gs for soldier #107 (first place) and soldier #58 (last place) fo[illegible]y measurements significant to greater than .05. As with the measurements in Figure 11, those in Figure 12 were aligned in order of significant value. The legend for the two figures is the same.

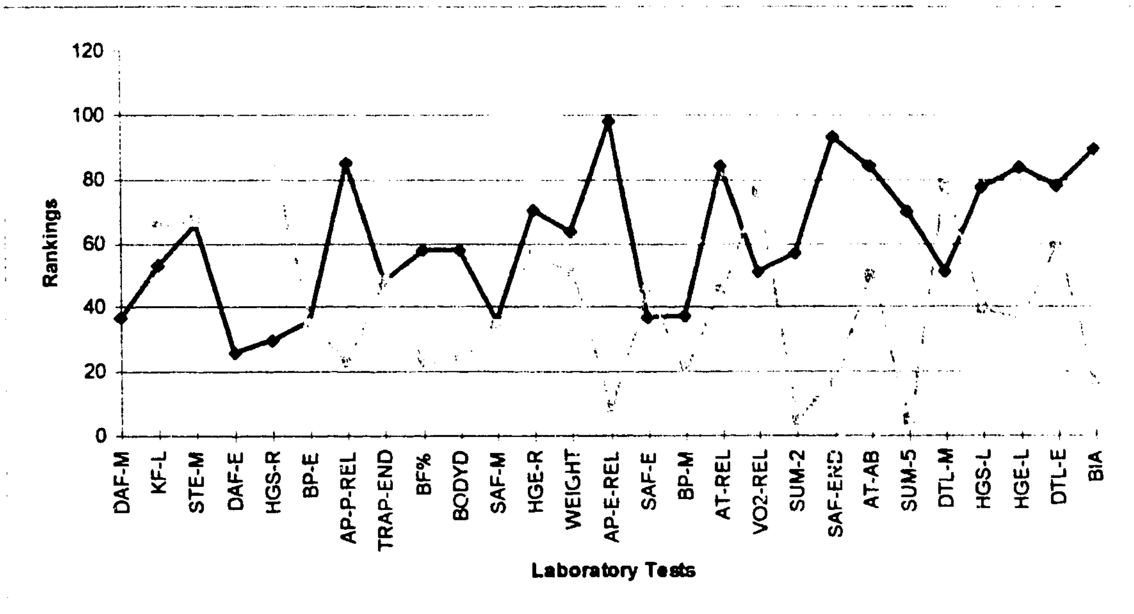

Figure 12. Rankings of First and Last Place Finishers in the Casualty Evacuation Field Test for Laboratory Measurements with Significant Values Greater than .05 ($p \geq .05$).

Note. The abbreviations for the Figure are: DAF-M, dynamic arm flexion maximal; KF-L, left knee flexion; STE-M, static trunk extension maximal; DAF-E, dynamic arm flexion mean; HGS-R, right hand grip strength; BP-E, bench press mean; AP-P-REL, arm relative power output ppo; TRAP-END, trapezius lift endurance; BF%, percent body fat; BODYD, body density; SAF-M, static arm flexion maximal; HGE-R, right hand grip endurance; WEIGHT, weight; AP-E-REL, arm relative power output mpo; SAF-E, static arm flexion mean; BP-M, bench press maximal; AT-REL, relative anaerobic threshold; VO2-REL, relative aerobic power; SUM-2. sum of 2 skin folds; SAF-END, static arm flexion endurance; AT-AB, absolute anaerobic threshold; SUM-5, sum of 5 skin folds; DTL-M, dynamic trapezius lift maximal; HGS-L, left handgrip strength; HGE-L, left hand grip endurance; DTL-E, dynamic trapezius lift mean.

The one area on measurements significant to .05 or greater where soldier #107 (first place) achieved relatively high rankings was arm flexion. The four arm flexion measures, dynamic arm flexion maximal (DAF-M), dynamic arm flexion mean (DAF-E), static arm flexion maximal (SAF-E) and static arm flexion mean (SAF-M), were all above average rankings and among the best rankings soldier #107 achieved after a significance of

.01. The group analysis did not support the necessity of arm strength and endurance to stabilize soldier B for top performance in the Casualty Evacuation Field Test. However, soldier #107's first place finish without an excellent ranking on measurements significant to .01 or less may have been assisted by strong stabilization of soldier B due to arm strength and endurance.

The data for soldiers #107 (first place) and #58 (last place) generally supported the conclusions from the group t-test analysis. The only area where soldier #107 significantly outperformed soldier #58 was on measurements significant to .01 or less. On laboratory tests significant to greater than .01 soldier #58 matched or outperformed soldier #107 on most measures. Indeed, soldier #58's (last place) performance steadily improved as the measurements become less significant, as he finished with 5 excellent rankings on the 14 least significant measures (Figure 12). It would have been difficult at any other position on Figure 11 or 12, other than on measures significant to .01 or less, to determine which of these soldiers finished first or last. Indeed, a decision based entirely upon Figure 12 would conclude that solder #58 (last place) finished ahead of soldier #107 (first place).

Analysis of Second and Second Last Place Finishers

Figure 13 displays the rank order finishings of the second place and second last place performers in the Casualty Evacuation Field Test on laboratory measurements significant to .05 or less. Table 21 in Appendix B3 lists complete laboratory measurement raw scores and resulting rankings for these soldiers.

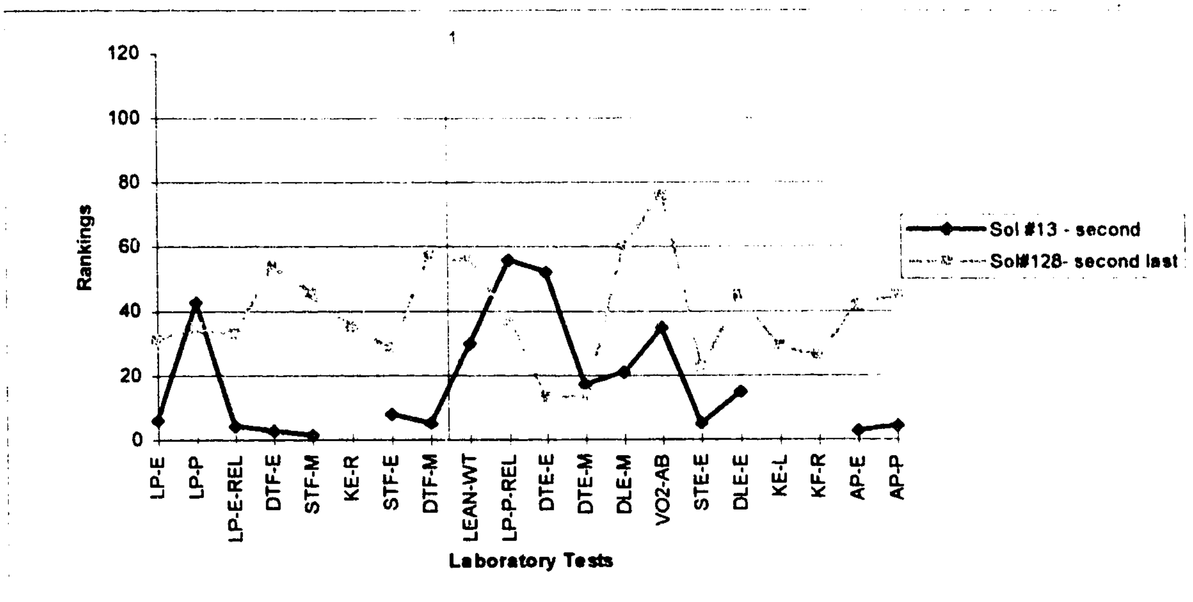

Figure 13. Rankings of Second and Second Last Place Finishers in the Casualty Evacuation Field Test for Laboratory Measurements with Significant Values of .05 or Less ($p \leq .05$).

Note. The abbreviations for the Figure are: LP-E, lean mean power output; LP-P, lean peak power output; LP-E-REL, leg relative power output mpo; DTF-E, dynamic trunk flexion mean; STF-M, static trunk flexion maximal; KE-R, right knee extension; STF-E, static trunk flexion mean; DTF-M, dynamic trunk flexion maximal; LEAN-WT, lean weight; LP-P-REL, leg relative power output ppo; DTE-E, dynamic trunk extension mean; DTE-M, dynamic trunk extension maximal; DLE-M, dynamic leg extension maximal; VO2-AB, absolute aerobic power; STE-E, static trunk extension mean; DLE-E, dynamic leg extension mean; KE-L, left knee extension; KF-R, right knee flexion; AP-E, arm mean power output; AP-P, arm peak power output

Soldier #13, the second place finisher in the Casualty Evacuation Field Test, produced results on measurements significant to .01 or less that would have been expected from a top performance. The subject achieved two excellent rankings in mean leg power measures (LEG-E, LEG-E-REL) and four excellent rankings in trunk flexion measures (DTF-E, STF-M, STF-E, DTF-M). There was no score recorded for soldier #13 in right knee extension (KE-R), the final measurement significant to .01 or less. On measurements significant to between .01 and .05, soldier #13 achieved excellent rankings in dynamic trunk extension (DTE-M), static trunk extension (STE-E), leg extension (DLE-M, DLE-E), and arm power (AP-E, AP-P).

Soldier #128, the second last place finisher, produced data that did not support the assumptions from the group analysis. With above average rankings in the first three leg power measurements (LP-E, LP-P, LP-E-REL), two above average rankings in static trunk flexion (STF-M, STF-E), two average rankings in dynamic trunk flexion measures (DTF-E, DTF-M) and an average ranking in the right knee extension measure (KE-R), all measures significant to .01 or less, it would have been predicted that soldier #128 would have finished better than second last. On measurements significant between .01 and .05, soldier #128 continued to perform average or above average. In fact, soldier #128 did not generate a poor ranking on any measurement significant to .05 or less. The only below average ranking soldier #128 achieved on measures significant to .05 or less was on absolute aerobic power (VO2-AB).

On measurements significant to .05 or greater (Figure 14), soldier #13's (second place) rankings shifted towards average. However, he still achieved eight excellent rankings out of the 27 measurements. Of those eight, four measurements were not related to measurements previously discussed. These were arm flexion dynamic (DAF-M, DAF-E), and trapezius lift dynamic (DTL-M, DTL-E) measurements. In the performance analysis of the Casualty Evacuation Field Test, it was speculated that arm flexion, and trapezius strength and endurance would be used by soldier A to stabilize soldier B. Soldier #13's results in the measurements related to these physiological factors may have contributed to his success in the Casualty Evacuation Field Test. However, his performance on measurements significant to less than .01 and .05 likely contributed more to his success.

On measurements significant to .05 or greater (Figure 14), soldier #128 (second last place) continued to perform well, with a number of excellent and above average rankings. In fact, in this range soldier #128 did not generate a poor ranking. Although soldier #128 had no area of weakness on measurements significant to .05 or less (Figure 13) to which his second last place performance could be attributed, there were three areas of relative weakness significant to greater than .05 (Figure 14): aerobic power, anaerobic threshold, and body fat percentage.

Soldier #128's worst rankings were in aerobic measurements. The four lowest rankings he achieved were on the two aerobic power measurements, absolute aerobic power (VO2-AB) and relative aerobic power (VO2-REL), and the two anaerobic threshold measurements, anaerobic threshold relative (AT-REL), and anaerobic threshold absolute (AT-AB). The group analysis did not show a significant involvement of aerobic factors, and it has been reported that events of the duration of the Casualty Evacuation Field Test (mean time: 46.9 s) derive approximately 80% of their energy from anaerobic systems and only 20% from the aerobic system (Fox et al, 1988). Therefore it seems unlikely that soldier #128's aerobic abilities were a deciding factor in his second last place finish.

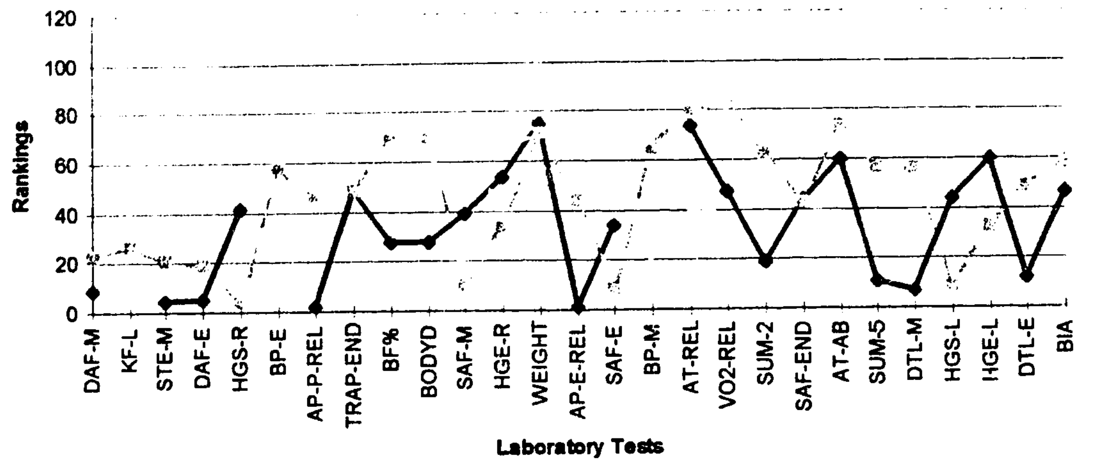

Figure 14. Rankings of Second and Second Last Place Finishers in the Casualty Evacuation Field Test for Laboratory Measurements with Significant Values Greater than .05 ($p \geq .05$).

Note. The abbreviations for the Figure are: DAF-M, dynamic arm flexion maximal; KF-L, left knee flexion; STE-M, static trunk extension maximal; DAF-E, dynamic arm flexion mean; HGS-R, right hand grip strength; BP-E, bench press mean; AP-P-REL, arm relative power output ppo; TRAP-END, trapezius lift endurance; BF%, percent body fat; BODYD, body density; SAF-M, static arm flexion maximal; HGE-R, right hand grip endurance; WEIGHT, weight; AP-E-REL, arm relative power output mpo; SAF-E, static arm flexion mean; BP-M, bench press maximal; AT-REL,relative anaerobic threshold; VO2-REL, relative aerobic power; SUM-2. sum of 2 skin folds; SAF-END, static arm flexion endurance; AT-AB, absolute anaerobic threshold; SUM-5, sum of 5 skin folds; DTL-M, dynamic trapezius lift maximal; HGS-L, left handgrip strength; HGE-L, left hand grip endurance; DTL-E,dynamic trapezius lift mean.

The second weakest area of performance for soldier #128 was body composition with two measurements over a 60 ranking: a body fat percentage (BF%) ranking of 69; and a body density (BODY D) ranking of 69. However, these rankings were in the average range (average ranking = 47-69). In addition, soldier #128's body composition rankings did not effect his relative leg or arm power rankings, which were above average or excellent. Again, it seems unlikely that the subjects body composition was a deciding factor in the second last place finish.

Although soldier #128's (second last place) rankings on measurements significant to .01 or less did not support the group data conclusions, it is difficult to attribute his second last place finish to any result. As stated in the Limitations from Chapter I, motivation and skill level could neither be controlled or monitored. One possibility for soldier #128's poor performance may have been his motivation or skill level during the performance of the Casualty Evacuation Field Test.

Analysis of Third and Third Last Place Finishers

Figure 15 displays the rank order finishings of the third place and third last place performers in the Casualty Evacuation Field Test on laboratory measurements significant to .05 or less. Table 22 in Appendix B4 lists complete laboratory measurement raw scores and resulting rankings for these soldiers.

At first assessment, the results for soldier #146, the third place finisher, did not support the group data conclusions. Soldier #146's rankings on measurements significant to .01 or less were: two below average (LP-E, LP-P) and one average (LP-E-REL) on the leg power measures; below average scores on all four trunk flexion measures (DTF-E, DTF-M, STF-E, STF-M); and an average score on the right knee extension measure (KE-R). In addition, soldier #146 achieved his highest rankings on the leg extension measurements (DLE-E, DLE-M) which were both significant to between .01 and .05.

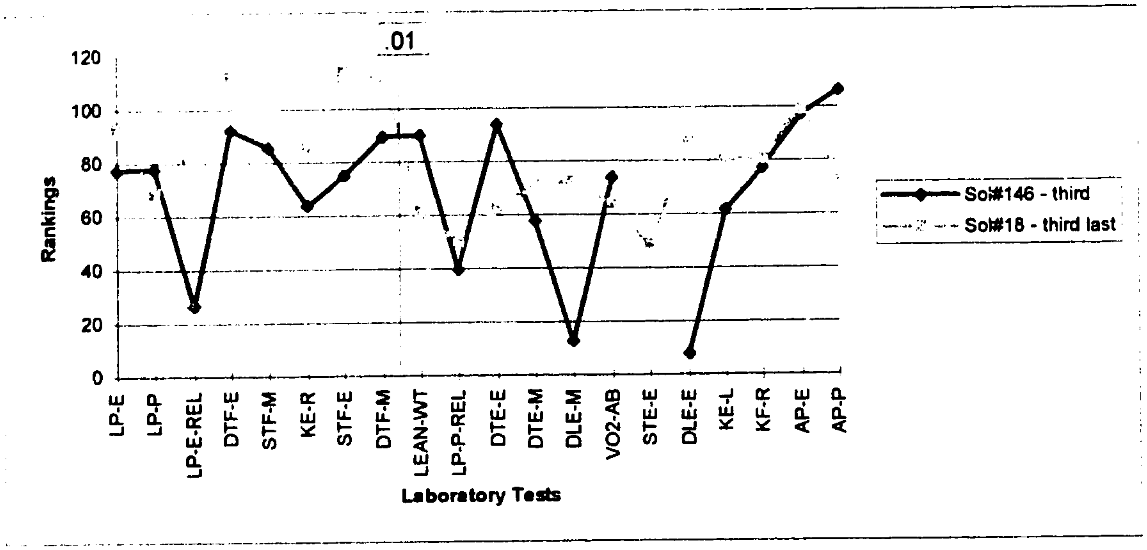

Figure 15. Rankings of Third and Third Last Place Finishers in the Casualty Evacuation Field Test for Laboratory Measurements with Significant Values of .05 or Less ($p \leq .05$).

Note. The abbreviations for the Figure are: LP-E, lean mean power output; LP-P, lean peak power output; LP-E-REL, leg relative power output mpo; DTF-E, dynamic trunk flexion mean; STF-M, static trunk flexion maximal; KE-R, right knee extension; STF-E, static trunk flexion mean; DTF-M, dynamic trunk flexion maximal; LEAN-WT, lean weight; LP-P-REL, leg relative power output ppo; DTE-E, dynamic trunk extension mean; DTE-M, dynamic trunk extension maximal; DLE-M, dynamic leg extension maximal; VO2-AB, absolute aerobic power; STE-E, static trunk extension mean; DLE-E, dynamic leg extension mean; KE-L, left knee extension; KF-R, right knee flexion; AP-E, arm mean power output; AP-P, arm peak power output.

The data for soldier #18, third last place finisher, supported the group data conclusions. Soldier 18 achieved one poor (LP-E), one below average (LP-E-REL) and one average (LP-P) on the three leg power measurements significant to .01 or less. In addition, he achieved four poor rankings on the trunk flexion measurements (DTF-E, DTF-M, STF-E, STF-M).

Some additional points were considered in an attempt to understand the diverse field test finishes with these two somewhat similar ranking results. One point to consider was the protocol of the majority of laboratory tests. The majority of laboratory tests resulted in the soldier who generated the greatest absolute force or power achieving the top score and therefore ranking. Fox et al. (1988) stated there is an increase in strength for an increase in muscle cross-sectional area. Therefore increased muscle mass would have been a benefit in absolute strength tests and measurements. Soldier #18 (third last place) had 5.58 kg more lean weight than soldier #146 (third place). With a ranking of #1 going to the soldier with the most lean weight and a ranking of #116 to the soldier with the least amount of lean weight, soldier #18's 63.74 kg of lean weight ranked him 61, while soldier #146's 58.16 ranked him 90. This was a difference in ranking for lean weight of 29 between the two soldiers.

When the measurements significant to .01 or less were reexamined in light of the differences in lean weight an understanding for the diverse Casualty Evacuation Field Test finishes may have been partially explained. Soldier #146, with significantly less muscle mass, outperformed solder #18 consistently on these measures. On the one relative measure, leg relative power output - mean power output (I P-E-REL), soldier #146 (third place) ranked above average while soldier #18 (third last place) ranked below average. Although it is impossible to state that soldier #146's data supported the group data conclusions, the difference in lean weight and the clear separation of rankings on these measurements may provide some insight into the differences in Casualty Evacuation Field Test performances.

Summary of Individual Analysis

Individual analysis indicated that data for four of the six soldiers analyzed moderately to strongly supported the group data conclusions. One soldier's (soldier #128) data that did not support the conclusions had no major areas of weakness to which his poor finish could be attributed. It was therefore speculated that motivation and/or skill level may have been a factor in his poor field test performance.

Summary of Casualty Evacuation Field Test

In the analysis of the laboratory measurements of Group A and B for the Casualty Evacuation Field Test the following differences between the groups were indicated. Group A was significantly superior from Group B in their performance on lower body and trunk region measurements. Group A was statistically similar to Group B in the upper Body/Arm region measurements. Group A was significantly superior to Group B in power measurements: absolute and relative leg power, absolute arm power and absolute aerobic power. Group A's superiority in power measurements was most prevalent in absolute measurements rather than relative measurements. Finally, Group A was significantly different from Group B in lean weight, with Group A have a larger lean mass than Group B.

B. Analysis of the Ammunition Box Field Test

The military is a mobile organization. Soldiers and equipment are frequently transported throughout the world for training exercises or military operations. Large amounts of ammunition, food, weapons, etc. are moved to the required location quickly and orderly. If the move is to a battle situation, one of the primary pieces of equipment transported will be ammunition. Much of the ammunition in the military is carried in standardized boxes weighing 20.9 kg. Many of the transport trucks the military utilizes have a standard bed height of 1.3 m (Chahal, 1993). Soldiers are required to load and unload ammunition boxes off transport trucks without injury, or fatiguing themselves for their other duties. For these reasons, the Ammunition Box Field Test was included in the field tasks recommended by Singh et al. (1991) to the Canadian Military.

The Ammunition Box Field Test required each soldier to lift a total of 48 ammunition boxes (20.9 kg each) from the floor to a table top of a height of 1.3 m (simulated height of truck bed). A soldier was required to perform at or below 70% of their maximal aerobic power. A maximal effort was not asked of the soldier due to the risk of injury. The recommended standard for the Ammunition Box Field Test was 300 s (five min) (Chahal, 1993).

Analysis of Group Data

In the performance of the Ammunition Box Field Test the following protocol was used. A table (1 m width, 2 m length and 1.3 m height) was placed in an open area. Six ammunition boxes were placed along the length of the table, three on each side. The ammunition boxes were placed one meter away from the base of the table (Figure 16). A soldier proceeded counterclockwise around the table, lifting the boxes from the floor to the table top. The boxes were lowered by other soldiers. The soldier continued in this manner until they had circled the table six times and lifted a total of 48 boxes.

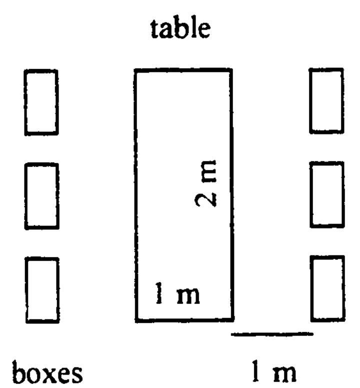

Figure 16. Layout Utilized for the Ammunition Box Field Test.

The soldiers wore Sport Tester Heart Rate Monitors during the field test. Subjects were directed to stop lifting when their heart rate became 5 beats per minute above 70% of their maximal aerobic power, and were allowed to continue when their heart rate dropped below the 70% value (Chahal, 1993).

Theoretical Analysis of Field Test

Singh et al. (1991) stated, "Lifting objects from ground level requires whole body involvement: back, legs, abdominal region, and arms, and for most people lifting capacity is limited by upper body strength". However the specific physiological requirements of lifting have not been identified. In an attempt to analyze Ammunition Box Field Test from a performance perspective the field test was broken down into the following components.

- the involvement of the lower body
- the involvement of the trunk region
- the involvement of the upper body/arms
- the energy system utilized

a. Involvement of the Lower Body

Proper technique to lift an object off the floor would have required bending the knees and keeping a straight back to initiate the lift. Pytel (1981) reported that lifting required both static and dynamic contractions, with the initial aspect of the lift closely resembling isometric exercises and requiring static contractions, and that as the inertia of the load is overcome, dynamic contractions occur. These initial dynamic contractions were most likely to have occurred in the lower body. Knee extension and hip extension occurred to straighten the legs and lift the box off the floor. The measurements that would have addressed this involvement were: absolute and relative leg power, dynamic leg extension, and knee extension.

b. Involvement of the Trunk Region

The muscles in the trunk region of the body were likely involved in stabilizing the trunk region of the body. Cailliet (1981) reported that when performing heavy lifts, the abdominals perform the role of increasing intra-abdominal pressure, therefore relieving the load on the spine. Other research has reported the importance of back extensors to the lifting process, with it being speculated that lumbar extensors are the limiting factor in lifting capacity (Norman, 1993; Wheeler, 1993). The involvement of these factors would have been addressed by the static and dynamic trunk flexion and extension laboratory measurements.

c. Involvement of Upper Body / Arms

In the initial aspect of the lifting process utilized in the Ammunition Box Field Test there was probably little involvement of the upper body and arms. However, the forearms and hands would have been involved in creating a firm enough handgrip to insure the box was lifted. Measurements for handgrip strength and endurance would have addressed this involvement. Once the lift had started, and the legs had begun to straighten, the involvement of the upper body and arms would likely have increased. The height of the lift appears to be an important factor in upper body/arm recruitment. As the height increases, the amount the person is able to lift decreases. In addition, as the height exceeds shoulder level this inverse relationship increases dramatically (Chaffin et al., 1975). Lifting height may have played an important role in the performance of the Ammunition Box Field Test. The table height was 1.3 m and the height of the ammunition box was approximately 0.3 m. Therefore, for many soldiers, the ammunition boxes would have been lifted to shoulder height or higher. The involvement of only the legs would have lifted the box to waist level. Involvement of the arm flexors would have brought the boxes to chest level. To lift the boxes above chest height to shoulder height would have required the involvement of the trapezius and the shoulder abductors. Measurements addressing arm flexion involvement were: absolute and relative arm power, and static and dynamic arm flexion. Measurements addressing the involvement of the trapezius and shoulder abductors were: the dynamic trapezius lift, and trapezius lift endurance.

d. Energy Systems

The Ammunition Box Field Test recommended standard was 300 s (five minutes). The mean performance time for the 116 soldiers was 164.3 s (2 min 44.3 s). Fox et al. (1988) stated that activities of a duration of approximately 2 min 30 s to 3 min have energy supplied equally by aerobic and anaerobic systems. Therefore both aerobic and anaerobic power should have been an important factor in the performance of the Ammunition Box Field Test.

Analysis of t-test Results

With this performance analysis in mind, a statistical analysis of the 116 soldiers Ammunition Box Field Test results was undertaken. The statistical analysis procedure was identical to the method utilized for the Casualty Evacuation Field Test. The results of this analysis are shown in Table 7 which lists the measurements which significantly differentiated the performance of the best and worst groups for the Ammunition Box Field Test to a significant value of .05 or less. The laboratory measurements are listed in order of significance. A complete list of all measurements and significant values for the Ammunition Box Field Test is available in Appendix C1.

Table 7 was analyzed in reference to the four performance components stated earlier: the involvement of the lower body; the trunk region; the upper body/arm region; and the energy system utilized. In addition, with this field test, body composition was analyzed as a separate section.

Table 7. Laboratory Measurements and Corresponding Significant Values from T-Test Analysis of the Ammunition Box Field Test to a Significance of 05 or Less.

Laboratory Test	Significant Value
absolute aerobic power	.000 **
lean weight	.000 **
leg mean power output	.001 **
absolute anaerobic threshold	.001 **
dynamic trunk flexion maximal	.009 **
arm mean power output	.010 **
leg peak power output	.011 *
dynamic trunk flexion mean	.016 *
weight	.026 *
relative aerobic power	.028 *
static trunk flexion maximal	.038 *
body density	.042 *
static trunk extension maximal	.042 *
percent body fat	.043 *
dynamic leg extension maximal	.043 *

* $p \leq .05$ ** $p \leq .01$

a. Lower Body

Two measurements of absolute leg power were significant to less than .05: leg mean power output (.001), leg peak power output (.011). Leg mean power output (.001) was the only laboratory measure of leg power or strength that was significant to less than .01. Neither relative measure of leg power, leg relative power output - mean power output (.107), or leg relative power output - peak power output (.422) were significant to less than .05.

Dynamic leg extension maximal (.043) was significant to less than .05. However, neither dynamic leg extension mean (.146) or either of the knee extension measurements, right knee extension (.186) or left knee extension (.345) were significant to .05 or less. Few studies on lifting addressed the importance of the lower body to the lifting motion. No study addressed the relative importance of leg strength and power.

b. Trunk Region

Four laboratory tests measuring the musculature involved in stabilization of the trunk were significant to less than .05. Three trunk flexion tests were significant, with dynamic trunk flexion maximal (.009) significant to less than .01, and dynamic trunk flexion mean (0.16) and static trunk flexion maximal (038) significant to less than .05. Static trunk extension maximal was significant to .042 and was the only trunk extension tests significant to less than .05. Research in lifting reported the importance of both trunk flexion and extension.

Wheeler (1993) stated that during the lifting process the lumbar extensors are generally considered the limiting factor in lifting capacity. It would therefore seem more likely then that trunk extension measurements would have been more significant than trunk flexion ones. One explanation may be that, due to the soldiers utilizing the bent knee, straight back lifting technique, abdominal support of the spinal column may have been more critical to the lift than the back extensors. Alexander (1985) speculated that abdominal muscles provide necessary support for the spinal column during the lifting process. Utilizing the bent knee technique keeps the back in a relatively stable position throughout the lift and may have resulted in a reduced stress on the back extensor muscles.

c. Upper Body / Arms

In the performance analysis, it was speculated that the handgrip strength and/or endurance may have been the most significant upper body/arm involvement in the initial phase of the lift. However, there were no handgrip measurements significant to less than .05, with the most significant handgrip test being left handgrip endurance (.087).

As for the involvement of other upper body/arms factors in the lift, only one related laboratory tests was significant to less than .05: arm mean power output (.010). No other upper body/ arm measurement, including: relative arm power, static and dynamic arm flexion, or trapezius lift strength or endurance were significant to less than .05. Absolute arm power having been significant to .01 did indicate the importance of arm power in the performance of the field test. However, the lack of significance in all other upper body/arm laboratory tests was revealing considering the height the ammunition boxes were required to be lifted to.

One possible explanation is that in generating force for lifting the ammunition box, the majority of power may have come from the initial stages when the larger muscles of the legs were involved to a greater degree. Therefore, the lift may not have occurred in two distinct phases, with the initial phase, utilizing the legs, lifting the box to the waist, and the final phase, utilizing the upper body/arms, lifting from the waist to shoulder level. Instead, in the initial phase the legs may have generated the majority of power required to lift the box, with the upper body / arms supplying some power and strength, but perhaps being utilized more to direct the placement of the boxes on the table. This assumption was not supported by any other research on lifting. However, no other study utilized a lifting height (1.3 m) as high as Singh et al. (1991).

d. Energy Systems

Fox et al. (1988) stated that events lasting three minutes forty-five seconds have approximately 50% of their energy contributed from aerobic sources and 50% from anaerobic. However, the event Fox used as an example of this time frame was the men's 1500 meter race. The intensity a runner would achieve in that race would likely exceed 70% of their maximal aerobic power. Therefore, in the performance of the Ammunition Box Field Test, where the soldiers performance was limited to 70%, a contribution of greater than 50% may have come from the aerobic energy system. This was supported by absolute aerobic power having had a significant value of .01 or less.

A number factors may have contributed to absolute aerobic power's significance. As stated earlier, the time frame of the exercise was such that at least 50% of the required energy would be derived from aerobic sources. In addition, the amount of work required from each soldier to perform the Ammunition Box Field Test would have been similar as each soldier lifted the same number of boxes (48) through the same distance (1.3 m). Brooks and Fahey (1985) stated, "There is very little variance among individuals in oxygen consumption performing the same work load". Thus, the higher the soldiers absolute aerobic power, or ability to consume oxygen, the lower the heart rate at performing a set amount of work. The soldier with high absolute aerobic power would have been able to perform the set amount of work required from the Ammunition Box

Field Test at a lower heart rate. In addition, it was also more likely that their heart rate would not have exceeded the 70% mark and therefore not have required a stoppage in the field test performance. Both of these circumstances could have contributed to a reduced time for completion of the field test. The relevance of absolute aerobic power was supported by the significance of the lean weight.

Another measurement significant to .01 or less was absolute anaerobic threshold (AT-AB). Lee (1992) defined anaerobic threshold as "the point of exercise intensity where blood lactate begins to accumulate significantly above resting levels". Lee further stated, "Individuals who have a high capacity for aerobic work not only have high maximal oxygen uptake but also can exercise at higher intensities (utilizing a greater percentage of lipid substrates) before accumulating blood lactate and muscle acidosis". The inclusion of two aerobic measurements significant to .01 or less indicated the importance of aerobic factors to the Ammunition Box Field Test.

There is little doubt that aerobic measurements would have been significant in an event of the duration of the Ammunition Box Field Test. However, the protocol for the field test may have overemphasized their importance. By using heart rate as the one criteria for controlling the soldiers progress through the field test, a number of difficulties, including physiological difficulties, equipment problems, and, individual differences in test administration, could have affected the performance times. An advantage would have gone to any soldier who was not required to stop at any time during the test. The protocol of the field test would seem to provide an extra advantage to those soldiers with higher absolute aerobic power and anaerobic threshold values.

e. Body Composition

Four other measurements were significant to less than .05. These were all body composition factors: lean weight (.000), weight (.026), body density (.042), and percent body fat (.043). Table 8 lists these four body composition factors and the mean results of the best and worst groups. Based on the results in Table 8, a soldier in the best 27% group weighed more, yet had less body fat and more lean weight than a soldier in the worst 27% group.

Table 8. Body Composition Means for Best and Worst Ammunition Box Field Test Groups.

Body Composition Factor	Mean of Best 27% Group	Mean of Worst 27% Group
Lean Weight	67.5 kg	59.8 kg
Weight	82.6 kg	75.8 kg
Body Density	1.06	1.05
Percent Body Fat	16.8%	20.2%

Lean weight's significant value was understandable. As cross-sectional diameter of muscle increases, strength potential increases (Fox et al., 1988). Therefore, increases in lean weight could have been related to the many strength and power factors significant to .05 or less, including leg power, arm power, and dynamic leg extension.

Percent body fat (.043) may also have been significant for a number of reasons. First, as the soldier bent down, grasp the box and lifted it to the table, increased body fat would have been added resistance with no benefit to performance. Secondly, increased body fat, especially if carried around the waist area, could have affected the ability of the soldier to quickly and easily assume the bent knee starting position for the lift.

Analysis of Individual Data

Further analysis was conducted on the laboratory measurements of the best (top three finishers) and worst (bottom three finishers) performers in the Ammunition Box Field Test. This examination was conducted to determine if the conclusions arrived at in the Analysis of Group Data section were supported by individual performances. The process followed was identical to that utilized in the analysis of the Casualty Evacuation Field Test.

Figure 17 displays rankings (from 1-116) on the Y axis, and the laboratory measurements on the X axis. The measurements were positioned on the graph according to the t-test analysis results from the Analysis of Group Data section. In the Analysis of Group Data section, Table 7 identified absolute aerobic power as having had the lowest significance value at .000. Therefore, on the graphs utilized for the Ammunition Box Field Test analysis, absolute aerobic power was the first factor on the X axis. A complete listing of the order of the measurements on the X axis is available in Appendix C2.

Analysis of First and Last Place Finishers

Figure 17 displays the rank order finishings of the first and last place performers in the Ammunition Box Field Test on laboratory measurements significant to .05 or less.

Table 24 in Appendix C2 lists complete laboratory measurement raw scores and resulting rankings for these soldiers.

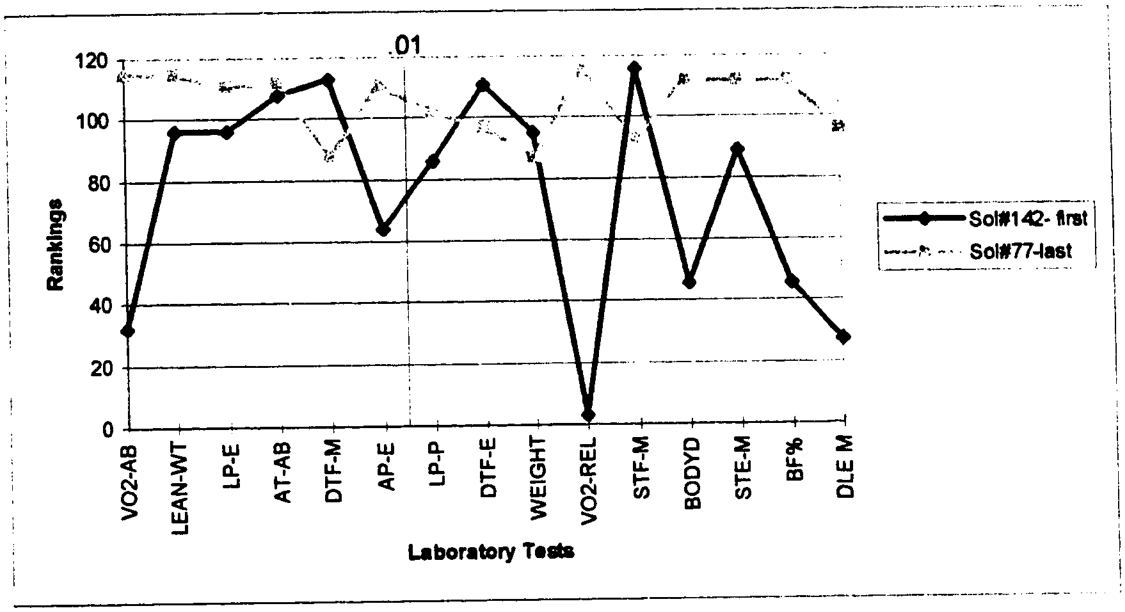

Figure 17. Rankings of First and Last Place Finishers in the Ammunition Box Field Test for Laboratory Measurements Significant to .05 or Less ($p \leq .05$).

Note. The abbreviations for the Figure are: VO2-AB, absolute aerobic power; LEAN-WT, lean weight; LP-E, lean mean power output; AT-AB, absolute anaerobic threshold; DTF-M, dynamic trunk flexion maximal; AP-E, arm mean power output; LP-P, lean peak power output; DTF-E, dynamic trunk flexion mean; WEIGHT, weight; VO2-REL, relative aerobic power; STF-M, static trunk flexion maximal; BODY-D, body density; STE-M, static trunk extension maximal; BF%, percent body fat; DLE-M, dynamic leg extension maximal.

In the performance of the Ammunition Box Field Test, a maximal effort test was not conducted for safety reasons. It was anticipated that the soldiers attempt to move the boxes as quickly as possible would have increased the risk of injury. Therefore, the soldiers heart rate while performing the field test was not to exceed 70% of their maximal aerobic power (Chahal, 1993). The soldiers were directed to stop lifting when their heart rate reached 5 beats per minute above the 70% value, and were allowed to continue when their heart rate dropped below the 70% value.

It appears soldier #142 (first place finisher) benefited from this protocol. In the 15 laboratory measurements significant to .05 or less, soldier #142 achieved only three above average or excellent rankings. Two of these measures reflected his aerobic abilities: an above average ranking on absolute aerobic power (VO2-AB), and an excellent ranking (third place) on relative aerobic power (AT-AB). Other evidence to the subjects relative aerobic abilities was the rankings for the anaerobic threshold measurement. Although soldier #142 achieved a poor ranking (108th) on absolute anaerobic threshold (AT-AB), he achieved an excellent ranking (5th) on relative anaerobic threshold (AT-AB), a laboratory measurement significant to greater than .05.

On other significant measurements, soldier #142 did not achieve the rankings expected from the group data analysis. For leg power measurements, soldier #142 achieved one below average ranking on leg peak power output (LP-P), and one poor on leg mean power output (LP-E). On trunk flexion measures, the subject ranked poor on all three measurements significant to .05 or less: dynamic trunk flexion maximal (DTF-M), dynamic trunk flexion mean (DTF-E), and static trunk flexion maximal (STF-M). In addition, soldier #142 achieved only an average ranking on the absolute arm power measurement (AP-E), which was significant to .01 or less. In summary, on the laboratory measurements significant to .01 or less, soldier #142 finished in the bottom half of the group (ranking greater than 58) on five of the six tests, and in the bottom fifth of the group (ranking greater than 93) on four of the six tests.

Not only did soldier #142's performance on laboratory measurements significant to .05 or less not meet first place finish expectations based on the conclusions of the group analysis, his performance on measurements significant to greater than .05 did not supply any additional answers. The one area on measurements significant to greater than .05 where the subject achieved an excellent ranking, in measurements not related to factors already discussed, was in right knee flexion. However, as the Ammunition Box Field Test utilized knee extension in the lifting of the boxes, and no force was overcome by knee flexion, it was unlikely the scores on this test was a key to his success.

The key factors that contributed to soldier #142's first place finish appear to have been his aerobic abilities and the protocol of the field test. Soldier #142 was highly ranked in the relative aerobic factors. He was ranked third in relative aerobic power (VO2-REL), and fifth in relative anaerobic threshold (AT-REL). Indeed, his absolute aerobic power measurement was such that with a lean weight ranking as high as 96, soldier #142 still managed to achieve an absolute aerobic power (VO2-AB) ranking of 32. In the performance of the field test the same amount of absolute work was performed by every soldier, and therefore, an advantage would theoretically have gone to the higher absolute aerobic power. Yet soldier #142, with only an above average ranking on absolute aerobic power, appears to have achieved success based upon his relative aerobic scores in aerobic power and anaerobic threshold. A likely scenario was that soldier #142, due to his aerobic abilities, did not exceed 70% of his maximal aerobic power and therefore performed the

Ammunition Box Field Test without stoppage. Soldier #142's laboratory measurements do not support the group data conclusions. However, they do support the importance of aerobic power and anaerobic threshold to a successful Ammunition Box Field Test performance.

Soldier #77's (second last place) rankings supported the group data conclusions. Of the 15 measurements significant to .05 or less, soldier #77 achieved 13 poor rankings, and two below average rankings on dynamic trunk flexion maximal (DTF-M) and weight (WEIGHT). Although soldier #77's rankings on measurements significant to .05 or less strongly supported the group data conclusion, an overall poor performance on the complete laboratory test battery (20 poor rankings on the 32 measurements with significant values greater than .05) reduced the certainty of concluding his last place finish was entirely a result of measurements significant to .05 or less.

Analysis of Second and Second Last Place Finishers

Figure 18 displays the rank order finishings of the second and second last place performers in the Ammunition Box Field Test on laboratory measurements significant to .05 or less. Table 25 in Appendix C3 lists complete laboratory measurement raw scores and resulting rankings for these soldier. Soldier #51, the second place finisher, achieved rankings on laboratory measures significant to .05 or less that were similar to soldier #142, the first place finisher in the Ammunition Box Field Test. Their strongest area of performance was in aerobic measures. Soldier #51 achieved three excellent rankings in aerobic factors significant to .05 or less: absolute aerobic power (ranking 14), absolute anaerobic threshold (ranking 3.5) and relative aerobic power (ranking 1). In addition, the subject ranked first in relative anaerobic threshold, although that measurement was not significant to .05 or less.

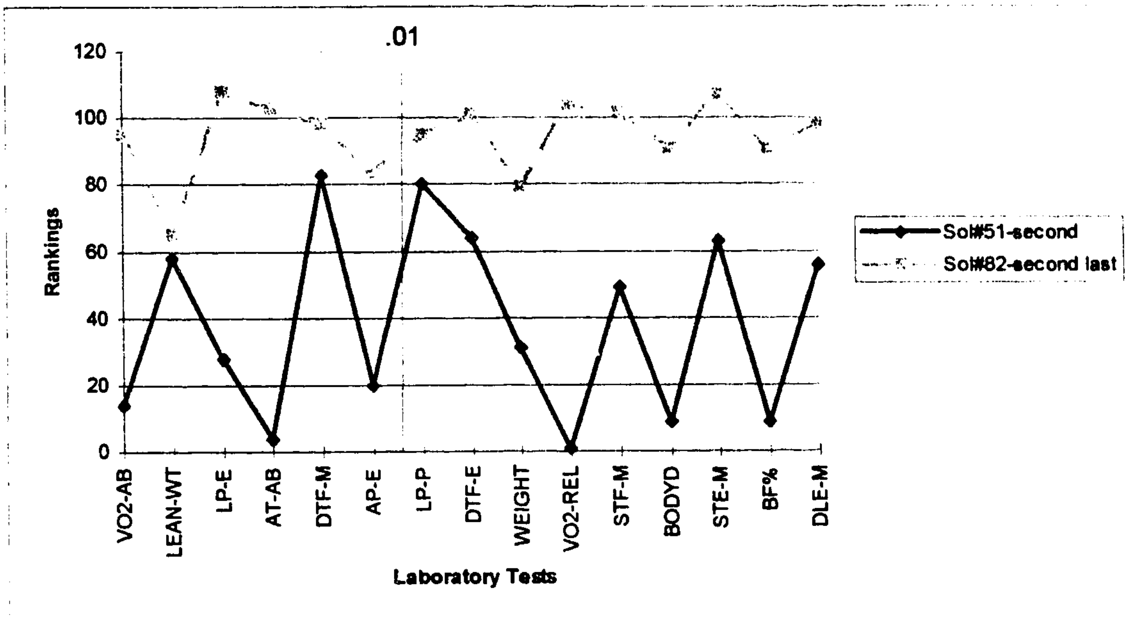

Figure 18. Rankings of S[illegible]nd and Second Last Place Finishers in the Ammunition Box Field Test for Laboratory Measurements Significant to .05 or Less ($p \leq .05$).

Note. The abbreviations for the Figure are: VO2-AB, absolute aerobic power; LEAN-WT, lean weight; LP-E, lean mean power output; AT-AB, absolute anaerobic threshold; DTF-M, dynamic trunk flexion maximal; AP-E, arm mean power output; LP-P, lean peak power output; DTF-E, dynamic trunk flexion mean; WEIGHT, weight; VO2-REL, relative aerobic power; STF-M, static trunk flexion maximal; BODY-D, body density; STE-M, static trunk extension maximal; BF%, percent body fat; DLE-M, dynamic leg extension maximal.

Soldier #51's performance in leg power, leg extension, and trunk flexion measurements was far from exceptional, again similar to soldier #142 (first place finisher). The subject achieved one above average (LP-E) and one below average (LP-P) ranking on the two leg power measurements significant to .05 or less. In the trunk flexion measurement, he achieved a below average ranking (DTF-M) on the test significant to .05 or less. In addition, soldier #51 did achieve an excellent ranking on the absolute arm power measurement (AP-P) significant to .01 or less.

When soldier #51's rankings on laboratory tests significant to greater than .05 were examined, other areas were identified that may have contributed to his success. In a number of areas soldier #51 excelled in relative scores. He achieved a first place ranking in relative anaerobic threshold, a second place ranking in leg power relative output - mean power output, and a third place ranking in arm power relative output - peak power output. In addition, he achieved two excellent rankings on right and left handgrip endurance, and two excellent rankings on the dynamic arm flexion tests.

Although the group data analysis suggested that for many measurements absolute achievement was more important than relative achievement for success in the Ammunition Box Field Test, soldier #51's success may have been partially a result of his extremely high rankings in the relative scores. In addition, other factors not significant to less than .05, including handgrip endurance and dynamic arm flexion, may have contributed more to his success than some factors significant to .05 or less. Although these points help explain his second place finish, the one ingredient that may have contributed most to his success, as it did with the first place finisher, may have been the protocol of the test. Excellent rankings in all four aerobic measures, which included first place rankings in relative aerobic power and relative anaerobic power, may have resulted in the scenario of soldier #51 not having to stop during the field test. Soldier #51's rankings again indicate the importance of aerobic factors to the performance of the Ammunition Box Field Test.

Soldier #82, the second last place finisher, achieved rankings on measurements significant to .05 or less that supported the group data conclusions. The subject had ten poor, four below average, and one average ranking on the 15 measurements. However, much like Soldier #77, the last place finisher in the Ammunition Box Field Test, soldier #82's performance on measurements significant to greater than .05, which included fourteen poor, and six below average out of a possible 32 measures, made it difficult to state conclusively that the poor finish was primarily due to the subjects performance on measurements significant to .05 or less.

In summary, the analysis of the second place and second last place finishers was similar to that of the first and last place finishers. The best performers were strong in the aerobic measurements, especially the relative ones. The poor performers had rankings on measurements significant to .05 or less that supported the group data conclusions. However, overall poor performances made it difficult to determine if their finishes were due primarily to their rankings on measurements significant to .05 or less.

Analysis of Third and Third Last Place Finishers

Figure 19 displays the rank order finishings of the third and third last place performers in the Ammunition Box Field Test on laboratory measurements significant to .05 or less. Table 26 in Appendix C4 lists complete laboratory measurement raw scores and resulting rankings for these soldier. Soldier #143's (third place finisher) rankings, especially on measurements significant to .01 or less support the group data. As with the first and second place finishers, soldier #143's strongest areas were aerobic. The subject achieved three excellent rankings on aerobic measurements significant to .05 or less: a ranking of three in absolute aerobic power (VO2-AB), a ranking of one in absolute anaerobic threshold (AT-AB), and a ranking of eight in relative aerobic power (VO2-REL).

The subject's performance was strong in other significant areas. Excellent rankings in all three leg strength and power measurements significant to .05 or less (LP-E, LP-P, and DLE-M). Two above average rankings (DTF-M, DTF-E) and one average ranking (STF-M) on the three trunk flexion measurements significant to .05 or less. And excellent rankings on the arm power measurement (ARM 25), and the trunk extension measurement (STE-M) significant to .05 or less.

Although soldier #143's rankings on laboratory tests significant to .01 or less support the group data conclusion, his performance on the tests significant to greater than .05 indicate additional areas that may have contributed to his success. Soldier #143 acquired 16 excellent rankings on the 32 measurements significant to greater than .05. Six were related to measurements identified before the .0[illegible] [illegible]owever, soldier #143 achieved excellent rankings in three additional areas.

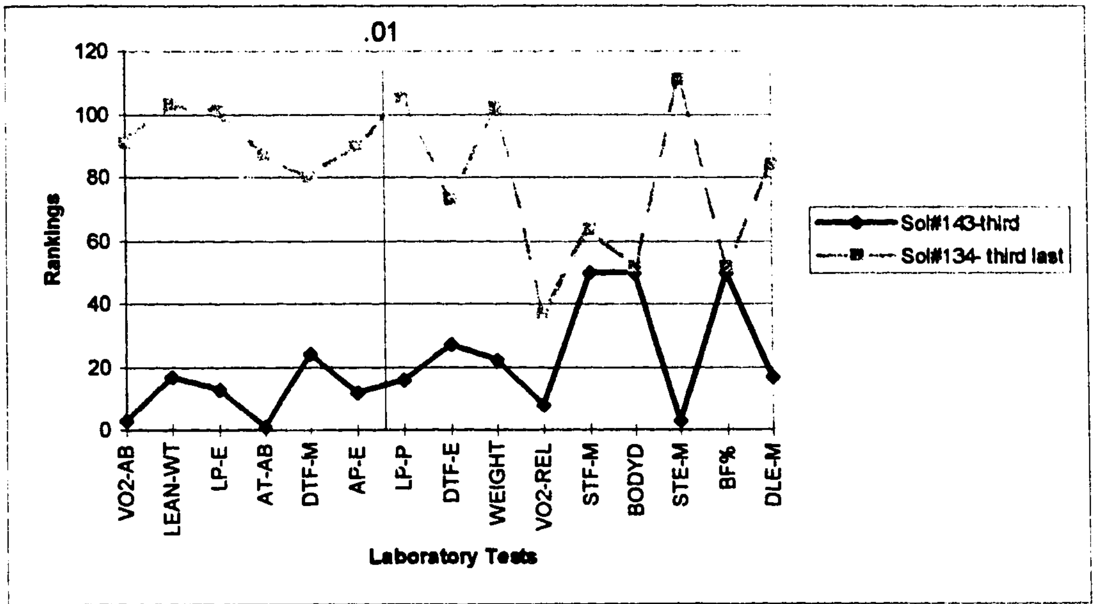

Figure 19. Rankings of Third and Third Last Place Finishers in the Ammunition Box Field Test for Laboratory Measurements Significant to .05 or Less ($p \leq .05$).

Note. The abbreviations for the Figure are: VO2-AB, absolute aerobic power; LEAN-WT, lean weight; LP-E, lean mean power output; AT-AB, absolute anaerobic threshold; DTF-M, dynamic trunk flexion maximal; AP-E, arm mean power output; LP-P, lean peak power output; DTF-E, dynamic trunk flexion mean; WEIGHT, weight; VO2-REL, relative aerobic power; STF-M, static trunk flexion maximal; BODY-D, body density; STE-M, static trunk extension maximal; BF%, percent body fat; DLE-M, dynamic leg extension maximal.

The first was bench press, where the subject achieved excellent rankings on bench press mean (BP-E) and bench press maximal (BP-M). The primary movements utilized in the isokinetic-concentric bench press strength test were extension of the elbow joint and adduction of the shoulder joint. These movements were not utilized during the lifting motion of the Ammunition Box Field Test. Therefore, it was unlikely the subjects bench press abilities significantly contributed to the third place finish.

The second area of excellent rankings was handgrip endurance. Soldier #143 achieved excellent rankings in both left and right handgrip endurance measurements. Although perhaps not a key to his success, handgrip endurance may have contributed to the subjects success. The final area of excellence was arm flexion. Soldier #143 had excellent rankings in all four arm flexion measurements: static arm flexion maximal, static arm flexion mean, dynamic arm flexion mean, and dynamic arm flexion maximal. In addition, the subject achieved an excellent ranking in the arm flexion endurance measurement: static arm flexion endurance. Although handgrip endurance and arm flexion strength and endurance were not identified by the group data analysis as being significant to best performance of the Ammunition Box Field Test, they are physiological factors that would seem to have been utilized in the lifting process. Soldier #143's results on laboratory test significant to .05 or less strongly supported the group data conclusions. However, other factors, specifically handgrip endurance and arm flexion strength may have contributed to his success.

Soldier #134's (third last place) performance on measurements significant to .01 or less (Figure 19) supported the group data conclusions. On the six measurements, soldier #134 achieved two poor and four below average rankings. The subject achieved two below average rankings on the two aerobic measurements significant to .01 or less, (VO2-AB, AT-AB). On the two leg power measurements significant to .05 or less, he achieved two poor rankings (LP-E, LP-P). The subject achieved two below average (DTF-M, DTF-E) and one average (STF-M) ranking on the three trunk flexion measurements.

Soldier #134's performance on measurements significant to .05 or less, and especially those significant to .01 or less, supported the group data conclusion. However, the subjects performance on measurements significant to greater than .05 revealed other factors that may have contributed to the poor performance. Soldier #134 achieved 12 poor rankings on the 32 measurements significant to greater than .05. Five of these were in areas related to factors significant to .05 or less. However, there were additional areas of weakness. Soldier #134 achieved poor rankings in two tests pertaining to arm flexion, three tests for handgrip strength and endurance, and two tests for trapezius lift strength. In the performance analysis of the Ammunition Box Field Test it was speculated that all three of these factors may have contributed to the lifting process. When the group data analysis did not identify them as significant, one reason suggested for their exclusion was that in the lifting process the legs may have generated the majority of the lifting force in the initial aspect of the lift. This power generated from the legs would have provide the majority of the force required to lift the box from waist to shoulder height. In soldier #134's case, with poor rankings in the two absolute leg power measurements (LEG 25, LEG 23) it was possible the subject could not generate the required force with the legs and was required to use his upper body/arms to lift the boxes to shoulder height. Soldier #82's weakness in these physiological factors may have contributed to the third last place finish.

Summary of Individual Analysis

Although four of the six individual performances analyzed generally support the group data conclusions, some inconsistencies were identified. In an attempt to provide an overview of the individual performances, the rankings of the best and worst performers were averaged on all the measurements significant to .05 or less, plus one other test, relative anaerobic threshold (AT-REL). These rankings were plotted on a graph and are displayed in Figure 20.

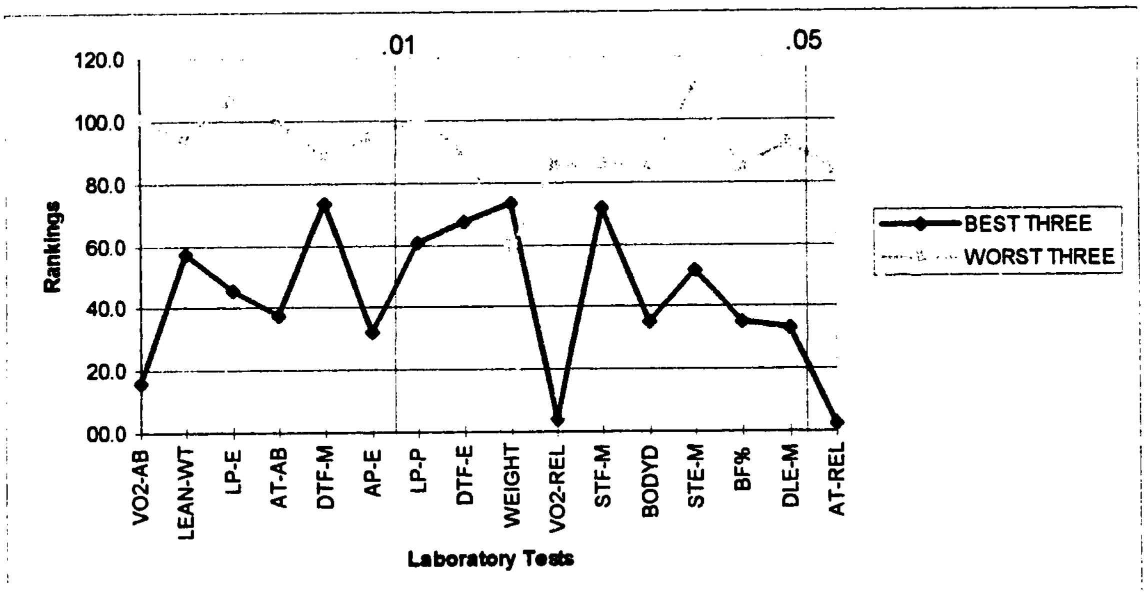

Figure 20. Average Rankings of Top and Bottom Three Finishers in the Ammunition Box Field Test for Laboratory Measurements Significant to .05 or Less ($p \leq .05$).

Note. The abbreviations for the Figure are: VO2-AB, absolute aerobic power; LEAN-WT, lean weight; LP-E, lean mean power output; AT-AB, absolute anaerobic threshold; DTF-M, dynamic trunk flexion maximal; AP-E, arm mean power output; LP-P, lean peak power output; DTF-E, dynamic trunk flexion mean; WEIGHT, weight; VO2-REL, relative aerobic power; STF-M, static trunk flexion maximal; BODY-D, body density; STE-M, static trunk extension maximal; BF%, percent body fat; DLE-M, dynamic leg extension maximal; AT-REL, relative anaerobic threshold.

In reviewing Figure 20, some issues were demonstrated.

1. The average rankings of the three worst performers, especially on measurements significant to .01 or less, strongly supported the group data conclusions.
2. Although the average rankings of the best three performers were consistently better than the worst three performers rankings, they were not generally in the range that would have been expected from the best performers based upon the group data conclusions.
3. For the best performers, the only measurements significant to .05 or less that averaged an excellent ranking were two aerobic ones: absolute aerobic power (VO2-AB, ranking = 16.2) and relative aerobic power (VO2-REL, ranking = 4.0).
4. The importance of anaerobic threshold to best performance was not strongly supported by the average ranking of the absolute anaerobic threshold measurement (AT-AB, ranking = 37.5). However, it was by the average ranking of the relative anaerobic threshold measurement (AT-REL, ranking = 2.6), a laboratory measurement significant to greater than .05.

Based on the analysis of the average rankings of the best and worst performers, it was difficult to determine if the individual analysis supported the group data conclusions. As stated earlier, the worst performances strongly support the conclusions. However, the best performances, on average, did not. The best performances supported the importance of aerobic factors. As stated earlier, in the discussions of the first and second place finishers, this may have been due to the protocol of the Ammunition Box Field Test. The average rankings of the best performers indicated that the heart rate control of the field test may have provided an unbalanced advantage to those possessing high aerobic abilities, particularly relative measures.

The heart rate control was implemented to reduce the risk of injury to the soldier performing the Ammunition Box Field Test (Chahal, 1993). An alternative to this protocol may be to have proper-lifting-technique as the controlling factor rather than heart rate. Therefore, as long as the soldier maintained proper-lifting-technique, they would continue the field test. Protocol for proper lifting technique would have to be determined and standardized for all testers. One additional factor that would be present, as it is in the current protocol, would be that the soldier could stop or pause during the field test any time they felt there was a risk of injury to themselves.

The proper-form-technique protocol may be beneficial for two reasons. First, although the heart rate protocol was adopted to reduce injury, a requirement of proper lifting technique may be a better safe guard against back injury than a submaximal heart rate. Theoretically, a soldier could be at risk of injury utilizing an improper lifting technique even thought they maintain a submaximal heart rate. Proper lifting technique at any heart rate may reduce this risk. Second, a protocol based upon proper lifting technique may provide data that is not as strongly influenced by aerobic factors, as the present protocol appears to have been.

Summary of Ammunition Box Field Test

In the analysis of the laboratory measurements of Group A and B for the Ammunition Box Field Test, the following differences between the groups were indicated. Group A was slightly different from Group B in the lower body and trunk regions. In the trunk region the greatest difference between the two groups was in trunk flexion measurements. Group A was statistically similar to Group B in the upper Body/Arm region measurements. Group A was significantly superior to Group B in aerobic measurements and Group A was significantly different from Group B in body composition: Group A weighed more, had a larger lean mass and a lower body fat percentage than Group B.

Group A was significantly superior to Group B in power measurements: absolute leg power, absolute arm power and absolute and relative aerobic power. Group A's superiority in power measurements was most prevalent in absolute measurements rather than relative measurements.

C. Analysis of the Maximal Dig Field Test

One of the basic tasks a soldier is required to perform is to dig a slit trench to provide a position for offensive and defensive maneuvers against the enemy. Although modern technology has supplied the military with a variety of methods of housing soldiers, the digging of a slit trench remains a fixture in military life. In a battle situation, the soldier's need for the physiological skills necessary to dig a slit trench are unquestionable. The slit trench provides the soldier with not only a position to protect themselves from enemy attack, but also a position from which the soldier can attack the enemy as safely as possible. The possible need to defend or attack after the slit trench has been dug further emphasizes the need for functional physical fitness in the physiological factors required to dig a slit trench. If a soldier is exhausted after digging the slit trench, their ability to defend themselves, either with shooting or fighting skills, will be diminished. Exhaustion may result in danger or death to the soldier or others in their unit. As a result of the importance of this task, the Maximum Dig Field Test was included in the field tasks recommended by Singh et al. (1991) to the Canadian Military (Lee, 1992).

To perform the Maximum Dig Field Test a soldier was required to shovel and/or throw all the gravel (0.486 cubic meters) out of a specifically designed box (dimensions: 1.80 m length; 0.60 m width; 0.45 m depth). The soldier was instructed to dig at the maximal rate possible and the time for completion was recorded (Chahal, 1993). The recommended standard for the Maximum Dig Field Test was 360 s (6 min). Mean performance time for the 116 soldiers was four min. and 22 s.

Analysis of Group Data

In the performance of the Casualty Evacuation Field Test the following protocol was used. The soldier stood with both feet in a box containing 0.486 m^3 of standard gravel. When the test began, the soldier shoveled all the gravel out of the box as quickly as possible. The soldier continued shoveling and/or throwing gravel from the box until less than one handful of gravel remained. One restriction on the soldier was that they must keep both feet within the box for the duration of the field test.

Although some research exists on digging, the involvement of muscular strength and endurance is not well understood or investigated. However, for optimal digging performance muscular strength and endurance of the arms, trunk and legs is necessary (Chakraborty et al., 1974; Stevenson et al., 1987,1988). As the act of digging shares some similarities with lifting, it is likely that the abdominals perform the role of increasing intra-abdominal pressure to provide support for the spine (Cailliet, 1981). In addition, Stevenson et al. (1988), in researching digging at a maximal rate, found energy was expanded at a constant submaximal rate of approximately 70% maximal aerobic power. However, the specific physiological requirements of digging have not been identified.

Theoretical Analysis of Field Test

In an attempt to analyze the Maximum Dig Field Test from a performance perspective the procedure was broken down into the following components:

- the involvement of the lower body
- in involvement of the trunk region
- the involvement of the upper body/ arms

- the energy system utilized

a. Involvement of Lower Body

The involvement of the lower body in the performance of the Maximum Dig Field Test was likely similar to its involvement in the Ammunition Box Field Test. However, in the Ammunition Box Field Test the range of motion was from a crouched position to a standing position, whereas in the Maximum Dig Field Test the lower body was involved in a more limited range of motion. The soldier, while digging, was unlikely to reach the same degree of knee flexion as would have been utilized in the crouched position for lifting the ammunition boxes. Similarly, while digging the soldier was unlikely to have extended the knee and hip joints to a standing position as they did in the performance of the Ammunition Box Field Test. Therefore, although knee and hip extension would have been utilized in the digging performance, they would likely have occurred through a limited range of motion. The laboratory measurements that would addressed this involvement were: leg power, dynamic leg extension and knee extension.

b. Involvement of Trunk Region

The stabilization of the trunk would likely have been an important element of the digging process. When lifting, it is generally advised to keep the back relatively straight to reduce the stress on the spine. In the performance of the Maximal Dig Field Test, keeping the back straight was an unlikely task. While digging, the soldier was in a bent over position, knees and hips slightly flexed, and arms extended downwards. This placed the back in a vulnerable position. In addition, the shovel acted as a lever to compound the forces on the trunk region when the gravel was lifted. Therefore, the muscles involved in the trunk region likely played an important role. The laboratory measurements that would have address this involvement were the static and dynamic, trunk flexion and extension tests.

c. Involvement of Upper Body / Arms

The upper body / arm region was involved in two elements of the digging process. The first involved pushing the shovel into the gravel. The second involved lifting the shovel to throw the gravel out of the box. Pushing the shovel into the gravel would have required shoulder flexion and elbow extension. Measurements that would have addressed this involvement were: bench press and arm power. Lifting the shovel will require flexion of the elbow joint and shoulder joint . Measurements addressing these actions were: dynamic and static arm flexion, static arm flexion endurance, arm power, dynamic trapezius lift, and trapezius lift endurance.

d. Energy Systems

The mean time for performance of the Maximum Dig Field Test was 262.0 s (4 min 22 s). Fox et al. (1988) stated that physiological events lasting three minutes to ten minutes have approximately 50% of their energy contributed from aerobic sources and 50% from anaerobic. In the analysis of the Ammunition Box Field Test, an event that took approximately the same time to complete as the Maximum Dig Field Test, it was speculated that, due to the protocol restricting the soldiers from lifting if their heart rates exceeded 70% maximal aerobic power, the aerobic contribution would have been greater than 50%. However, as there was no heart rate restriction during the performance of the Maximum Dig Field Test, the soldiers were likely working closer to maximal effort.

Therefore, the energy sources were likely more aligned with those stated by Fox: 50% aerobic and 50% anaerobic.

Analysis of t-test Results

With this performance analysis in mind, a statistical analysis of the 116 soldiers Maximum Dig Field Test results was undertaken. The statistical analysis procedure was identical to the method utilized for the Casualty Evacuation Field Test. The results of this analysis are shown in Table 9 which lists the laboratory measurements which significantly differentiated the performance of the best and worst groups for the Maximal Dig Field Test to a significant value of .05 or less. The measurements were listed in order of significant value. A complete list of all measurements and their significant values, including those that were significant to greater than .05, is available in Appendix D1.

Table 9 was analyzed in reference to the four performance components stated earlier: the involvement of the lower body; the trunk region; the upper body/arm region; and the energy system utilized. In addition, body composition factors were analyzed in an additional section.

a. Lower Body

The t-test analysis results (Table 9), showed a number of lower body measurements were significant at differentiating best and worst performance of the Maximum Dig Field Test. Both absolute leg power measurements (mean and peak) were significant to .000. In addition, both relative leg power measurements were significant to less than .01. Therefore, all four measurement this study used for the construct leg power were significant to less than .01.

Table 9. Maximal Dig Field Test T-Test Results for Laboratory Measurements with Significant Values of .05 or Less.

Laboratory Measurement	Significant Value
leg peak power output	.000 **
leg mean power output	.000 **
absolute aerobic power	.000 **
absolute anaerobic threshold	.000 **
static trunk extension mean	.000 **
static trunk extension maximal	.000 **
dynamic arm flexion mean	.000 **
dynamic trunk extension maximal	.000 **
dynamic leg extension maximal	.000 **
arm mean power output	.001 **
dynamic arm flexion maximal	.001 **
dynamic trunk extension mean	.001 **
dynamic leg extension mean	.001 **
lean weight	.003 **
left knee flexion	.004 **
left knee extension	.004 **
leg relative power output ppo	.005 **
leg relative power output mpo	.007 **
arm relative power output mpo	.014 *
relative anaerobic threshold	.017 *
static arm flexion endurance	.018 *
relative aerobic power	.021 *
trapezius lift endurance	.025 *
dynamic trunk flexion mean	.029 *
static trunk flexion mean	.034 *
static trunk flexion maximal	.034 *
right handgrip endurance	.040 *
bench press maximal	.042 *
weight	.044 *
dynamic trunk flexion maximal	.044 *
right handgrip strength	.046 *
body density	.050 *
percent body fat	.050 *

* $p \leq .05$ ** $p \leq .01$

Although absolute and relative leg power measures were significant to less than .01, two factors should be considered. First, the soldiers in the best group (mean lean weight 67.6 kg) had a mean lean weight 6.7 kg greater than the worst group (mean lean weight 60.9 kg). Second, the Maximum Dig Field Test required the movement of a standard amount of gravel. Therefore, the field test would have required a standard amount of work from each soldier (Fox et al., 1988). It seems reasonable that absolute leg power may have been more important to field test performance than relative leg power.

Other lower body measurements were significant. Dynamic leg extension, knee flexion and knee extension were all significant at .01 or less. For both knee flexion and knee extension, it was the left knee that was significant to .01 or less. Neither right knee flexion (.056) or right knee extension (.100) were significant to less than .05. When a right handed person was digging, their left foot was forward and most of the weight was carried on that foot. The left/right dominance of the soldiers was not recorded. However a significantly larger portion of the population is right side dominant. Therefore, the significance of the left knee flexion and extension may have been a result of the requirement of the flexion and extension of the non-dominant knee joint in bearing the weight of, and stabilizing, the body while performing the dig.

b. Trunk Region

All four measurements addressing trunk extension (static and dynamic; mean and maximal) were significant at .01 or less. All four measurements addressing trunk flexion (static and dynamic; mean and maximal) were significant to between .01 to .05. During the performance of the Maximal Dig Field Test, soldiers were bent over for a great deal of the time, placing the back in a vulnerable position. In addition, forces generated when lifting the gravel filled shovel would have increased the stress on the back. Working maximally for the time frame involved (mean performance time = 4 min 22 s) would have resulted in approximately 50% of the energy contribution being provided by the aerobic system (Fox et al., 1988). It is probable that increased function of the aerobic system would have resulted in an increase in the depth and rate of breathing, which in the bent over position may have reduced the effectiveness of the abdominal muscles to generate the intra-abdominal pressure necessary for support of the spine. Therefore, in the bent over position required during the Maximal Dig Field Test, the trunk extensors may have performed a greater role in trunk stabilization than the trunk flexors. These results support Wheeler's (1993) statement that the lumbar extensors are the limiting factor in the lifting process.

c. Upper Body / Arms

A number of upper body/ arm laboratory measurements were significant to less than .05. Both dynamic arm flexion measurements (dynamic arm flexion maximal; dynamic arm flexion mean) were significant at .01 or less. Neither static arm flexion measurement was significant to .05 or less. As the Maximum Dig Field Test required dynamic contractions of the arm flexors these results seemed reasonable. However, static arm flexion endurance was significant to less than .05.

Other upper body/arm measurements that were significant to less than .05 were arm mean power output and arm relative power output - mean power output. While the mean aspect of these measurements were significant to .05 or less, the peak aspects, arm peak power output (.076) and arm relative power output - peak power output (.596) were not. In the performance of the 30 s Wingate laboratory test, mean power was defined as the mean work output of the 30 s period. Peak power was defined as the highest power output in a 5 s period (MacDougall et al., 1991). As a soldiers performance time in the field test was dependent upon his having been able to generate muscular power over an extended period of time (mean performance time = 4 min 22 s) rather than a short period of time (5 s), the greater significance of mean power seems reasonable.

Three other upper body/arm measurements were significant. The right handgrip endurance and right handgrip strength measurements were both significant to less than .05. However, left handgrip strength (.082) and left handgrip endurance (.118) were not. Most people are right handed, and would therefore dig with their right hand or dominant hand near the end of the shovel (in handgrip). The shovel used for the field test had a shaft approximately 1 m long with a D-shaped handle for the handgrip. These results indicated that right hand (or dominant hand) strength and/or endurance may have been required to control of the shovel in the performance of the field test.

Other significant upper body/arm measurements were those for the bench press strength test. The bench press strength test required elbow extension and shoulder adduction. These two movements would have been utilized in pushing the shovel into the gravel. Another laboratory tests that measured these movements was the Wingate Upper Body test, the test used to measure arm power. As stated earlier, absolute and relative mean power measures were significant to .05 or less while peak measurements were not.

These results may indicate the importance of elbow extension and shoulder adduction in inserting the shovel into the gravel during the field test. However, the consistency of the gravel, less than one centimeter in diameter, would have enabled the shovel to be relatively easily inserted. The shovel design (pointed insertion end) and loosely packed gravel would have reduced the effort required to insert the shovel in the gravel. The laboratory measurements related to elbow extension and shoulder flexion may have been more significant if the product being dug had been hard packed dirt rather than loosely packed gravel.

d. Energy Systems

In the performance analysis of the Maximum Dig Field Test it was postulated that the energy source utilization would likely be 50% aerobic and 50% anaerobic. This was supported by the t-test analysis which indicated measurements for absolute aerobic power, absolute anaerobic threshold and absolute leg and arm power were all significant at less than .05.

e. Body Composition

The one measurement significant to .05 or less not yet covered was body fat percentage. Body fat percentage (.050) may have been significant for two reasons. First, excess body fat on the soldier would have added to the resistance that was required to be lifted when the soldier straighten, without providing any physiological advantage. Second, body fat, especially if carried around the waist area, could have affected the soldier's ability to bend over to the position required to push the shovel into the gravel. Body fat percentage was significant in the Ammunition Box Field Test to a similar value (.043).

Both field tests required bending and lifting, and the similarity of significance of percent body fat for each supported the importance of body composition to performance of the two field tests.

Analysis of Individual Data

Further analysis was conducted on the laboratory results of the best (top three finishers) and worst (bottom three finishers) performers in Maximum Dig Field Test. This examination was conducted to determine if the conclusions arrived at in the Analysis of Group Data section would be supported by individual performances. The process followed was the same as that utilized in the analysis of the Casualty Evacuation Field Test.

Figure 21 displays rankings (from 1-116) on the Y axis, and the laboratory measurements on the X axis. The measurements were positioned on the graph according to the t-test analysis results from the Analysis of Group Data section. A complete listing of the order of the laboratory measurements on the X axis is available in Appendix D1.

Analysis of First and Last Place Finishers

Figure 21 displays the rank order finishings of the first and last place performers in the Maximum Dig Field Test on laboratory measurements significant at .01 or less. Table 28 in Appendix D2 lists all laboratory measurement raw scores and resulting rankings for these soldiers. The ranking for soldier #16 (first place finisher) and soldier #77 (last place finisher) strongly supported the group data conclusions. Soldier #16 achieved 14 excellent rankings out of 18 measurements significant to .01 or less. Soldier #77 achieved 17 poor rankings out of the 18 measurements at .01 or less.

The one area of weakness for soldier #16 (first place) on measurements significant at .05 or less was lower leg involvement. The subject achieved one excellent (leg power mean, LP-E), one above average (leg power peak, LP-P), two average (dynamic leg extension mean, DLE-E; leg relative power output - mean, LP-E-REL), and one below average (leg relative power output - peak, LP-P-REL) rankings in this area.

Soldier #16's strongest areas were aerobic and dynamic trunk extension. The subject achieved high rankings for both absolute aerobic measures: absolute aerobic power (VO2-AB), and absolute anaerobic threshold (AB-AT). Although the soldier achieved excellent rankings in the trunk extension static tests (STE-E, STE-M), they were exceeded by rankings of five on both trunk extension dynamic tests: dynamic trunk extension maximal (DTE-M), and dynamic trunk extension mean (DTE-E).

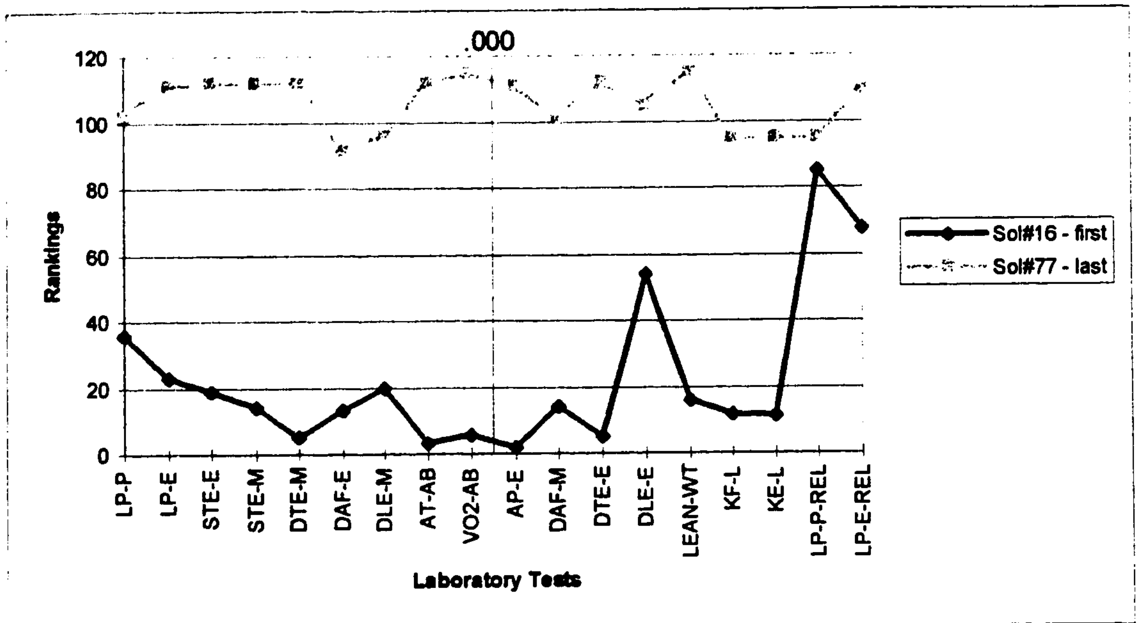

Figure 21. Rankings of First and Last Place Finishers in the Maximum Dig Field Test for Laboratory Measurements with Significant Values of .01 or Less ($p \leq .01$).

Note. The abbreviations for the Figure are: LP-P, lean peak power output; LP-E, lean mean power output; STE-E, static trunk extension mean; STE-M, static trunk extension maximal; DTE-M, dynamic trunk extension maximal; DAF-E, dynamic arm flexion mean; DLE-M, dynamic leg extension maximal; AT-AB, absolute anaerobic threshold; VO2-AB, absolute aerobic power; AP-E, arm mean power output; DAF-M, dynamic arm flexion maximal; DTE-E, dynamic trunk extension mean; DLE-E, dynamic leg extension mean; LEAN-WT, lean weight; KF-L, left knee flexion; KE-L, left knee extension; LP-P-REL, leg relative power output ppo; LP-E-REL, leg relative power output mpo.

On the measurements significant from .01 to .05, the differences in rankings between the two soldiers continued. However, each soldier moved slightly towards the average rankings. Soldier #16 achieved nine excellent, four above average, and two average rankings on the 15 measurements between .01 and .05. Soldier #77 achieved 11 poor, two below average, one average and one above average on the same 15 measures.

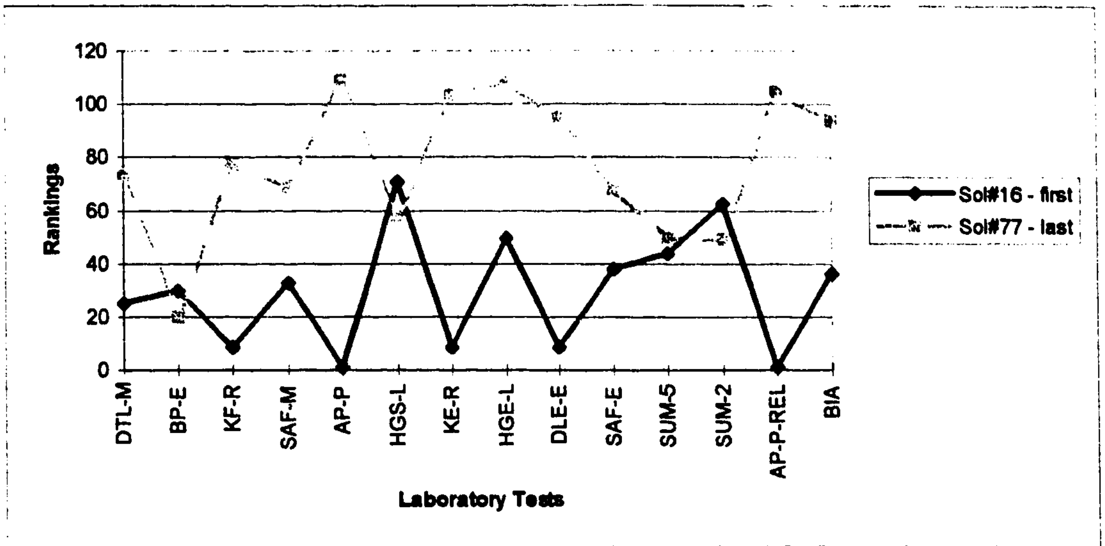

Figure 22. Rankings of First and Last Place Finishers in the Maximum Dig Field Test for Laboratory Measurements with Significant Values Greater than .05 ($p \geq .05$).

Note. The abbreviations for the Figure are: DTL-M, dynamic trapezius lift maximal; BP-E, bench press mean; KF-R, right knee flexion; SAF-M, static arm flexion maximal; AP-P, arm peak power output; HGS-L, left handgrip strength; KE-R, right knee extension; HGE-L, left hand grip endurance; DLE-E, dynamic leg extension mean; SAF-E, static arm flexion mean; SUM-5, sum of 5 skin folds; SUM-2. sum of 2 skin folds; AP-P-REL, arm relative power output ppo;

On measurements significant to greater than .05, the two soldier's rankings continue their move towards the average range. Figure 22 displays the rankings for the two soldiers on the 14 measurements that were significant to greater than .05. Soldier #16 (first place) achieved five excellent, six above average, two average and one below average on the 14 measurements significant to greater than .05. Soldier #77 achieved six poor, two below average, five average and one excellent on the same measures. The rankings displayed in Figures 20 and 21 indicated that the two soldiers were quite different in their rankings. However, their differences were the greatest on the measurements significant to .01 or less. These differences were reduced as the measurements become less significant, with the least difference in ranking having occurred on the measurements significant to greater than .05. This continual progression towards the average range for both subjects as the measurements become less significant supported the group data conclusions.

Analysis of Second and Second Last Place Finishers

Figure 23 displays the rank order finishings of the second and second last place performers in the Maximum Dig Field Test on laboratory measurements significant to .01 or less. Table 29 in Appendix D3 lists all laboratory measurement raw scores and resulting rankings for these soldiers.

The rankings for soldier #160 (second place finisher) and soldier #70 (second last place finisher) were extremely similar to those of the first and last place finishers. There was a clear differentiation in the rankings of the two soldiers. This differentiation continues throughout the complete range of the laboratory measurements, although there was a slight move towards the average range for both soldiers as the measurements became less significant.

Soldier #160's (second place) rankings before .01 were indicative of a good performance in the Maximum Dig Field Test as he achieved 14 excellent rankings out of a possible 18 measures. Although soldier #160 did not have an area of weakness, his strongest area was the trunk region. On the trunk extension measurements, static trunk extension mean (STE-E), static trunk extension maximal (STE-M), dynamic trunk extension mean (DTE-E), and dynamic trunk extension maximal (DTE-M), all which were significant to .01 or less, the subject achieved two number one rankings and one 4.5 ranking. Of the four trunk flexion measurements, all of which were significant to between .01 and .05, soldier #160 achieved an average ranking of 3.25.

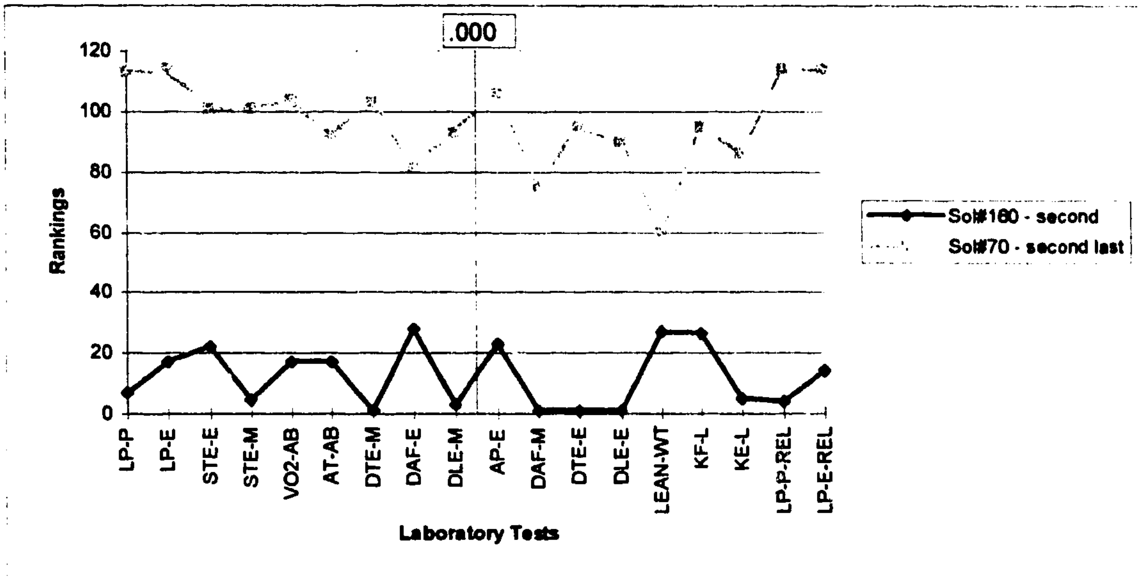

Figure 23. Rankings of Second and Second Last Place Finishers in the Maximum Dig Field Test for Laboratory Measurements with Significant Values of .01 or Less ($p \leq .01$).

Note. The abbreviations for the Figure are: LP-P, lean peak power output; LP-E, lean mean power output; STE-E, static trunk extension mean; STE-M, static trunk extension maximal; VO2-AB, absolute aerobic power; AT-AB, absolute anaerobic threshold; DTE-M, dynamic trunk extension maximal; DAF-E, dynamic arm flexion mean; DLE-M, dynamic leg extension maximal; AP-E, arm mean power output; DAF-M, dynamic arm flexion maximal; DTE-E, dynamic trunk extension mean; DLE-E, dynamic leg extension mean; LEAN-WT, lean weight; KF-L, left knee flexion; KE-L, left knee extension; LP-P-REL, leg relative power output ppo; LP-E-REL, leg relative power output mpo.

Soldier #70's (second last place) rankings on measurements significant to .01 or less supported a poor performance in the Maximum Dig Field Test. He achieved 12 poor rankings out of 18 measurements. Leg power appeared to be soldier #70's weakest area as he achieved a ranking of 113 on leg peak power output (LP-P), and three rankings of 114 on: leg mean power output (LP-E); leg relative power output - mpo (LP-E-REL); and leg relative power output - ppo (LP-P-REL).

Although the differentiation in ranking between these two soldiers continued throughout the test, there was a slight move towards average rankings for both of them. On the 18 measurements significant at .01 or less, soldier #160 (second place) achieved 14 excellent and 4 above average rankings. On measures significant to greater than .05, the second place finisher achieved 9 excellent, 2 above average, and 3 average rankings. Soldier #70 achieved 12 poor, 5 below average and 1 average ranking on the 18 laboratory tests significant at .01 or less. On the laboratory tests significant to greater than .05 he achieved 7 poor, 2 below average, 3 average, and 2 above average.

This slight move towards the average range for both soldiers supported the group data conclusions by having the greatest differentiation of the soldiers rankings occurring on measurements significant at .01 or less, and decreasing as the measurements become less significant. As stated earlier, this situation was similar to the analysis of the first and last place finishers in this field test. This extreme differentiation in rankings between the best and worst performers may have been a result of the requirements of the field test.

The Maximal Dig Field Test required an approximately 4 min 22 s maximal effort from the soldiers to perform a standard amount of work. Working maximally for this time frame would theoretically have taxed anaerobic and aerobic sources (Fox et al., 1988). In addition, the muscular activity required to perform the dig would have been dynamic contractions from most muscle groups of the body. No other field tests was as concentrated a combination of duration and intensity. The Casualty Evacuation Field Test may have been more intense but for a much shorter duration (> 60 sec). The Ammunition Box Field Test was of similar duration but required a submaximal effort. Finally, the Weight Load March Field Test had an extended duration (< 2 hr) but, again, a submaximal intensity.

This analysis was supported by the t-test results. Table 10 lists the number of measurements that were significant at: .01 or less; at .01 to .05; and the total of these for all four field tests. Table 10 demonstrated that the Maximum Dig Field Test (Max-Dig) had more measurements significant to .01 or less, and to .05 and less than the other field tests. In total, the Maximum Dig Field Test had 12 laboratory measurements more than the next closest field test (21 measurements in the Casualty Evacuation Field Test). The extreme differentiation experienced with the first and last place finishers, and the second and second last place finishers seemed reasonable.

Table 10. Number of Measurements Significant at Different Levels in the Four Field Tests.

Significant value	Number of Laboratory Tests Significant in Each Field Test			
	Cas-Evac	Amm-Box	Max-Dig	March
.01 or less	9	6	18	3
.01 - .05	12	9	15	10
TOTAL	21	15	33	13

Note. The four field tests are abbreviated on Table 10 as follows: Casualty Evacuation Field Test (Cas-Evac); Ammunition Box Field Test (Amm-Box); Maximum Dig Field Test (Max-Dig); and Weight Load March Field Test (March).

Analysis of the third and third last place finishers

Figure 24 displays the rank order finishings of the third and third last place performers in the Maximum Dig Field Test on laboratory measurements significant to .01 or less. Table 30 in Appendix D4 lists all laboratory measurement raw scores and resulting rankings for these soldiers.

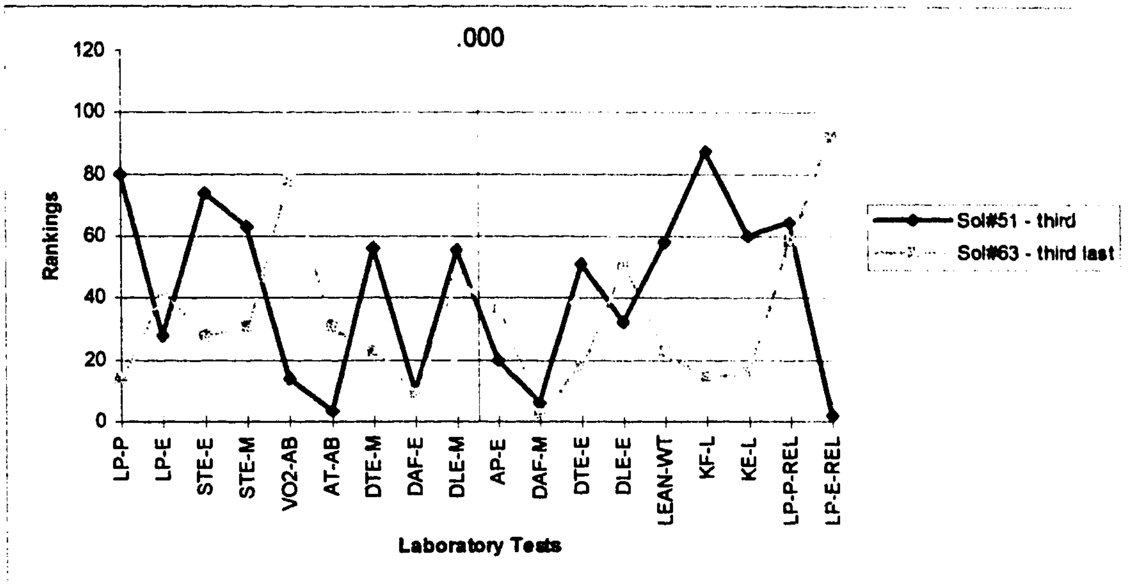

Figure 24. Rankings of Third and Third Last Place Finishers in the Maximum Dig Field Test for Laboratory Measurements with Significant Values of .01 or Less ($p \leq .01$).

Note. The abbreviations for the Figure are: LP-P, lean peak power output; LP-E, lean mean power output; STE-E, static trunk extension mean; STE-M, static trunk extension maximal; VO2-AB, absolute aerobic power; AT-AB, absolute anaerobic threshold; DTE-M, dynamic trunk extension maximal; DAF-E, dynamic arm flexion mean; DLE-M, dynamic leg extension maximal; AP-E, arm mean power output; DAF-M, dynamic arm flexion maximal; DTE-E, dynamic trunk extension mean; DLE-E, dynamic leg extension mean; LEAN-WT, lean weight; KF-L, left knee flexion; KE-L, left knee extension; LP-P-REL, leg relative power output ppc; LP-E-REL, leg relative power output mpo.

These two performances did not support the group data conclusions. Soldier #63, the third last place finisher, achieved more excellent and above average rankings than the third place finisher, soldier #51, on measurements significant at .01 or less. A breakdown of the soldiers rankings for measurements significant at .01 or less is shown in Table 11. A prediction based on the group data conclusions and the data from Table 11, showing soldier #63 (third last place) had more excellent and above average rankings than soldier

#51 (third place), would have had soldier #63 as a more likely candidate for third place than soldier #51.

Table 11. Breakdown of Rankings for Soldier #51 (third place) and #63 (third last place) on Laboratory Measures with Significant Values of .01 or Less.

Soldier number	excellent rankings	above average rankings	average rankings	below average rankings	poor rankings
51 (third)	6	2	7	3	0
63 (third last)	8	6	2	2	0

Although the rankings of these soldiers did not support the group data conclusions, a further analysis of the data was conducted to determine if the reasoning for their respective finishes could be determined. To determine the factors that contributed to soldier #51's third place ranking, the measurements on which the subject achieved an excellent ranking were reviewed. To determine the factors that contributed to soldier #63's third last place ranking, the measurements on which the subject achieved a poor or below average ranking were reviewed. In total 16 laboratory measurements were selected for review. Interestingly, of these 16, ten were common to both soldier. Figure 25 displays the two soldiers rankings for these 16 selected laboratory measurements.

Although it was not one of the 16 laboratory measurements selected, one physiological factor that likely contributed to the both soldiers performances was lean weight. Soldier #51 (third place finisher) had a lean weight of 64.2 kg. Soldier #63 (third last place finisher) had a lean weight of 70.9 kg. This constituted a difference in lean weight of 6.7 kg and a difference in lean weight ranking of 35.

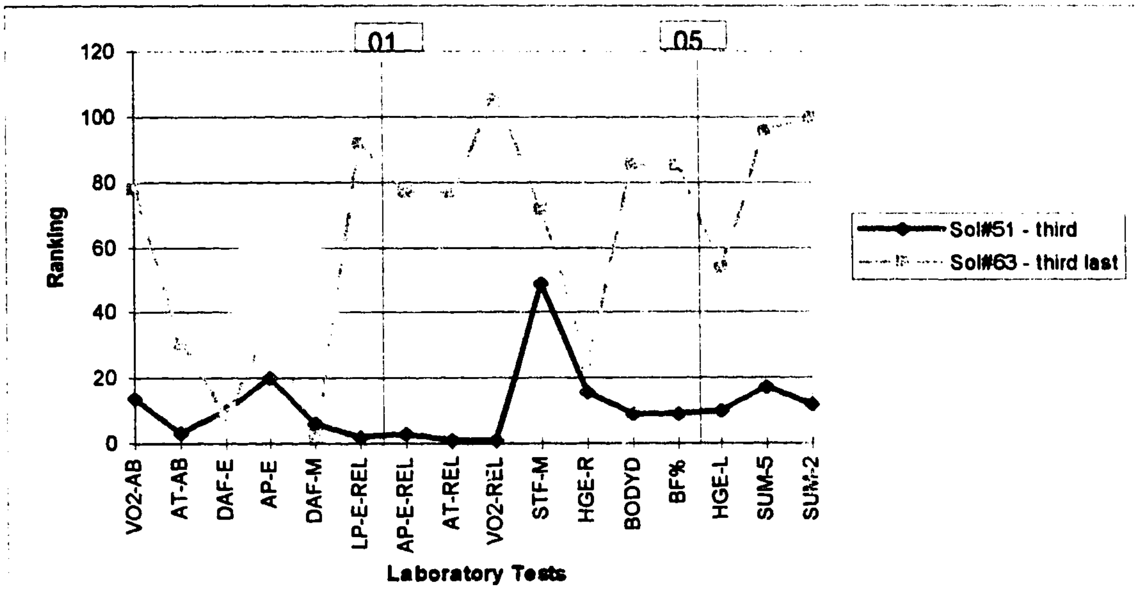

Figure 25. Rankings for Third and Third Place Finishers in the Ammunition Box Field Test for Sixteen Selected Laboratory Measurements.

Note. The abbreviations for the Figure are: VO2-AB, absolute aerobic power; AT-AB, absolute anaerobic threshold; DAF-E, dynamic arm flexion mean; AP-E, arm mean power output; DAF-M, dynamic arm flexion maximal; LP-E-REL, leg relative power output mpo; AP-E-REL. arm relative power output mpo; AT-REL, relative anaerobic threshold; VO2-REL, relative aerobic threshold; STF-M, static trunk flexion maximal; HGE-R, right hand grip endurance; BODYD. body density; BF%, percent body fat; HGE-L, left hand grip endurance; SUM-5, sum of 5 skin folds; SUM-2, sum of two skin folds.

The most significant measurements that were considered from Figure 25 were the aerobic ones. Soldier #51, with less lean weight than soldier #63, still outperformed him on the absolute aerobic measurements. Soldier #51 achieved an excellent ranking on both absolute aerobic power (VO2 - AB) and absolute anaerobic threshold (AT -AB), while soldier #63 achieved a below average (VO2 -AB) and above average (AT-AB) ranking. This differentiation increased when the relative aerobic measurements were examined. Soldier #51 (third) achieved the top ranking in both the relative aerobic power (VO2-REL) and relative anaerobic threshold (AT-REL). Soldier #63 achieved a below average ranking on relative anaerobic threshold (AT-REL), and his lowest ranking, a ranking of 105.5, on the relative aerobic power (VO2-REL). All these laboratory measurements were significant to .05 or less.

The next area examined was the upper body/ arm. Both soldiers achieved excellent rankings on the two dynamic arm flexion measurement (DAF-E, DAF-M). However with arm mean power absolute (AP-E), soldier #51 (third place), with less lean weight, outperformed soldier #63 (third last place). This ranking differentiation was more distinct when the results were expressed relatively. On arm relative power output - mpo (AP-P-REL) soldier #51 again achieved one of the highest rankings (third place ranking) while soldier #63 achieved a below average ranking (ranking of 77). Soldier #51 also achieved excellent rankings on both handgrip endurance tests (HGE-L, HGE-R).

There was only one lower leg measurement that was examined, leg relative power output - mpo (LP-E-REL). This measurement continued soldier #51's dominance in relative measures as he achieved a number two ranking, and soldier #63 achieved a number 92 ranking.

The final area covered was body composition. As stated earlier, soldier #51 had a lean weight of 6.7 kg less than soldier #63. In addition, soldier #51 was measured at a body fat percentage of 10.4% (number 9 ranking) while soldier #63 was measured at 21.4% (number 85 ranking).

Based on this analysis, soldier #51's third place finish was likely a result of a number of factors. First, his aerobic abilities, especially his top relative rankings on aerobic power and anaerobic threshold measurement; second, the subjects excellent rankings in dynamic arm flexion measurement; and third, his high ranking in relative arm and leg power.

Soldier #63's third last place finish was also attributable to similar factors. First, in aerobic power and anaerobic threshold measurements, soldier #63 achieved two of his lowest rankings. The subjects lowest ranking was on relative aerobic power (VO2-REL). Second, this poor ranking in relative measures continued with leg and arm power measurements. Thirdly, the soldier's body composition ranked him as having had one of the higher body fat percentages of all the soldiers. This extra body fat may have made the task of digging difficult and cumbersome, and the added resistance of the body fat may have increased the difficulty of the task.

Summary of the Individual Analysis

Four of the six individual performances analyzed supported the group data conclusion. Two of the individuals, the third place and third last place finishers, achieved rankings that did not support the group data conclusions. However, many of the measured factors that were determined to contribute to their success were significant to .05 or less, including arm flexion dynamic, relative arm power, relative leg power and body fat percentage. In addition, the individual analysis indicated that aerobic factors may have been the most important physiological factors contributing to best performance of the field test.

Summary of the Maximum Dig Field Test

The greatest difference between Group A and B for any field test occurred on the Maximal Dig Field Test. Group A was significantly superior to Group B in all three regions of the body: lower body, trunk region, and upper body/ arms. Group A was significantly superior to Group B in power measurements in all aspects: absolute and relative leg power, absolute and relative arm power and absolute and relative aerobic power. Group A was superior to Group B in all aerobic measurements. Finally, Group A was significantly different from Group B in body composition. Group A weighed more, had a larger lean mass and a lower body fat percentage.

D. Analysis of the Weight Load March Field Test

Weight Load Marching is simply marching while carrying a relatively heavy load. The Canadian Military performs weight load marching while wearing Full Fighting Order equipment. Full Fighting Order equipment consists of: rucksack, helmet, webbing, gas mask, and rifle (including basic ammunition load). The weight of Full Fighting Order equipment is 24.5 kg. Training with weight load marching has been a part of many militaries. The Israeli Army felt it was such a valuable training tool they abandoned traditional Western methods of fitness training, such as running and calisthenics, to utilize weight load marching as their primary method of conditioning (Ruc[illegible], 1987, Bar-Khama, 1980).

Regardless of the physical fitness benefits of weight load marching, there remains the need for the activity. In a wartime situation, the availability of mechanized transportation to the battle scene may not be possible due to environmental, strategic or safety reasons. The only method available may be to carry the necessary equipment in on the backs of the soldiers. Advances in technology have supplied the new soldier with additional equipment such as night vision goggles and protective equipment against radiological, chemical and biological weapons (Marston et al., 1981). For these reasons, the Weight Load March Field Test remains a key component of the military and was therefore included in the field tasks recommended by Singh et al. (1991) to the Canadian Military.

Analysis of Group Data

Utilizing the soldiers performance in the Weight Load March Field Test, an attempt was made to identify the laboratory measures that were associated with best performance. To accomplish this, the method utilized was similar to that for the Casualty Evacuation Field Test. However, with the Weight Load March Field Test there was a difficulty in interpreting the soldiers data which resulted in some alterations to the method utilized to identify the best and worst groups.

The difficulty was in differentiating soldiers who did not complete the full 16,000 m march. The soldiers who did not finish the full march did so for one of two reasons. The first reason was that they had dropped out of the march due to various difficulties such as blisters, injury, etc. The second reason was that they had marched the full time but were unable to maintain the standard military pace and therefore did not finish the full 16,000 m distance (Chahal, 1993).

For all soldiers who finished the 16,000 m in the standard time (2 hours, 26 minutes), a distance of 16,000 m was recorded. No time was recorded for the soldiers because they had all theoretically marched at a standard military pace (equivalent to 5.33 km/h) and should therefore have finished with the same time. The soldiers who marched for the full time but could not maintain the standardized pace were stopped from marching at the end of the standard allotted time. Instead of having 16,000 m recorded as their distance, they had the distance recorded they had covered, for example 14,500 m. Soldiers who dropped out during the march due to various difficulties (e.g. blisters, injury, etc.) had the distance recorded they had covered before dropping out, for example

10,000 m.

This situation presented a problem as there was no way to identify why a soldier had a recorded distance of less than 16,000 meters: did they drop out, or finish the march at a slower than standard pace? As a result it was impossible, in the standard method that had been utilized with the previous three field tests, to clearly identify the soldiers who would make up the worst group (bottom 27%). Therefore it was resolved to exclude all soldiers with a recorded distance of less than 16,000 m from the data to be analyzed. This resulted in a smaller number of soldiers being used in the statistical analysis. With the other three field tests data, Casualty Evacuation Field Test, Ammunition Box Field Test, and Maximum Dig Field Test, data was available for most of the 116 soldiers who participated in the study. With the Weight Load March Field Test, only 54 soldiers of the 116 who participated had usable data for the t-test statistical analysis.

In addition, no simple method was available to rank order the 54 soldiers and identify the best (top 27%) and worst (bottom 27%) groups. In the previous three field tests, time required to complete the field test had been utilized. However, as all 54 soldiers had the same recorded distance (16,000 m) in the same time (standard military pace) that method would not work.

Therefore, to devise a method to rank the 54 soldiers, the purpose of the Weight Load March Field Test was examined. The Weight Load March Field Test simulated the need of the soldier to carry a heavy load to the battle scene. However, the physiological requirements of the soldier would not end when they arrived at the battle. Indeed, it is then that the soldier must possess a useable reserve of fitness to allow them to meet whatever challenge is present: enemy attack, digging in a defensive position, setting up camp, etc. As a result of the need for a useable reserve of fitness, the following method was devised to rank order the 54 soldiers and identify the best and worst groups:

- Only soldiers (54) who finished the compete march (16,000 m) were utilized in the statistical analysis.
- For these soldiers, the following data was available: maximum heart rate (derived from a treadmill maximal aerobic power test) and heart rate at the finish of the march (Sport Tester heart rate monitors recorded heart rate measures every 500 m). These heart rates were used to rank order the 54 soldiers.
- Soldiers maximum heart rates were divided by their finishing heart rate. This produced a result which indicated at what percentage of their maximal heart rates the soldier finished the Weight Load March Field Test at. For example, if a soldier's maximal heart rate was 200 bpm and they finished the march with a heart rate of 180 bpm, the resulting percentage would be 90% (200/180 = 90%).
- The soldiers were then rank ordered inversely to this percentage. Therefore, the soldier who finished with the smallest percentage, and therefore theoretically the greatest reserve of fitness, was ranked number one and the soldier with the highest percentage was ranked number 54.

- From this rank order, the top 15 soldiers were identified as the best performing group and the bottom 15 soldiers were identified as the worst performing group.

From this point, the statistical process utilized was identical to that of the previous three field tests. However, there were problems with this method. Utilizing only 54 soldiers instead of the standard 116 not only reduced the number of soldiers in the best and worst groups, but also reduced the number of soldiers separating the best and worst groups. This situation may have contributed to the Weight Load March Field Test having had fewer laboratory measurements significant at .01 and .05 than any of the other three field tests.

In the performance of the Weight Load March Field Test the following protocol was utilized. The soldiers, wearing Full Fighting Order equipment (rucksack, helmet, webbing, gas mask, and rifle), were required to march 16 km (16,000 m) at a set speed of 88.9 m per min (equivalent to 5.33 km/h). An electronic timer pulsed every 34 seconds to assist the soldier at pace maintenance. Sport Tester heart rate monitors were utilized and a heart rate score was recorded every 500 m. The rucksacks were equipped with shoulder and waist straps. The soldiers carried the rifle in their hands. The rifle could be carried in either hand or with both hands (Lee 1992).

As with digging, marching has most often been examined in terms of aerobic power. However, little research has been conducted into marching with a ruck pack the size and weight of that used in Singh et al.'s (1991) study. As research generally considered marching to have been aerobic in nature, maximal aerobic capacity was believed to be the primary physiological factor (Chahal, 1993). However, the current consensus of army personnel appears to be that high levels of muscular strength and endurance are as important as high levels of oxygen consumption for weight load marching (Lee, 1992).

Theoretical Performance Analysis of Field Test

In an attempt to analyze the Weight Load March Field Test from a performance perspective the field test was broken down into the following components.

- the involvement of the lower body
- the involvement of the trunk region
- the involvement of the upper body/arm
- the energy system utilized

a. Involvement of Lower Body

The involvement of the lower body in the performance of the Weight Load March Field Test was similar to its involvement in the Casualty Evacuation Field Test. However, in the Weight Load March Field Test, although the weight carried was significantly less, the distance was significantly greater. Force, when walking, would have been generated by hip and knee extension and planter flexion (Tortora, 1989). The stress on these actions would have been increased due to the extra weight carried and the distance which the soldier traveled. Research on injuries sustained from marching with extra load supplied information on the areas the extra stress may affect. Jordaan and Schwellnus (1994) reported the majority of the injuries in marching studies involved the lower extremities and lower back. They reported, "...injuries to the knee, lower leg, and ankle accounted for more than 80% of all injuries". Strength training in these areas can reduce the risk of injury (Arnheim, 1985). Therefore, strength in the lower extremities and lower back may be required in marching. This is supported by Dziados et al. (1987), who reported hamstring strength to be the only predictor of marching time in a study with soldiers in full combat gear. The laboratory measurements that addressed these areas were: leg power, dynamic leg extension and knee extension.

b. Involvement of Trunk Region

In walking without load the trunk region of the body remains relatively erect. In the Weight Load March Field Test a significant weight was carried on the back. The addition of this weight would likely have resulted in a forward leaning compensation of the trunk by the soldier to bring the center of balance over the support of the legs. This forward lean, accompanied by the weight of the rucksack would have resulted in an increased requirement of trunk stabilization. Although the trunk region was not in as vulnerable a position as it was while lifting in field tests such as the Ammunition Box Field Test and Maximum Dig Field Test, the significant weight of the rucksack and the extended time frame of the march (2 h 26 min) would likely have put significant stress on the musculature of the trunk region. The laboratory measurements that would have addressed this involvement were: static and dynamic trunk flexion and extension.

c. Involvement of Upper Body / Arms

With the upper body/ arm region of the body, there were two likely areas of involvement. The first was the muscles of the shoulder region, specifically the trapezius muscle, in the support of the rucksack. Wells (1983), working with postal workers carrying lighter loads (11 to 16 kg.) than those utilized by Singh et al. (1991) found fatigue in the neck and shoulder regions to be a concern to the subjects involved. As some of the weight of the rucksack was supported by straps across the shoulder region of the body, the trapezius muscles would have been involved in supporting the weight. Dynamic trapezius lift and trapezius lift endurance laboratory measurements would have addressed this involvement. The second aspect that may have required the involvement of the upper body/ arm region of the body was the muscular strength and endurance of the arm/hand region of the body in carrying the rifle during the march. The weight of the rifle utilized in the Weight Load March Field Test was 4.5 kg (Colonel D. Tabbernor, personal communication, July 16, 1995). One requirement of the Weight Load March Field Test was that the soldier had to carry the rifle in their hand(s). The rifle could not be carried in the rucksack or over the shoulder (Chahal 1993). Therefore, the soldiers carried the rifle in their left hand, right hand or both hands. This would have resulted in the elbow joint being utilized. Laboratory measurements that would have addressed this involvement were arm power, static arm flexion (strength), and static arm flexion endurance. In addition, the muscles of the forearm would have been involved in maintaining the grip on the rifle for the duration of the march. Handgrip strength and endurance measurements would have addressed this involvement.

d. Energy Systems

The Weight Load March Field Test required the soldiers to march for two hours and 26 minutes (146 minutes) (Lee, 1992). Fox et al. (1988) stated that events lasting 135 minutes or greater utilize the aerobic system for close to 100% of their energy source.

Given these facts, it was not surprising that most research on marching has focused on aerobic factors (Lee, 1992). Laboratory measurements that addressed the aerobic contribution are: aerobic power absolute and relative, and anaerobic threshold absolute and relative.

Analysis of t-test Results

With this performance analysis in mind, a statistical analysis of the 116 soldiers Weight Load March Field Test results was undertaken. The statistical analysis procedure was identical to the method utilized for the Casualty Evacuation Field Test. The results of this analysis are shown in Table 12 which lists the laboratory measurements which significantly differentiated the performance of the best and worst groups for the Weight Load March Field Test to a significant value of .05 or less. The laboratory measurements are listed in order of significance. A complete list of all laboratory measurements, including the ones that were significant to greater than .05 is available in Appendix E1.

Table 12. Weight Load March Field Test T-Test Results for Laboratory Measurements with Significant Values of .05 or Less.

Laboratory measurements	Significant Value
leg mean power output	.000 **
leg relative power output mpo	.002 **
leg peak power output	.009 **
leg relative power output ppo	.011 *
static trunk extension mean	.014 *
static trunk extension maximal	.015 *
percent body fat	.028 *
lean weight	.028 *
body density	.029 *
right handgrip strength	.031 *
dynamic trunk flexion mean	.038 *
absolute aerobic power	.039 *

* $p \leq .05$ ** $p \leq .01$

Table 12 was analyzed in reference to the four performance components stated earlier: the involvement of the lower body; the trunk region; the upper body/arm region; and the energy system utilized. In addition. body composition factors were analyzed in an additional section.

a. Lower Body

The analysis identified absolute and relative mean and peak leg power measurements as having being significant to less than .05. The three leg power measurements significant at .01 or less were the only measurements significant in this range. No other lower body measurements, including all strength and endurance measures were significant at .05 or less.

These results were quite revealing. The Weight Load March Field Test lasted two hours and twenty-six minutes. However, the Lower Body Wingate Lower Body Test, utilized to measure leg power in this study, lasted a fraction of that time (30 s). One possible explanation for the significance of power may have been that due to the resistance being increased by 24.5 kg (Full Fighting Order), leg power, more than leg strength or endurance, was utilized in the push off by the foot. It may have been that a burst of power was utilized to push the body and the added resistance forward, followed by a period of recovery until the next push off.

b. Trunk Region

Three measurements related to the trunk region were significant to .05 or less: both mean and maximal measurements for trunk extension static, and the mean measurement for trunk extension dynamic. Table 13 lists the eight trunk region measurements and their significant values for this field test.

Table 13. Trunk Region Measurements and their Significant Values for Weight Load March Best and Worst Performers.

Laboratory measurements	**Significant Value**
static trunk extension mean	.014
static trunk extension maximal	.015
dynamic trunk flexion mean	.038
static trunk flexion maximal	.061
static trunk flexion mean	.063
dynamic trunk extension maximal	.082
dynamic trunk extension mean	.111
dynamic trunk flexion maximal	.279

Note. The shaded laboratory measurements and their significant values are the only measurements significant at .05 or less ($p \leq .05$).

The arrangement of the significant values for measurements related to the trunk region was revealing. The only factor with both aspects of the measurement significant to .05 or less was static trunk extension mean. Considering the soldier was trying to maintain his back in a slightly forward bent position, not bending too far forward so as to cause excessive stress to the back, yet not straightening up so as to keep the center of gravity over the support of the legs, the importance of the muscles utilized for static trunk extension seems reasonable. Strength in the this area may also have reduced the incidence of injury to the soldiers during the march. Jordaan and Schwellnus (1994) reported that many of the injuries in marching studies involve the lower back.

Maintaining the trunk in a slightly forward bent position would have likely utilized the abdominals muscles also. Of the four measurements addressing this area, only one, dynamic trunk flexion mean, was significant to .05 or less. Two other static trunk flexion measurements (maximal and mean) were significant to just greater than .05 (.061 and .063). These results may be interpreted in two ways. First, dynamic trunk flexion may be important to the performance of the field test. However, dynamic trunk flexion maximal, the other dynamic trunk flexion measurement, was the least significant trunk region measurement at .279. Second, the significant values of the static trunk flexion measurements, just slightly over .05, may indicate that, in combination with the significant values of static trunk extension measures (.014 and .0[illegible]5), static strength and endurance in the trunk region was more important than dynamic. This was supported by the results which showed only one of the four dynamic trunk region measurements significant to .05 or less (dynamic trunk flexion mean), and the least three significant trunk region measurements being dynamic ones.

c. Upper Body / Arms

There was only one upper body/ arm measurement significant at .05 or less: right handgrip strength (.031). Right handgrip endurance (.056) was significant to slightly greater than .05. However, left handgrip endurance (.115) and left handgrip strength (.205) were far less significant. These results may have been related to the dominant hand more so than right or left hand. Right or left side dominance was not recorded for the soldiers. However, the majority of people are right handed. The significance of right handgrip strength and endurance may have indicated the fatiguing effect of carrying a 4.5

kg rifle for approximately 2.5 hours and the relevance of dominant hand strength to the field test performance.

No other upper body / arm measurements were significant to .05 or less. In the theoretical analysis of the field test it was speculated that the trapezius muscle may have been important to the support of the back pack. However, all three laboratory measurements that addressed this area: trapezius lift endurance, and dynamic trapezius lift mean and maximal, had significant values far greater than .05.

d. Energy Systems

Absolute aerobic power was significant to .05 or less. However, relative aerobic power was not (.083). Considering all soldiers carried an additional standard weight of 24.5 kg, it seems reasonable that absolute aerobic power would have been more important than relative. Theoretically, a specific amount of work would have been required to transport the addition 24.5 kg's 16,000 m. If two muscle masses of equal size had equal relative aerobic power values and one muscle was doubled in size, the larger muscle mass would still have equal relative aerobic power but doubled absolute aerobic power and therefore should be able to produce the same amount of work at a decreased level of exertion. As the criteria for determining best and worst performance of the Weight Load March Field Test was maximum heart rate divided by heart rate at the finish of the march, the larger muscle mass would have functioned at a lower percentage of its maximum to perform the additional work of carrying the ruck pack. This lower percentage of maximum would have been reflected in a lower heart rate during the march and at the end of the march. The importance of absolute over relative was supported by the significance of lean weight (.028), which indicated the best group (mean lean weight = 66.4 kg) had a significantly larger (6.0 kg) lean muscle mass than the worst group (mean lean weight = 60.4).

The significance of absolute aerobic power was not unexpected. However, its significant value was quite revealing. Two reasons may apply as to why it was not more significant. First, the Treadmill VO_2max test utilized in the study was a measure of aerobic power. MacDougall et al. (1991) defined aerobic power as the rate at which energy is provided from aerobic metabolism. Although the rate at which energy was supplied was an important factor, a more important factor may have been the soldiers capacity to supply energy for the extended time frame (2 h 26 min) of the field test. Second, quite simply due to the physiological challenges of performing the Weight Load March Field Test, other physiological factors may have been a greater requirement for success.

e. Body Composition

Body Composition factors made up the remaining physiological factors significant to less than .05. Percent body fat (.028) was the most significant of these. The best group had a mean body fat percentage of 16.5%. The worst group had a mean body fat percentage of 22.3%. As performance time passes one hour, fats become more important as a source for ATP resynthesis, therefore a small percentage of body fat would have been required as essential body fat and fuel during the Weight Load March Field Test (Fox et al., 1988). Additional body fat would have served only as excess weight to be carried. The significant value of both percent body fat and lean weight indicated the importance of body composition to the best performance of the Weight Load March Field Test.

Analysis of Individual Data

Further analysis was conducted on the laboratory results of the best (top three finishers) and worst (bottom three finishers) performers in Maximum Dig Field Test. This examination was conducted to determine if the conclusions arrived at in the Analysis of Group Data section were supported by individual performances. The process followed was the same as that utilized in the analysis of the Casualty Evacuation Field Test.

Analysis of First and Last Place Finishers

Figure 26 displays the rank order finishings of the best and worst performers in the Weight Load March Field Test on laboratory measurements significant to .01 or less. Table 32 in Appendix E2 lists all laboratory measurement raw scores and resulting rankings for these soldiers. There was a clear differentiation in rankings of soldier #160 (first place finisher) and soldier #77 (last place finisher) in the laboratory measurements significant to .05 and less. Soldier #160 achieved 10 excellent rankings out of the 12 laboratory tests. Soldier #77 achieved 11 poor rankings out of the 12 laboratory tests.

Although soldier #160's first place finish in the Weight Load March Field Test was supported by his rankings in the measurements significant to .05 or less, the subject did rank highly in other measures which may have contributed to his success. One area of high performance for soldier #160 was in the laboratory measurements related to trunk extension and flexion. There were three trunk region measurements significant to .05 or less: static trunk extension mean (STE-E), static trunk extension maximal (STE-M), and dynamic trunk flexion mean (STF-E). On all these tests the subject achieved an excellent ranking. In addition, there were five static and dynamic trunk flexion or extension laboratory tests significant to greater than .05. Soldier #160 achieved a ranking of less than five on all of these tests. Soldier #160's excellent performance in all trunk flexion and extension measurements supported the importance of trunk strength to the performance of the Weight Load March Field Test.

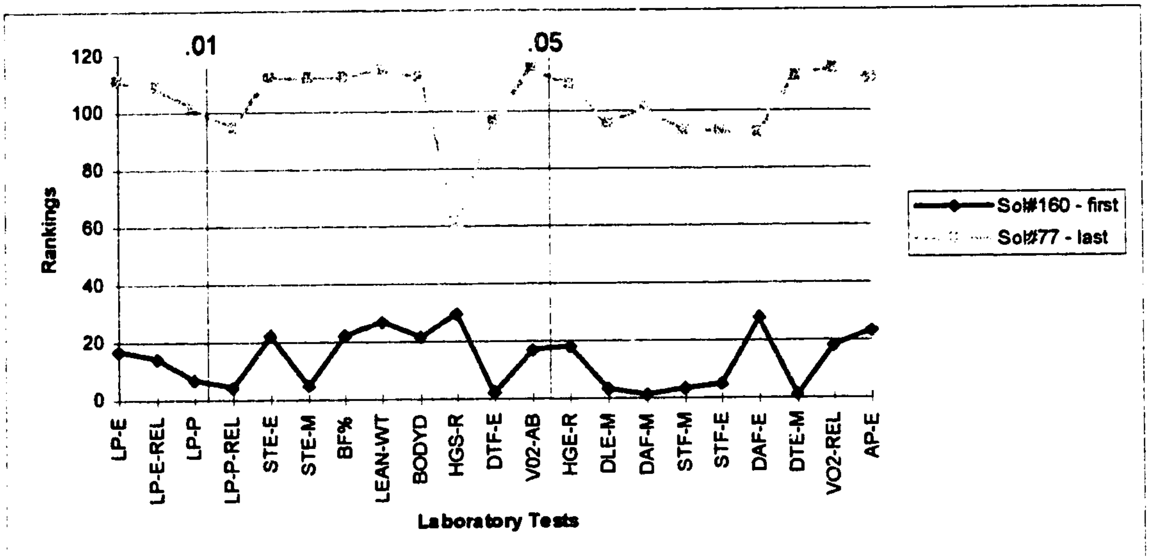

Figure 26. Rankings of First and Last Place Finishers in the Weight Load March Field Test for Laboratory Measurements with Significant Values of .10 or Less ($p \leq .10$).

Note. The abbreviations for the Figure are: LP-E, lean mean power output; LP-E-REL, leg relative power output mpo; LP-P, lean peak power output; LP-P-REL, leg relative power output ppo; STE-E, static trunk extension mean; STE-M, static trunk extension maximal; BF%, percent body fat; LEAN-WT, lean weight; BODYD, body density; HGS-R, right hand grip strength; DTF-E, dynamic trunk flexion mean; VO2-AB, absolute aerobic power; HGE-R, right hand grip endurance; DLE-M, dynamic leg extension maximal; DAF-M, dynamic arm flexion maximal; STF-M, static trunk flexion maximal; STF-E, static trunk flexion mean; DAF-E, dynamic arm flexion mean; DTE-M, dynamic trunk extension maximal; VO2-REL, relative aerobic power; AP-E, arm mean power output.

Other areas where soldier #160 achieved high rankings were: dynamic leg extension, dynamic trapezius lift, and static arm flexion. In all measurements related to these areas, soldier #160 achieved a ranking of five or less. Soldier #160's performance on measurements significant to .05 or less may have been the key to his success. However, the subjects performance in additional areas may have assisted in the first place finish. The leg strength he demonstrated in the dynamic leg extension tests may have assisted in supporting the ruck sack for the extended march. As the ruck sack was partially supported by shoulder straps, strength in the trapezius area would have assisted in this effort. Finally, strong static arm flexion would have been an asset in carrying the 4.5 kg rifle for the 2.6 hour time frame.

Soldier #77's (last place) rankings on measurements significant to .05 or less supported a poor performance in the field test. Of the 12 measurements significant to .05 or less, the only one the subject did not achieve a poor ranking on was right handgrip strength (HGS-R). Although soldier #77's rankings never dramatically improved on the measurements significant to greater than .05 (18 poor rankings out of 35 tests), the subjects performance did gradually improve as the measures become less significant. Table 14 displays soldier #77's rankings for the 12 most significant (significant to .05 or less) and 12 least significant measurements. Soldier #77's performance on the last 12 measurements were far superior to the performance on the first 12. These results supported the conclusion that soldier #77's last place finish was primarily a result of his performance on the factors related to measurements significant to .05 or less.

Table 14 Soldier #77's Rankings for the 12 Most Significant and 12 Least Significant Laboratory Measurements for the Weight Load March Field Test.

Laboratory Measurements	Breakdown of Rankings				
	excellent rankings	above average rankings	average rankings	below average rankings	poor rankings
First 12 Tests	0	0	1	0	11
Last 12 Tests	1	1	4	3	3

Analysis of Second and Second Place Finishers

Figure 27 displays the rank order finishings of the second place and second last place performers in the Weight Load March Field Test on laboratory measurements significant to .01 or less. Table 33 in Appendix E3 lists all laboratory measurement raw scores and resulting rankings for these soldiers. The analysis of the rankings of these two soldiers was qui: revealing. The one area on Figure 27 where soldier #108 (second place finisher) consist .tly outperformed soldier #19 (second last place finisher) was in the five most significant n .asurements. From that point on, the results of the two soldiers were quite similar.

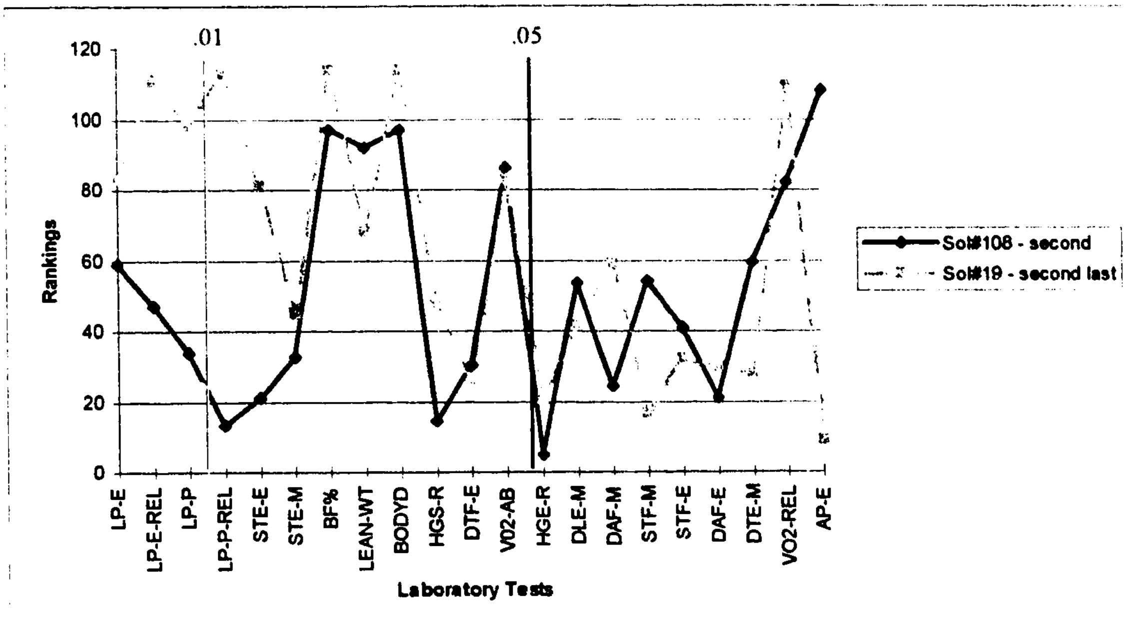

Figure 27. Rankings of Second and Second Last Place Finishers in the Weight Load March Field Test for Laboratory Measurements with Significant Values of .10 or Less ($p \leq .10$).

Note. The abbreviations for the Figure are: LP-E, lean mean power output; LP-E-REL, leg relative power output mpo; LP-P, lean peak power output; LP-P-REL, leg relative power output ppo; STE-E, static trunk extension mean; STE-M, static trunk extension maximal; BF%, percent body fat; LEAN-WT, lean weight; BODYD, body density; HGS-R, right hand grip strength; DTF-E, dynamic trunk flexion mean; VO2-AB, absolute aerobic power; HGE-R, right hand grip endurance; DLE-M, dynamic leg extension maximal; DAF-M, dynamic arm flexion maximal; STF-M, static trunk flexion maximal; STF-E, static trunk flexion mean; DAF-E, dynamic arm flexion mean; DTE-M, dynamic trunk extension maximal; VO2-REL, relative aerobic power; AP-E, arm mean power output.

In an effort to more clearly understand the physiological reasons for their finishes, each soldier's measurements were reviewed individually. To attempt to understand soldier #108's second place finish, all the measurements on which the subject achieved an excellent or above average ranking were examined. To understand soldier #19's second last place finish, all the subjects measurements with poor and below average rankings were examined.

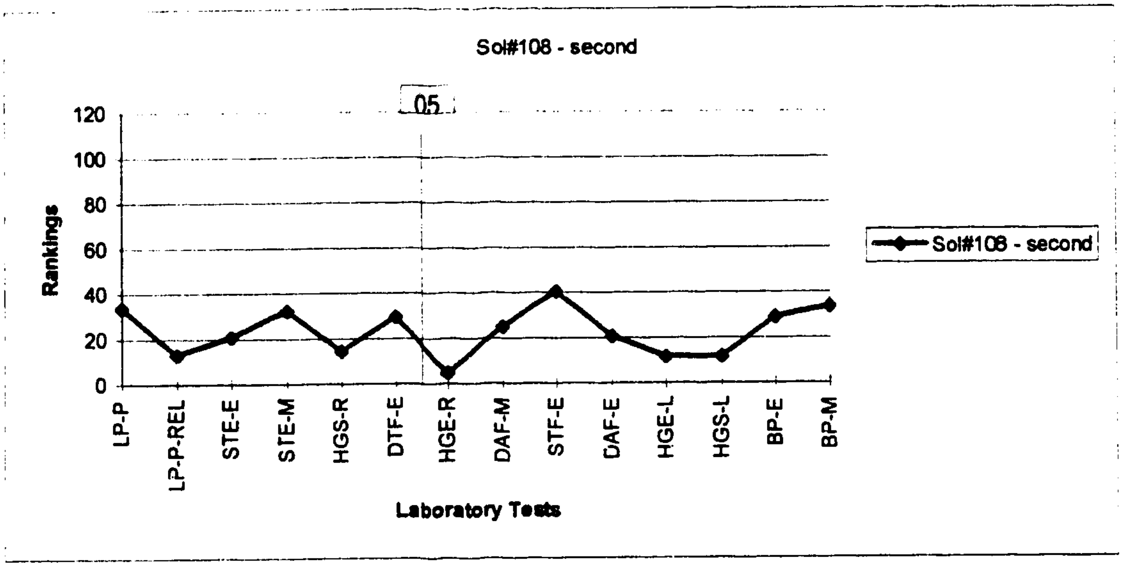

Figure 28. Excellent Laboratory Measurement Rankings for Second Place Finisher in the Weight Load March Field Test.

Note. The abbreviations for the Figure are; LP-P, lean peak power output; LP-P-REL, leg relative power output ppo; STE-E, static trunk extension mean; STE-M, static trunk extension maximal; HGS-R, right hand grip strength; DTF-E, dynamic trunk flexion mean; HGE-R, right hand grip endurance; DAF-M, dynamic arm flexion maximal; STF-E, static trunk flexion mean; DAF-E, dynamic arm flexion mean; HGE-L, left hand grip endurance; HGS-L, left hand grip strength; BP-E, bench press mean; BP-M, bench press maximal.

Figure 28 is a graphic display of the measurements soldier #108 (second place) achieved a excellent or above average ranking on measurements significant to .05 or less, soldier #108 has representation from many of the factors the group analysis identified as important to top performance. Included were: leg power (LP-P, LP-P-REL), static trunk extension (STE-E, STE-M), handgrip strength (HGS-R), and dynamic trunk flexion

(DTF-E). Indeed, soldier #108 achieved an excellent or above average ranking on six of the twelve measurements significant to .05 or less.

On the measurements soldier #108 achieved an excellent or above average ranking on that were significant to greater than .05, only four were not related to a previously discussed factors. These were two measures for arm flexion dynamic (DAF-M, DAF-E), and two for bench press (BP-E, BP-M). In the theoretical analysis of the Weight Load March Field Test it was speculated that arm flexion would have been important to performance. This was not supported by the t-test group analysis. However, it may have played a role in soldier #108's second place finish. Contrarily, soldier #108's above average rankings in the bench press measurements did not likely assist in his performance, as the motions utilized in the bench press (shoulder adduction and elbow extension) did not play a prominent role in the Weight Load March Field Test performance.

Figure 29 displays poor and below average rankings for soldier #19 (second last place). Soldier #19 achieved a poor or below average ranking on seven of the twelve measurements significant to .05 or less. However, soldier #19 achieved only two poor or below average rankings on the 35 measurements significant to greater than .05. Therefore, it was likely that soldier #19's performance in the field test was contributable to the measurements significant to .05 or less.

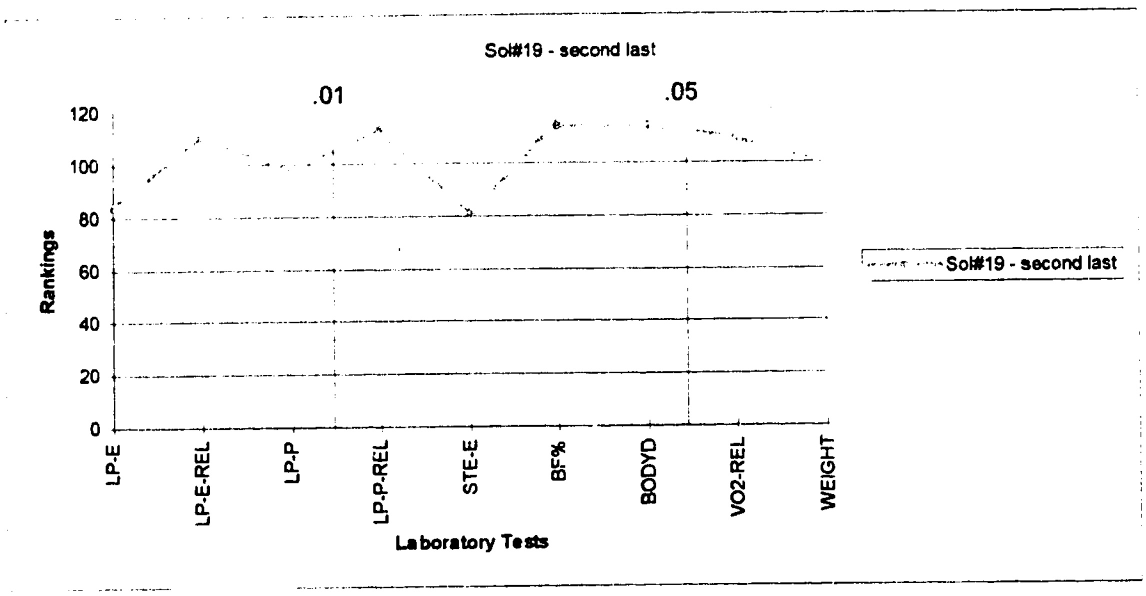

Figure 29. Po r and Below Average Laboratory Measurement Rankings of Second Last Place Finisher in the Weight Load March Field Test.

Note. The abbreviations for the Figure are: LP-E, lean mean power output; LP-E-REL, leg relative power output mpo; LP-P, lean peak power output; LP-P-REL, leg relative power output ppo; STE-E, static trunk extension mean; BF%, percent body fat; BODYD, body density; VO2-REL, relative aerobic power; WEIGHT, weight.

Analysis of Third and Third Place Finishers

Figure 30 displays the rank order finishings of the third place and third last place performers in the Weight Load March Field Test on laboratory measurements significant to .01 or less. Table 34 in Appendix E4 lists all laboratory measurement raw scores and resulting rankings for these soldiers.

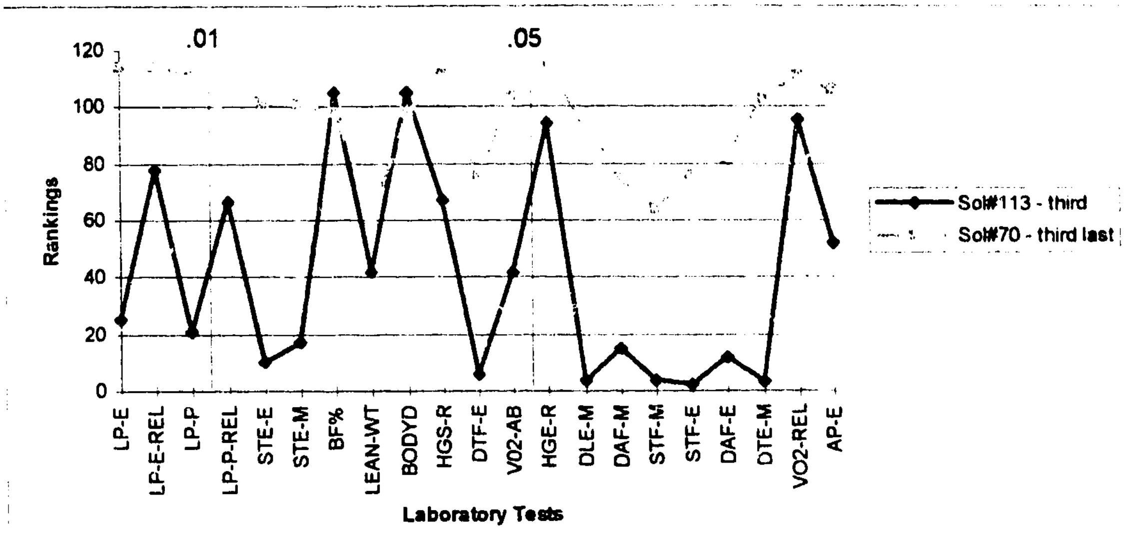

Figure 30. Rankings of Third and Third Last Place Finishers in the Weight Load March Field Test for Laboratory Measurements with Significant Values of .10 or Less ($p \leq .10$).

Note. The abbreviations for the Figure are: LP-E, lean mean power output; LP-E-REL, leg relative power output mpo; LP-P, lean peak power output; LP-P-REL, leg relative power output ppo; STE-E, static trunk extension mean; STE-M, static trunk extension maximal; BF%, percent body fat; LEAN-WT, lean weight; BODYD, body density; HGS-R, right hand grip strength; DTF-E, dynamic trunk flexion mean; VO2-AB, absolute aerobic power; HGE-R, right hand grip endurance; DLE-M, dynamic leg extension maximal; DAF-M, dynamic arm flexion maximal; STF-M, static trunk flexion maximal; STF-E, static trunk flexion mean; DAF-E, dynamic arm flexion mean; DTE-M, dynamic trunk extension maximal; VO2-REL, relative aerobic power; AP-E, arm mean power output.

A key to interpreting soldier #113's (third place finisher) rankings was his body composition measurements, most notably body fat percentage. Soldier #113's 25.8% body fat percentage resulted in a ranking of 105. The subjects excessive body fat (when compared to the other soldiers) resulted in his relative rankings being considerable worse than his absolute. He achieved excellent rankings on both absolute leg power measurements (LP-E, LP-M), both static trunk flexion tests (STE-E, STE-M), and the one dynamic trunk flexion test (DTF-M) that were significant to .05 or less. Soldier #113's excellent rankings in trunk region measurements continued on measurements significant to between .05 and .10.

In this range were three more trunk region measurements: static trunk flexion maximal (STF-M), static trunk flexion mean (STF-E), and dynamic trunk flexion maximal (DTE-M). On all of these, soldier #113 achieved an excellent ranking. Therefore, although soldier #113's body fat percentage affected his rankings on relative measures significant to .05 or less, it did not affect his Weight Load March Field Test performance. In addition, soldier #113's excellent rankings on all measurements of the trunk region may have been a key factor in his top ranking performance. Soldier #113's results partially supported the group data conclusions. On the absolute measurements significant to .05 or less his data supported the conclusions. However, his relative leg power, and body fat percentage/body density measurements were not in the range that would have been expected from a third place field test performance.

Soldier #70's (third last place finisher) performance (ten poor rankings out of 12 measures) on measurements significant to .05 or less were indicative of a poor performance. On the three leg power tests significant to less than .01, soldier #70 achieved two rankings of 114 (leg mean power output - LP-E, leg relative power output - mean power output - LP-E-REL) and one ranking of 113 (leg peak power output - LP-P). On the other leg power measurement, leg relative power output - peak power output (LP-

P-REL), soldier #70 achieved a ranking of 114. These extremely poor rankings on the four most significant measurements and the subjects poor field test performance strongly supported the group data analysis. On the other measurements significant to between .01 and .05, soldier #70's rankings improved only slightly. The subject achieved six poor, one average and one below average ranking on the remaining eight measurements significant to between .01 and .05. In summary, soldier #70's rankings strongly supported the group data analysis.

Summary of Individual Analysis

Figure 31 displays the averaged rankings for the three top and bottom performers in the Weight Load March Field Test on laboratory measurements significant at .05 or less. Although there was clear separation of the rankings, which supported the group data analysis, the graph displayed some interesting results. First, the strongest support for the group data conclusions occurred on the most significant measurements. Second, for body composition measurements there was strong support from the bottom three soldiers data, yet poor support from the best three soldiers data, although the best soldiers clearly out performed the worst soldiers on these measurements. These results made it difficult to clearly determine the importance of body composition to performance of the field test.

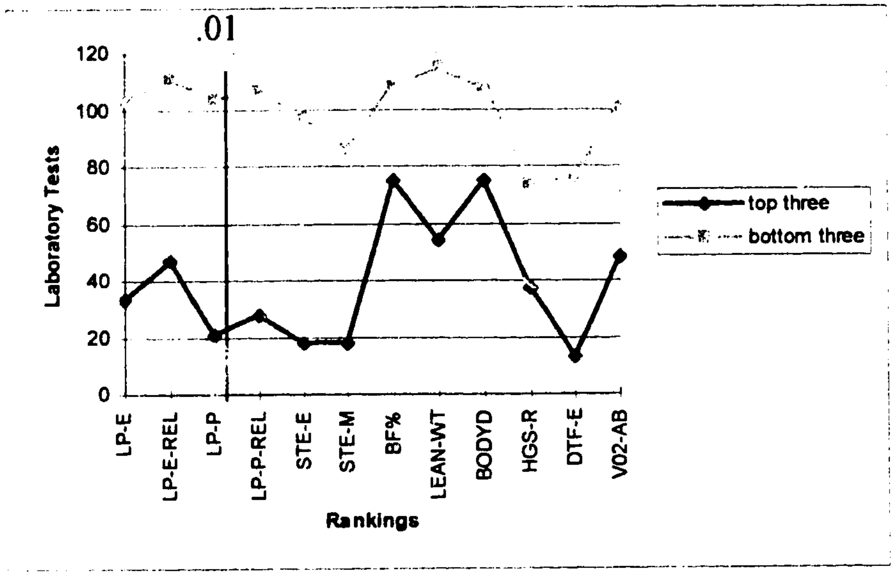

Figure 31. Average Rankings for the Top Three and Bottom Three Performers in the March Field Test for Laboratory Measurements with Significant Values of .05 or Less ($p \leq .05$).

Note. The abbreviations for the Figure are: LP-E, lean mean power output; LP-E-REL, leg relative power output mpo; LP-P, lean peak power output; LP-P-REL, leg relative power output ppo; STE-E, static trunk extension mean; STE-M, static trunk extension maximal; BF%, percent body fat; LEAN-WT, lean weight; BODYD, body density; HGS-R, right hand grip strength; DTF-E, dynamic trunk flexion mean; VO2-AB, absolute aerobic power.

The final interesting result was the overall rankings of the bottom finishers. Their rankings, most predominantly poor and below average, would have been the rankings expected in the usual 116 soldier field. However in the analysis of the Weight Load March Field Test only data from 54 soldiers was used in the analysis, with the remaining 62 soldiers' data having been eliminated. The 62 soldiers data was eliminated because they did not finish the complete 16,000 m march. Soldiers did not complete the march for one of two reasons: injury or inability to maintain the standard military marching pace.

Although no data was kept to determine the physical condition of the 62 soldiers who failed to finish the 16,000 m, it would have been reasonable to assume that a number of them failed due to the physiological requirements of the march. The physiological requirements of the march could have adversely affected either of the two sub-16,000 m groups: injury or reduced pace. That is, the physical requirements of the march may have resulted in injury to some soldiers, or a reduced pace in others.

It seems likely, if the group data analysis was accurate, that those soldiers who were affected by the physiological requirements of the march, and therefore recorded a distance of less than 16,000 m, would have achieved poor or below average rankings on measurements significant to .05 or less. This theory was impossible to test, as it could not be determined which of the sub-16,000 m performances was due to the physiological requirements of the march and which were not. However, if it was assumed that a number of the sub-16,000 m soldiers would have achieved poor and below average rankings in the measurements significant to .05 or less, than it would be reasonable to expect the soldiers who did finish the complete 16,000 m march to have achieved higher rankings on those measurements.

However, as is clearly demonstrated in Figure 31, this was not the case with the worst three performers. The worst three performers achieved rankings on measurements significant to .05 or less that were typical of the worst three in the other three field tests: tests that used data from all 116 soldiers. Further analysis of other poor Weight Load March Field Test performers (fourth last place, fifth last place, etc.) may have helped clarify the situation. However, the inability to clearly identify the reason for sub-16,000 m performances would have clouded the issue regardless of the findings.

The rankings of the best and worst Weight Load March Field Test performers supported the group data analysis, perhaps stronger than what was expected. However, the protocol of the field test made it difficult to identify best and worst performers and difficult to clearly analyze the results. Alterations to the protocol of the field test may help to eliminate some of these difficulties. One alteration that may prove beneficial would be to allow soldiers to march at the fastest pace they could maintain (and therefore complete the required distance as quickly as possible) rather than marching at a standard military pace. This procedure would allow performance time to be the only criteria necessary for ranking performances as it was for the Casualty Evacuation and Maximal Dig Field Tests. In addition, this method would provide participating soldiers with an easy method of determining improvement.

There are difficulties with this alteration. The Weight Load March was conducted indoors to control environmental factors as much as possible. Utilizing a standard pace allowed testers to monitor numerous soldiers at one time and easily identify which soldier was finishing the 16,000 m march. Allowing numerous soldiers to march at their own pace in an indoor facility would have greatly reduced the certainty of identifying when soldiers were finishing the march. Conducting the march outdoors on a continuous 16 km route would eliminate this problem, but would introduce environmental factors that may vary from day to day and from location to location. Further study is required in this area.

Summary of the Weight Load March Field Test

In the analysis of the laboratory measurements of Group A and B for the Weight Load March Field Test, the following differences between the groups were indicated. Group A was slightly different from Group B in the lower body and trunk regions. In the trunk region the greatest difference between the two groups was in trunk extension measurements. Group A was statistically similar to Group B in the upper Body/Arm region measurements. Group A was significantly different from Group B in body composition: Group A had a larger lean mass and a lower body fat percentage than Group B. Group A was significantly superior to Group B in leg power measurements, both absolute and relative, and absolute aerobic power.

E. Identification of Laboratory Measurements Key to Field Test Performance

The t-test analysis conducted in sections A to D in this Chapter identified certain measurements that differentiated the best and worst performers to a significant value of .05 or less in the four field tests. These field tests were developed to represent the various job-related physical tasks soldiers were required to perform (Chahal, 1993). Therefore, the collation of these measurements from the four field tests should provide an overview of the key physiological requirements necessary for success as a soldier.

The analysis conducted on the four field test was intended to explore the field and laboratory test date collected by Singh et al. (1991) as thoroughly as possible. The purpose was to analyze all measurements to best understand the importance of different physiological factors on the performance of each field test. The analysis touched on laboratory measurements of <u>any</u> significant value to explore the arrangement and relationship between them. As a result of this approach, there was a greater concern of Type II error then Type I error: a greater concern of excluding a measurement that was important to field test performance, than including one that was not. Therefore, alpha was set at 0.05.

This section on the identification of key measurements, however, focused only on laboratory measurements that had significant values of .01 or less. The theoretical analysis of each field test considered that most muscle groups of the body would be utilized in the performance of each and every field test. This study does not dispute that point.

However, the purpose of this section was to correctly identifying only the key measurements that differentiated best and worst performance of the field tests.

Utilizing numerous t-tests, as there were in this study, increases the probability of Type I error (Stevens et al., 1992). This section was concerned with identifying key measurements as correctly as possible. Therefore there was a greater concern for Type I error than Type II: greater concern about including a measurement that was not key to field test performance, than excluding one that was. Supporting this was the analysis results of the best and worst three individual performances of the four field tests. Often, in the analysis, there was a much clearer differentiation of the best and worst performers for measurements significant to .01 or less than there was for those significant from .01 to .05.

For these reasons, only laboratory measurements significant to .01 or less were included in the section. The one exception was the results of the Weight Load March Field Test. Due to the inability to utilize the results from all 116 soldiers, only the data from 54 soldiers were used in the Weight Load March Field Test calculations. In the analysis to determine laboratory measurements significant at differentiating best and worst performance in the Weight Load March Field Test, only three measurements were significant to .01 or less, and only 13 significant to .05 or less. With the other three field tests (Casualty Evacuation Field Test, Ammunition Box Field Test, and Maximum Dig Field Test), there were on average, 10.2 laboratory measurements significant to .01 or less, and 22.0 significant to .05 and less.

The reduction in the number of subjects utilized in the Weight Load March Field Test would have affected the obtained significant values in a number of ways. First, reducing the subjects from 116 to 54 would have reduced statistical power and increased beta. Increased beta would have increased the probability of Type II error, or accepting the null hypothesis when it was false. Second, not only was there a reduction in subject number, but the subjects eliminated were most likely the weaker performers of the field test. Therefore, there was an increase in the homogeneity of the remaining 54 subjects, again affecting the obtained significant values.

The exact effect of these two factors can not be measured. However, it is clear that the significant values generated from Weight Load March Field Test data were subjected to more severe factors than the other three field tests. Therefore, it was decided to include Weight Load March Field Test laboratory measurements that were significant to .05 or less in the following section.

Table 15. Laboratory Measurements Significant to .01 or less for All Field Tests Arranged in Alphabetical Order.

Laboratory Measurements	Cas-Evac	Amm-Box	Max-Dig	March
absolute aerobic power		*	*	*
absolute anaerobic threshold		*	*	
arm mean power output		*	*	
dynamic arm flexion maximal			*	
dynamic arm flexion mean			*	
dynamic leg extension maximal			*	
dynamic leg extension mean			*	
dynamic trunk extension maximal			*	
dynamic trunk extension mean			*	
dynamic trunk flexion maximal	*	*		
dynamic trunk flexion mean	*			*
lean weight		*	*	*
left knee extension			*	
left knee flexion			*	
leg mean power output	*	*	*	*
leg peak power output	*		*	*
leg relative power output mpo	*		*	*
leg relative power output ppo			*	*
percent body fat				*
right handgrip strength				*
right knee extension	*			
static trunk extension maximal			*	*
static trunk extension mean			*	*
static trunk flexion maximal	*			
static trunk flexion mean	*			

Note. Abbreviations for field tests were as follows: Casualty Evacuation (Cas-Evac), Ammunition Box (Amm-Box), Maximal Dig (Max-Dig), and Weight Load March (Weight).
Note. The * symbol in the table identified that the laboratory measurement to the left of the symbol was significant to less than .01 in that columns field test.

Table 15 displays all laboratory measurements significant to .01 or less for any of the four field tests. A total of 25 out of a possible 43 laboratory measurements were included in at least one field test. In an attempt to better understand the importance of each laboratory measurement, the information was arranged according to the number of field tests the measurements were included in (Table 16).

Table 16. Laboratory Measurements Significant to .01 or less for All Field Tests Arranged According to Number of Field Tests Significant In.

Laboratory Measurements	Cas-Evac	Amm-Box	Max-Dig	March
leg mean power output	*	*	*	*
absolute aerobic power		*	*	*
lean weight		*	*	*
leg peak power output	*		*	*
leg relative power output mpo	*		*	*
absolute anaerobic threshold		*	*	
arm mean power output		*	*	
dynamic trunk flexion maximal	*	*		
dynamic trunk flexion mean	*			*
leg relative power output ppo			*	*
static trunk extension maximal			*	*
static trunk extension mean			*	*
dynamic arm flexion maximal			*	
dynamic arm flexion mean			*	
dynamic leg extension maximal			*	
dynamic leg extension mean			*	
dynamic trunk extension maximal			*	
dynamic trunk extension mean			*	
left knee extension			*	
left knee flexion			*	
percent body fat				*
right handgrip strength				*
right knee extension	*			
static trunk flexion maximal	*			
static trunk flexion mean	*			

Note. The shaded rows separate laboratory measurements that were significant in different numbers of field tests.

Considering the results displayed in Table 16, the laboratory measurements were analyzed according to the number of field tests they were included in: four, three, two or one.

Included in Four Field Tests

Leg Mean Power Output

This was the only measurement included in all four field tests. This supported the importance of leg power to field test performance.

Included in Three Field Tests

Absolute Aerobic Power

Absolute aerobic power was included in all field tests except the Casualty Evacuation Field Test. Fox et al. (1988) stated that approximately two minutes are required for the aerobic system to be a major energy supplier. As the mean performance time for the Casualty Evacuation Field Test was 46.9 seconds and the mean time for all other [illegible] reater than three minutes, this result seemed reasonable.

[illegible] ic power was included in three field tests. Relative aerobic power [illegible] field test. These results supported the importance of absolute [illegible] n field test performance.

[illegible] Power

With the inclusion of leg peak power in three field tests, both absolute measures of leg power were strongly supported as being important to performance in the field tests. Leg mean power was included in four field tests and leg peak power was included in only three. These results supported the importance of mean over peak values.

Lean Weight

The inclusion of lean weight in three field tests supported the importance of increased muscle mass to field test performance. These results also supported the importance of absolute values over relative values in field test performance.

Relative Mean Leg Power

The inclusion of relative mean leg power further supported the importance of leg power for field test performance. Relative mean leg power was included in more field tests than relative peak leg power. The same relationship existed with absolute mean and peak measurements. These results further supported the importance of mean values over peak values for field test performance. In the Wingate lower body power test, peak power was a measure of the greatest amount of power generated in any five second period. Mean power was the measure of the average sustained power for the testing time (30 s)(MacDougall et al., 1991). All field test mean performance times were at least 46.9 s in length. The person who could maintain their power output for an extended period of time would have had an advantage over someone who, although they may reach a higher level of power for a short period, could not. Therefore, the importance of mean over peak power seems reasonable.

Inclusion in Two Field Tests

Absolute Anaerobic Threshold

The inclusion of absolute anaerobic threshold in two field tests again supported the importance of aerobic abilities to field test performance. In addition, as relative anaerobic threshold was not included in any field test, the results supported absolute values over relative ones.

Arm Mean Power Output

This was the first appearance of any arm power measurement. Arm mean power output was the only one, of a possible four arm power measurements, included in any field test. As no relative arm power measurements were included in any field test, this supported the importance of absolute over relative values for field test performance. In addition, as arm peak power output was not included in any field test, this further supported the importance of mean over peak values.

Dynamic Trunk Flexion Mean and Maximal, and Static Trunk Extension Mean and Maximal

This was the first appearance of any measurement of the trunk region. The inclusion of both mean and maximal measures for both tests suggested the equal importance of mean and maximal values.

Leg Relative Power Output - Peak Power Output

With the inclusion of leg relative power output - peak power output in two field tests, all four leg power measurements were significant to .01 or less in at least two field tests. This result supported: the importance of leg power to field test performance; the importance of absolute over relative values, and mean over peak power.

Inclusion in One Field Test

Dynamic Arm Flexion Maximal and Mean

This was the first inclusion of any upper body/arm strength or endurance measurement. The inclusion of mean and maximal measures for both tests suggested the equal importance of these values. The only other upper body/arm strength or endurance measurement included was right handgrip strength. Many upper body/arm measurements were not included in any field test. Only two of a possible 14 upper body/arm strength and endurance measurements were significant to .01 or less in any field test. If arm power measurements were included, only four upper body/arm strength, endurance or power measurements, out of a possible 18, were significant to .01 or less in any field test.

Dynamic Leg Extension Maximal and Mean

This was the first inclusion of any leg strength measurements. Again mean and maximal was not an issue. In addition, as let power measurements were included in a far greater number of field tests than leg strength measures, the importance of leg power over strength for field test performance was supported.

Dynamic Trunk Extension Mean and Maximal, and Static Trunk Flexion Mean and Maximal

With the inclusion of these measurements, all eight trunk region measurements were included in at least one field test. This supported the importance of the muscles of the trunk region to field test performance. In addition, again mean and maximal was not an issue.

Left Knee Flexion and Extension, and Right Knee Extension

Knee extension measurements were included in two field tests and flexion in only one. Soldiers would have primarily used knee extension rather than knee flexion to generate force in the performance of the field tests. Therefore, the inclusion of extension measures in a greater number of field tests seems reasonable. In total five of six possible lower body strength measurements were included in at least one field test. The only lower body measurement not included was right knee flexion. This supported the importance of lower body strength to field test performance

Percent Body Fat

Lean weight was included in three field test and percent body fat was only included in one. The only field test a body composition measurement was not significant in was the Casualty Evacuation Field Test. This test was of the shortest duration of all field tests, and did not require any bending or lifting in the performance aspect. Therefore body composition was supported as having been important to field test performance, with lean weight having been more important than percent body fat.

Right Handgrip Strength

This measurement was included in only the Weight Load March Field Test. Only one out of a possible four handgrip strength or endurance measurements were included in any field test.

Summary

In summary, the field tests required a soldier to perform a standard and substantial amount of work in the shortest time possible. No field test was under 5 s in duration. All

Summary

In summary, the field tests required a soldier to perform a standard and substantial amount of work in the shortest time possible. No field test was under 5 s in duration. All field tests required the lifting of objects from ground level, or the supporting of heavy objects on the shoulder area. These aspects would theoretically require the same factors this study identified as important to field test performance: power over strength; absolute values over relative values; mean power over peak power; aerobic power; the musculature of the trunk region; and the importance of the lower body being greater than the upper body.

Based on these results, the following training proposals are recommended. These recommendations should improve a soldiers ability to achieve the required standards of the field tests, or if already successful, to improve their performance.

- training should occur to increase the lean body mass of the body
- the focus of the training should be in the following order
    1. lower body training
    2. aerobic power training with a secondary focus on anaerobic threshold training
    3. trunk flexion and extension training
    4. upper body / arms training

after the development of increased lean body mass there should be a conversion of the increased strength into power in all regions of the body

F. Alterations to Field Test Battery

Considering the results displayed in Table 17 the Ammunition Box Field Test could be removed from the field test battery. Table 17 displays the six laboratory measurements that were significant to .01 or less for the Ammunition Box Field Test. In addition, Table 17 displays the other field tests that these six measurements were significant to .01 or less in. For example, the measurement absolute aerobic power was not only significant to .01 or less in the Ammunition Box Field Test, but also the Maximal Dig and Weight Load March Field Tests. Every measurement that was significant to .01 or less in the Ammunition Box Field Test was significant to the same level in at least one other field test. This situation occurred only for the Ammunition Box Field Test. All other field tests included measurements that were significant to .01 or less that were not included in any other field test.

Table 17. Laboratory Measurements Significant to .01 or Less in the Ammunition Box Field Test

Laboratory Measurements	Cas-Evac	Amm-Box	Max-Dig	March
absolute aerobic power		*	*	*
absolute anaerobic threshold		*	*	
arm mean power output		*	*	
dynamic trunk flexion maximal	*	*		
lean weight		*	*	*
leg mean power output	*	*	*	*

Note. Abbreviations for field tests were as follows: Casualty Evacuation (Cas-Evac), Ammunition Box (Amm-Box), Maximal Dig (Max-Dig), and Weight Load March (Weight).

Note. The * symbol in the table identified that the laboratory measurement to the left of the symbol was significant to less than .01 in that column's field test.

A result of this arrangement may be that the Ammunition Box Field Test could be removed from the field test battery. Due to the speculated risk of injury, the protocol for the Ammunition Box Field Test was structured so that participants were temporarily stopped from lifting when their heart rate exceeded 70% of maximal. The individual analysis for the best and worst Ammunition Box Field Test performers indicated that this protocol proved excessively favorable to soldiers with high levels of relative and absolute aerobic power. Alterations to the protocol, such as basing stoppages on lifting technique rather than heart rate, may address the imbalance. However the situation may be best resolved by eliminating the field test entirely.

No field test can stress the exact physiological factors as another. However, the results in Table 17 indicated that it may be possible to remove the Ammunition Box Field Test from the field test battery and still stress the soldiers in the same physiological factors. The removal of the Ammunition Box Field Test from the group of field tests would reduce the time and equipment required for testing and eliminate the associated risk of injury.

CHAPTER V. SUMMARY AND RECOMMENDATIONS

A. Summary

The Canadian Military is perceived by many as a physical occupation. Throughout the history of this organization, many methods have been utilized to try to measure the physical fitness of the soldiers. Most methods were either too general in scope, or measured physiological factors that many felt did not accurately reflect the physical requirements of being a soldier. In 1978, The Canadian Federal Government passed the Human Rights Act. Included in the Act were the Canadian Human Rights Commission Bona Fide Occupational Guidelines. These guidelines required the demonstration of a relationship between occupational needs and physical fitness.

As a result of this Act, the Department of National Defense contracted the University of Alberta. The University research team was to assist them in improving and standardizing the Canadian Military's physical fitness program to meet the guidelines of the Canadian Human Rights Act. The primary purpose of the University of Alberta's investigation was to develop task-related minimum physical fitness performance standards for the Canadian Army. Four recommend field tasks and standards were developed by Singh et al. and approved by the Canadian Military. These field tests were: a simulated casualty evacuation; digging of a simulated slit trench; loading of a set number of ammunition boxes from a simulated truck bed; and a 16 km weight load march. In the development of these field tasks, the University of Alberta research team utilized laboratory tests to assess and quantify the physical fitness of 116 male soldiers.

Laboratory tests were used to measure the following fitness components: aerobic power, anaerobic power, muscular strength, muscular endurance and body composition.

While these field tests and standards allowed the military to determine the physical readiness of their soldiers, the question still remained of what to do with soldiers who failed to meet the standards. The next logical step would be the development of training programs to effectively assist soldiers in the achievement of the required standards. However, what was first required was an understanding of the specific physiological factors required for success in each of the four field tests.

The purpose of this study was to attempt to provide that understanding. This study statistically analyzed the physiological data base Singh et al. developed on the 116 male soldiers in an attempt to determine the relationship between performance in the field tasks and measured physiological components. The analysis procedure identified the top field test performers (top 27% of field task performances) and bottom performers (bottom 27% of field task performances), and statistically analyzed (t-test method) these two groups performance's in all laboratory measurements. This analysis identified the laboratory measurements that differentiated the performance of the top and bottom performers in each field task to a significant value of .05 or less.

In addition, analysis was conducted on the best three (first, second and third place finishers) and worst three (last place, second last place and third last place) performers in each of the four field tests. All laboratory performances of these individuals were analyzed to determine if their performances supported or contradicted the assumptions generated in the group analysis.

In summary, the analysis demonstrated that successful field test performance was related to the following key factors (in order of importance): leg power, aerobic power, increased lean weight, muscular strength of the trunk region, and arm power. The following trends were also identified: power was more prominent than strength; absolute values more prominent than relative values; mean power more prominent than peak power. In general, the field tests required a soldier to perform a standard and substantial amount of work in the shortest time possible. No field test was under 5 s in duration. All field tests required the lifting of objects from ground level, or the supporting of heavy objects on the [illegible]lder area. These aspects would theoretically require the same factors this study [illegible] as important to field test performance.

B. Recommendations

1. This study identified the physiological components that were most significantly related to successful performance of the field tests. Training programs for the soldiers of the Canadian Forces should be developed based upon these physiological components.
2. A training study should be developed that will measure the effectiveness of different methods of training at improving the identified physiological components and the soldiers field test performance. Three different training methods could be used: one utilizing classical methods as the basis of training (weight lifting; running; etc.); one utilizing field test activities as the basis of training (casualty evacuation; maximal dig; etc.); one using a combination of these.

3. In order to develop task related performance standards for women, and physical fitness training programs designed specifically for their physiological requirements, a similar study should be conducted on a comparable or larger sample size of women.

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APPENDIX A. LABORATORY MEASUREMENTS

1. Laboratory Measurements and Related Abbreviations Utilized in Study

APPENDIX A1. LABORATORY MEASUREMENTS AND RELATED ABBREVIATIONS UTILIZED IN STUDY

Table 18. Laboratory Measurements and Related Abbreviations Utilized in Study.

Laboratory Measurements	Abbreviation
absolute anaerobic threshold	AT-AB
relative anaerobic threshold	AT-REL
absolute aerobic power	VO2-AB
relative aerobic power	VO2-REL
arm peak power output	AP-P
arm mean power output	AP-E
arm relative power output mpo	AP-E-REL
arm relative power output ppo	AP-P-REL
bench press mean	BP-E
bench press maximal	BP-M
dynamic arm flexion mean	DAF-E
dynamic arm flexion maximal	DAF-M
weight	WEIGHT
dynamic leg extension mean	DLE-E
dynamic leg extension maximal	DLE-M
dynamic trunk extension mean	DTE-E
dynamic trunk extension maximal	DTE-M
dynamic trunk flexion mean	DTF-E
dynamic trunk flexion maximal	DTF-M
dynamic trapezius lift mean	DTL-E
dynamic trapezius lift maximal	DTL-M
percent body fat	BF%
lean weight	LEAN-WT
leg peak power output	LP-P
leg mean power output	LP-E
leg relative power output mpo	LP-E-REL
leg relative power output ppo	LP-P-REL
static arm flexion mean	SAF-E
static arm flexion maximal	SAF-M
static trunk extension mean	STE-E
static trunk extension maximal	STE-M
static trunk flexion mean	STF-E
static trunk flexion maximal	STF-M
right knee flexion	KF-R
right handgrip endurance	HGE-R

left handgrip endurance	HGE-L
trapezius lift endurance	TRAP-END
static arm flexion endurance	SAF-END
left knee flexion	KF-L
right knee extension	KE-R
left knee extension	KE-L
right handgrip strength	HGS-R
left handgrip strength	HGS-L

APPENDIX B. CASUALTY EVACUATION FIELD TEST INFORMATION

1. **Laboratory Measurements and Significant Values**

2. **The Rankings and Raw Data for the Laboratory Measurements of the First Place and Last Place Finishers in the Casualty Evacuation Field Test**

3. **The Rankings and Raw Data for the Laboratory Measurements of the Second Place and Second Last Place Finishers in the Casualty Evacuation Field Test**

4. **The Rankings and Raw Data for the Laboratory Measurements of the Third Place and Third Last Place Finishers in the Casualty Evacuation Field Test**

APPENDIX B1. LABORATORY MEASUREMENTS AND SIGNIFICANT VALUES

Table 19. Casualty Evacuation Field Test T-Test Results for All Laboratory Measurements.

Laboratory Measurement	Significant Value
leg mean power output	.000 **
leg peak power output	.001**
leg relative power output mpo	.001**
dynamic trunk flexion mean	.001**
static trunk flexion maximal	.003**
right knee extension	.004**
static trunk flexion mean	.005**
dynamic trunk flexion maximal	.010**
lean weight	.011*
leg relative power output ppo	.013*
dynamic trunk extension mean	.014*
dynamic trunk extension maximal	.017*
dynamic leg extension maximal	.020*
absolute aerobic power	.021*
static trunk extension mean	.021*
dynamic leg extension mean	.023*
left knee extension	.026*
right knee flexion	.033*
arm mean power output	.039*
arm peak power output	.041*
dynamic arm flexion maximal	.055
left knee flexion	.055
static trunk extension maximal	.062
dynamic arm flexion mean	.104
right handgrip strength	.104
bench press mean	.116
arm relative power output ppo	.141
trapezius lift endurance	.153
percent body fat	.171
body density	.178
static arm flexion maximal	.181
right handgrip endurance	.196
weight	.214
arm relative power output mpo	.217

static arm flexion mean	.220
bench press maximal	.257
relative anaerobic threshold	.273
relative aerobic power	.319
static arm flexion endurance	.463
absolute anaerobic threshold	.522
dynamic trapezius lift maximal	.642
left handgrip strength	.650
left handgrip endurance	.654
dynamic trapezius lift mean	.682

* $p \leq .05$ ** $p \leq .01$

B2. The Rankings and Raw Data for the Laboratory Measurements of the First Place and Last Place Finishers in the Casualty Evacuation Field Test

Table 20 lists the complete laboratory measurement rankings and raw scores for the first place and last place finishers in the Casualty Evacuation Field Test. If a soldier did not participate in a specific laboratory test, no rank or raw score for the related measurements was listed in the table. Full names of the laboratory measurements represented by the abbreviations are available in Appendix A1.

Table 20. Lists the Laboratory Measurement Abbreviations and Corresponding Rankings and Raw Scores for First and Last Place Finishers in the Casualty Evacuation Field Test.

Laboratory Measurement Abbreviation	Results for First Place Finisher: Soldier #107 Casualty Evacuation		Results for Last Place Finisher: Soldier #58 Casualty Evacuation	
	Rankings	**Raw Score**	**Rankings**	**Raw Score**
LP-E	81	558.76	97	517.88
LP-P	29	846.31	92	680.17
LP-[illegible]-REL	89	7.04	98.5	6.72
DTF-E	37.5	67.92	113	46.95
STF-M	30	75.76	108.5	55
KE-R	47.5	163	74	146
STF-E	38	69.53	112	47.44
DTF-M	48	74.62	110	54.54
LEAN-WT	57	64.31	43	66.19
LP-P-REL	17	10.66	94	8.82
DTE-E	86	126.16	60	140.56
DTE-M	84	143.29	37.5	172.94
DLE-M	77	227.93	78.5	226.1
VO2-AB	45	4.33	80	3.97
STE-E	50	151.84	72	136.16
DLE-E	75	166.92	42	189.27
KE-L	33	171	43.5	163
KF-R	58	114	93.5	98
AP-E	91	265.09	22	348.04
AP-P	75	409.53	32	486.8
DAF-M	37	83.65		

KF-L	53	144	65	108
STE-M	66	163.36	67	162.91
DAF-E	26	60.06		
HGS-R	29.5	60	87	50
BP-E	36	89.39	35	89.79
AP-P-REL	85	5.16	23	6.31
TRAP-END	48.5	100	48.5	100
BF%	58	18.34	23	13.25
BODYD	58	1.06	23	1.07
SAF-M	36	51.45	34.5	53.33
HGE-R	70.5	96	57	120
WEIGHT	63.5	79.4	51	77.1
AP-E-REL	98	3.34	9	4.51
SAF-E	37	43	45	40.36
BP-M	37.5	125.77	21	135.91
AT-REL	84	41.3	45.5	47.6
VO2-REL	51	54.4	76	51.3
SAF-END	93	73	16.5	153
AT-AB	84	3.28	50	3.68
DTL-M	51	60.82	78.5	51.01
HGS-L	77.5	49	39.5	56
HGE-L	83.5	76	37	128
DTL-E	78	32.74	59	36.51

B3. The Rankings and Raw Data for the Laboratory Measurements of the Second Place and Second Last Place Finishers in the Casualty Evacuation Field Test

Table 21 lists the complete laboratory measurement rankings and raw scores for the second place and second last place finishers in the Casualty Evacuation Field Test. If a soldier did not participate in a specific laboratory test, no rank or raw score for the related measurements was listed in the table. Full names of the laboratory measurements represented by the abbreviations are available in Appendix A1.

Table 21. Lists the Laboratory Measurement Abbreviations and Corresponding Rankings and Raw Scores for Second and Second Last Place Finishers in the Casualty Evacuation Field Test.

Laboratory Measurement Abbreviation	Results for Second Place Finisher: Soldier #13 Casualty Evacuation		Results for Second Last Place Finisher: Soldier #128 Casualty Evacuation	
	Rankings	**Raw Score**	**Rankings**	**Raw Score**
LP-E	6.00	737.43	31.00	651.65
LP-P	43.00	805.81	35.00	821.83
LP-E-REL	4.00	9.06	33.00	8.12
DTF-E	3.00	85.57	54.00	63.87
KE-R			35.50	169.00
DTF-M	5.00	92.18	57.00	73.70
LEAN-WT	30.00	68.37	56.00	64.34
LP-P-REL	56.00	9.90	37.00	10.23
DTE-3	52.00	144.77	13.00	172.62
DTE-M	17.00	188.23	14.00	189.83
DLE-M	21.00	313.71	60.00	248.00
VO2-AB	35.00	4.46	76.00	4.01
STE-E	5.00	191.91	23.00	170.74
DLE-E	15.00	232.32	45.00	188.01
KE-L			29.50	172.00
KF-R			26.50	132.00
AP-E	3.00	411.89	42.00	319.54
AP-P	4.00	647.13	45.00	466.87

DAF-M	9.00	107.14	22.00	92.58
KF-L			26.50	130.00
STE-M	4.50	221.99	21.00	193.71
DAF-E	5.00	83.70	19.00	64.99
HGS-R	41.50	58.00	3.50	70.00
BP-E			58.00	76.08
AP-P-REL	2.00	7.95	47.00	5.81
TRAP-END	48.50	100.00	48.50	100.00
BF%	28.00	14.00	69.00	19.18
BODYD	28.00	1.07	69.00	1.05
SAF-M	39.00	50.67	10.00	70.86
HGE-R	53.50	123.00	33.50	136.00
WEIGHT	75.00	81.40	71.50	80.30
AP-E-REL	1.00	5.06	44.50	3.98
SAF-E	34.00	43.24	8.00	58.63
BP-M			65.00	111.21
AT-REL	74.00	44.10	79.00	42.70
VO2-REL	47.50	54.70	84.00	49.80
SAF-END	44.00	120.00	43.00	121.00
AT-AB	60.00	3.60	74.00	3.43
DTL-M	7.00	89.53	56.00	59.39
HGS-L	44.50	55.00	9.00	63.00
HGE-L	60.00	104.00	33.00	131.00
DTL-E	12.00	55.24	49.00	39.02
STF-E	8.00	81.08	29.00	71.24
STF-M	1.50	94.69	45.50	73.02

B4. The Rankings and Raw Data for the Laboratory Measurements of the Third Place and Third Last Place Finishers in the Casualty Evacuation Field Test

Table 22 lists the complete laboratory measurement rankings and raw scores for the third place and third last place finishers in the Casualty Evacuation Field Test. If a soldier did not participate in a specific laboratory test, no rank or raw score for the related measurements was listed in the table. Full names of the laboratory measurements represented by the abbreviations are available in Appendix A1.

Table 22. Lists the Laboratory Measurement Abbreviations and Corresponding Rankings and Raw Scores for Second and Second Last Place Finishers in the Casualty Evacuation Field Test.

Laboratory Measurement Abbreviation	Results for Third Place Finisher: Soldier #146 Casualty Evacuation		Results for Third Last Place Finisher: Soldier #18 Casualty Evacuation	
	Rankings	**Raw Score**	**Rankings**	**Raw Score**
LP-E	77.00	572.87	93.00	542.25
LP-P	78.00	711.54	69.00	736.04
LP-E-REL	26.50	8.23	85.00	7.12
DTF-E	92.00	55.59	112.00	47.24
KE-R	64.00	153.00	85.50	140.00
DTF-M	89.50	65.26	111.50	53.40
LEAN-WT	90.00	58.16	61.00	63.74
LP-P-REL	39.50	10.22	50.00	10.00
DTE-3	94.00	123.67	62.00	139.39
DTE-M	58.00	162.68	71.00	152.41
DLE-M	13.00	331.96	73.00	232.26
VO2-AB	74.00	4.02	64.00	4.11
STE-E			49.00	152.07
DLE-E	8.00	248.81	87.00	158.75
KE-L	61.50	152.00	81.00	140.00
KF-R	77.50	104.00	80.50	103.00
AP-E	97.00	257.88	99.00	253.56
AP-P	106.00	337.30	74.00	410.65
DAF-M	52.00	75.60	43.00	78.37

KF-L	82.00	100.00	84.50	99.00
KF-L			58.00	168.84
DAF-E	48.00	51.37	43.00	55.39
HGS-R	82.50	51.00	76.50	52.00
BP-E	66.00	73.11	67.00	72.24
AP-P-REL	95.50	4.85	62.50	5.58
TRAP-END	48.50	100.00	100.00	66.00
BF%	37.00	14.84	21.00	13.14
BODYD	36.50	1.07	21.50	1.07
SAF-M	87.00	31.49	103.00	25.12
HGE-R	75.00	93.00	102.50	62.00
WEIGHT	24.50	69.60	33.50	73.60
AP-E-REL	73.00	3.71	90.50	3.45
SAF-E	84.00	29.26	100.00	22.92
BP-M	77.00	98.86	89.00	89.23
AT-REL	29.00	49.40	36.50	48.60
VO2-REL	25.50	57.60	39.50	55.70
SAF-END	86.50	77.00	111.00	38.00
AT-AB	71.00	3.45	60.00	3.60
DTL-M	101.00	41.64	24.00	76.86
HGS-L	77.50	49.00	87.50	47.00
HGE-L	42.00	124.00	100.50	58.00
DTL-E	94.00	29.25	13.00	55.22
STF-E	75.00	58.52	114.00	45.62
STF-M	85.50	62.07	115.00	47.24

APPENDIX C. AMMUNITION BOX FIELD TEST INFORMATION

1. **Laboratory Measurements and Significant Values**

2. **The Rankings and Raw Data for the Laboratory Measurements of the First Place and Last Place Finishers in the Ammunition Box Field Test**

3. **The Rankings and Raw Data for the Laboratory Measurements of the Second Place and Second Last Place Finishers in the Ammunition Box Field Test**

4. **The Rankings and Raw Data for the Laboratory Measurements of the Third Place and Third Last Place Finishers in the Ammunition Box Field Test**

APPENDIX C1. LABORATORY MEASUREMENTS AND SIGNIFICANT VALUES

Table 23. Ammunition Box Field Test T-Test Results for All Laboratory Measurements.

LABORATORY MEASUREMENT	SIGNIFICANCE VALUE
absolute aerobic power	.000**
lean weight	.000**
leg mean power output	.001**
absolute anaerobic threshold	.001**
dynamic trunk flexion maximal	.009**
arm mean power output	.010**
leg peak power output	.011*
dynamic trunk flexion mean	.016*
weight	.026*
relative aerobic power	.028*
static trunk flexion maximal	.038*
body density	.042*
static trunk extension maximal	.042*
percent body fat	.043*
dynamic leg extension maximal	.043*
dynamic trunk extension maximal	.070
static trunk extension mean	.077
bench press mean	.078
static trunk flexion mean	.084
left handgrip endurance	.087
static arm flexion maximal	.092
dynamic trunk extension mean	.102
relative anaerobic threshold	.104
leg relative power output mpo	.107
left knee flexion	.110
left handgrip strength	.124
dynamic leg extension mean	.146
right handgrip endurance	.146
trapezius lift endurance	.150
bench press maximal	.159
right handgrip strength	.160
arm peak power output	.166
right knee extension	.186

right knee flexion	.195
static arm flexion mean	.223
static arm flexion endurance	.244
arm relative power output mpo	.246
left knee extension	.345
dynamic arm flexion mean	.349
dynamic trapezius lift maximal	.354
dynamic trapezius lift mean	.388
leg relative power output ppo	.422
dynamic arm flexion maximal	.656
arm relative power output ppo	.999

* $p \leq .05$ ** $p \leq .01$

C2. The Rankings and Raw Data for the Laboratory Measurements of the First Place and Last Place Finishers in the Ammunition Box Field Test

Table 24 lists the complete laboratory measurement rankings and raw scores for the first place and last place finishers in the Ammunition Box Field Test. If a soldier did not participate in a specific laboratory test, no rank or raw score for the related measurements was listed in the table. Full names of the laboratory measurements represented by the abbreviations are available in Appendix A1.

Table 24. Lists the Laboratory Measurement Abbreviations and Corresponding Rankings and Raw Scores for First and Last Place Finishers in the Ammunition Box Field Test.

Laboratory Measurement Abbreviation	Results for First Place Finisher: Soldier #142 Ammunition Box		Results for Last Place Finisher: Soldier #77 Ammunition Box	
	Rankings	**Raw Score**	**Rankings**	**Raw Score**
VO2-AB	32	4.5	115	2.71
LEAN-WT	96	55.71	115	47.85
LP-E	96	521.83	111	493.33
AT-AB	108	2.83	112	2.42
DTF-M	113	52.26	88	65.49
AP-E	64	289.9	111	225.31
LP-P	86	692.29	102	625.72
DTF-E	111	47.39	97	54.54
WEIGHT	95	68.2	87	71.3
VO2-REL	3	65.8	115	38
STF-M	116	46.33	93	60.02
BODYD	46	1.06	112	1.02
STE-M	89	151.5	112	121.16
BF%	46	16.36	112	32.13
DLE-M	27.5	280.17	96	195.3
DTE-M	59.5	162.22	112	109.75
STE-E	68	138.4	112	85.94
BP-E	53	79.65	20	94.73
STF-E	115	43.82	93	53.66
HGE-L	43.5	123	108	41
SAF-M	68	39.32	69	39.21

DTE-E	65	138.8	112	98.77
AT-REL	5	56	112	33.9
LP-E-REL	61.5	7.65	109	6.16
KF-L	33	125	95	94
HGS-L	102	40	57.5	52
DLE-E	66	173.2	105	139.64
HGE-R	81	89	109.5	57
TRAP-END	48.5	100	106	35
BP-M	52.5	118.05	32	129.74
HGS-R	112.5	41	61.5	55
AP-P	82	399.62	109	315.45
KE-R	103.5	122	103.5	122
KF-R	17	137	77.5	104
SAF-E	67	34.01	68	33.34
SAF-END	39	124	106.5	55
AP-E-REL	21	4.25	105.5	3.16
KE-L	105.5	121	95	129
SAF-E	99	33.15	92	36.25
DTL-M	86	48.03	74	51.45
DTL-E	86	30.35	95	29.23
LP-P-REL	43	10.15	95	8.78
DAF-M	69	68.21	101	47.15
AP-P-REL	45	5.86	105	4.42

C3. The Rankings and Raw Data for the Laboratory Measurements of the Second Place and Second Last Place Finishers in the Ammunition Box Field Test

Table 25 lists the complete laboratory measurement rankings and raw scores for the second place and second last place finishers in the Ammunition Box Field Test. If a soldier did not participate in a specific laboratory test, no rank or raw score for the related measurements was listed in the table. Full names of the laboratory measurements represented by the abbreviations are available in Appendix A1.

Table 25. Lists the Laboratory Measurement Abbreviations and Corresponding Rankings and Raw Scores for Second and Second Last Place Finishers in the Ammunition Box Field Test.

Laboratory Measurement Abbreviation	Results for Second Place Finisher: Soldier #51 Ammunition Box		Results for Second Last Place Finisher: Soldier #82 Ammunition Box	
	Rankings	Raw Score	Rankings	Raw Score
VO2-AB	14	4.97	95	3.64
LEAN-WT	58	64.23	65	62.53
LP-E	28	663.5	108	464.93
AT-AB	3.5	4.6	103	2.99
DTF-M	83	66.63	98	63.21
AP-E	20	350.22	83.5	269.55
LP-P	80	702.27	95	665.05
DTF-E	64	62.2	101	53.64
WEIGHT	31	72.3	79	82.2
VO2-REL	1	68.6	104	44.2
STF-M	49	71.88	102	57.73
BODYD	9	1.08	91	1.05
STE-M	63	166.33	107	128.23
BF%	9	10.42	91	22.99
DLE-M	55.5	254.16	98	192.34
DTE-M	56	163.59	101	135.99
STE-E	74	135.6	102	114.7
BP-E	47	81.91	91	59.18
STF-E	65	61.17	90	54.43
HGE-L	10	167	53.5	108

SAF-M	89	30.94	73	38.11
DTE-E	51	145.19	103	119.42
AT-REL	1	63.5	109.5	36.3
LP-E-REL	2	9.18	113	5.66
KF-L	87.5	98	57	113
HGS-L	54	53	71	50
DLE-E	32	207.07	101	146.11
HGE-R	16	172	39	132
TRAP-END	48.5	100	48.5	100
BP-M	46	121.91	98	79.79
HGS-R	61.5	55	29.5	60
AP-P	52	449.01	50	453.34
KE-R	74	146	43	165
KF-R	73	106	46	119
SAF-E	93	25.79	69	33.04
SAF-END	35.5	125	98	65
AP-E-REL	3	4.84	102.5	3.28
KE-L	60	153	48.5	160
SAF-E	10	74.95	71	43.58
DTL-M	96	44.73	105	38.22
DTL-E	81	32.09	103	24.18
LP-P-REL	64.5	9.71	107	8.09
DAF-M	6	118.27	83	62.59
AP-P-REL	28	6.21	66	5.52

C4. The Rankings and Raw Data for the Laboratory Measurements of the Third Place and Third Last Place Finishers in the Ammunition Box Field Test

Table 26 lists the complete laboratory measurement rankings and raw scores for the third place and third last place finishers in the Ammunition Box Field Test. If a soldier did not participate in a specific laboratory test, no rank or raw score for the related measurements was listed in the table. Full names of the laboratory measurements represented by the abbreviations are available in Appendix A1.

Table 26. Lists the Laboratory Measurement Abbreviations and Corresponding Rankings and Raw Scores for Second and Second Last Place Finishers in the Ammunition Box Field Test.

Laboratory Measurement Abbreviation	Results for Third Place Finisher: Soldier #143 Ammunition Box		Results for Third Last Place Finisher: Soldier #134 Ammunition Box	
	Rankings	**Raw Score**	**Rankings**	**Raw Score**
VO2-AB	3	5.61	91	3.72
LEAN-WT	17	72.87	103	53.38
LP-E	13	706.43	101	509.1
AT-AB	1	5.28	87.5	3.25
DTF-M	24	81.23	80	68
AP-E	12	366.24	90	266.42
LP-P	16	888.15	105	611.61
DTF-E	27	71.85	73	60.52
WEIGHT	22	88.8	102	65.9
VO2-REL	8	63.1	37	56.3
STF-M	50	71.42	63.5	66.63
BODYD	50	1.06	52	1.06
STE-M	3	222.45	111	123.89
BF%	50	17.19	52	17.49
DLE-M	17	330.58	84.5	217.89
DTE-M	2	221.08	100	136.21
STE-E	1	204.45	103	113.8
BP-E	3	127.64	89	60.07
STF-E	49	64.1	72	58.96
HGE-L	6	181	76.5	86

SAF-M	8	72.84	94.5	29.51
DTE-E	2	208.78	87	125.88
AT-REL	2	59.3	30.5	49.2
LP-E-REL	43.5	7.96	57.5	7.73
KF-L	20.5	134	92	95
HGS-L	31.5	58	113	35
DLE-E	22	218.79	93	152.34
HGE-R	6	228	107	59
TRAP-END	48.5	100	48.5	100
BP-M	1	203.39	91	88.83
HGS-R	41.5	58	115	36
AP-P	15	523.14	72	411.28
KE-R	26	179	28.5	176
KF-R	88.5	99	34	129
SAF-E	16	52.06	87	28.47
SAF-END	7	193	100.5	61
AP-E-REL	28.5	4.12	39	4.04
KE-L	29.5	172	92	130
SAF-E	8	76.98	76	43.19
DTL-M	14	82.43	102	40.76
DTL-E	30	47.05	102	24.51
LP-P-REL	50	10	82	9.28
DAF-M	13	101.07	42	78.58
AP-P-REL	43	5.89	25	6.24

APPENDIX D. MAXIMAL DIG FIELD TEST INFORMATION

1. **Laboratory Measurements and Significant Values**

2. **The Rankings and Raw Data for the Laboratory Measurements of the First Place and Last Place Finishers in the Maximal Dig Field Test**

3. **The Rankings and Raw Data for the Laboratory Measurements of the Second Place and Second Last Place Finishers in the Maximal Dig Field Test**

4. **The Rankings and Raw Data for the Laboratory Measurements of the Third Place and Third Last Place Finishers in the Maximal Dig Field Test**

APPENDIX D1. LABORATORY MEASUREMENTS AND SIGNIFICANT VALUES

Table 27. Maximal Dig Field Test T-Test Results for All Laboratory Measurements

Laboratory Measurement	Significant Value
leg peak power output	.000**
leg mean power output	.000**
static trunk extension mean	.000**
static trunk extension maximal	.000**
absolute aerobic power	.000**
absolute anaerobic threshold	.000**
dynamic arm flexion mean	.000**
dynamic trunk extension maximal	.000**
dynamic leg extension maximal	.000**
arm mean power output	.001**
dynamic arm flexion maximal	.001**
dynamic trunk extension mean	.001**
dynamic leg extension mean	.001**
lean weight	.003**
left knee flexion	.004**
left knee extension	.004**
leg relative power output ppo	.005**
leg relative power output mpo	.007**
arm relative power output mpo	.014*
relative anaerobic threshold	.017*
static arm flexion endurance	.018*
relative aerobic power	.021*
trapezius lift endurance	.025*
dynamic trunk flexion mean	.029*
static trunk flexion mean	.034*
static trunk flexion maximal	.034*
right handgrip endurance	.040*
bench press maximal	.042*
weight	.044*
dynamic trunk flexion maximal	.044*
right handgrip strength	.046*
body density	.050*
percent body fat	.050*
dynamic trapezius lift maximal	.055
bench press mean	.055

right knee flexion	.056
weight	.060
static arm flexion maximal	.066
arm peak power output	.076
left handgrip strength	.082
right knee extension	.100
left handgrip endurance	.118
dynamic trapezius lift mean	.126
static arm flexion mean	.144
arm relative power output - ppo	.596

* $p \leq .05$ ** $p \leq .01$

D2. The Rankings and Raw Data for the Laboratory Measurements of the First Place and Last Place Finishers in the Maximal Dig Field Test

Table 28 lists the complete laboratory measurement rankings and raw scores for the first place and last place finishers in the Maximal Dig Field Test. If a soldier did not participate in a specific laboratory test, no rank or raw score for the related measurements was listed in the table. Full names of the laboratory measurements represented by the abbreviations are available in Appendix A1.

Table 28. Lists the Laboratory Measurement Abbreviations and Corresponding Rankings and Raw Scores for First and Last Place Finishers in the Ammunition Box Field Test.

Laboratory Measurement Abbreviation	Results for First Place Finisher: Soldier #16 Maximal Dig		Results for Last Place Finisher: Soldier #77 Maximal Dig	
	Rankings	**Raw Score**	**Rankings**	**Raw Score**
LP-P	36	818.21	102	625.72
LP-E	23	670.38	111	439.33
STE-E	19	173	112	85.94
STE-M	14	201.23	112	121.16
DTE-M	5	208.99	112	109.75
DTE-E	13	71.31	92	36.25
DLE-M	20	322.83	96	195.3
AT-AB	3.5	4.6	112	2.42
VO2-AB	5.5	5.2	115	2.71
AP-E	2	428.81	111	225.31
DAF-M	14	101	101	47.15
DTE-E	5	190.44	112	98.77
DLE-E	54	182.37	105	139.64
LEAN-WT	16	73.18	115	47.85
KF-L	12	144	95	94
KE-L	11.5	193	95	129
LP-P-REL	85	9.14	95	8.78
LP-E-REL	68	7.49	109	6.16
AP-E-REL	4	4.79	105.5	3.16

AT-REL	18	51.4	112	33.9
SAF-END	4	210	106.5	55
VO2-REL	24	58	115	38
TRAP-END	48.5	100	106	35
DTE-E	9	79.94	97	54.54
STF-E	12	75.65	93	53.66
STF-M	11	83.74	93	60.02
HGE-R	3	256	109.5	57
BP-M	60	113.28	32	129.74
WEIGHT	95	89.5	29	71.3
DTF-M	7	90.36	88	65.49
HGS-R	41.5	58	61.5	55
BODYD	45	1.06	112	1.02
BF%	45	16.27	112	32.13
DTL-M	25	75.35	74	51.45
BP-E	30	91.08	20	94.73
KF-R	8.5	144	77.5	104
SAF-M	33	53.52	69	39.21
AP-P	1	743.55	109	315.45
HGS-L	71	50	57.5	52
KE-R	9	197	103.5	122
HGE-L	50	112	108	41
DLE-E	9	56.77	95	29.23
SAF-E	38	42.85	68	33.34
AP-P-REL	1	8.31	105	4.42

D3. The Rankings and Raw Data for the Laboratory Measurements of the Second Place and Second Last Place Finishers in the Maximal Dig Field Test

Table 29 lists the complete laboratory measurement rankings and raw scores for the second place and second last place finishers in the Maximal Dig Field Test. If a soldier did not participate in a specific laboratory test, no rank or raw score for the related measurements was listed in the table. Full names of the laboratory measurements represented by the abbreviations are available in Appendix A1.

Table 29. Lists the Laboratory Measurement Abbreviations and Corresponding Rankings and Raw Scores for Second and Second Last Place Finishers in the Maximal Dig Field Test.

Laboratory Measurement Abbreviation	Results for Second Place Finisher: Soldier #160 Maximal Dig		Results for Second Last Place Finisher: Soldier #70 Maximal Dig	
	Rankings	**Raw Score**	**Rankings**	**Raw Score**
LP-P	7	931.04	113	540.36
LP-E	17	698.41	114	431.31
STE-E	22	172.3	101	118.07
STE-M	4.5	221.99	101	135.76
VO2-AB	17	4.88	104	3.54
AT-AB	17	4.08	92	3.14
DTE-M	1	233.17	103	134.16
DAF-E	28	59.44	82	41.84
DLE-M	3	414.77	93	208.53
AP-E	23	347.35	106	239.4
DAF-M	1	133.71	75	64.9
DTE-E	1	210.33	95	123.34
DLE-E	1	318.68	90	156.4
LEAN-WT	27	69.36	60	63.98
KF-L	26.5	140	95	94
KE-L	5	203	86	134
LP-P-REL	4	11.41	114	6.33
LP-E-REL	14	8.56	114	5.05
AP-E-REL	19	4.26	113	2.8

AT-REL	28	49.9	108	36.7
SAF-END	49.5	113	97	66
VO2-REL	18	59.7	111	41.3
TRAP-END	48.5	100	104	44
DTF-E	2	86.61	75	60.42
STF-E	5	84.7	76	57.28
STF-M	3	93.55	63.5	66.63
HGE-R	18	170	114	33
BP-M	29	131.39	75	99.53
WEIGHT	77	81.6	89	85.4
DTF-M	3	97.2	60.5	72.34
HGS-R	29.5	60	112.5	41
BODYD	21.5	1.07	98	1.04
BF%	22	13.19	98	24.37
DTL-M	5	90.15	50	61.49
BP-E	40	86.53	63	73.73
KF-R	30	130	88.5	99
SAF-M	1	107.24	46	47.92
AP-P	49	454.36	94	376.95
HGS-R	64	51	102	40
KE-R	705	201	89	136
HGE-L	23	142	113	24
DTL-E	2	66.21	44	42
SAF-E	1	88.82	36	43.03
AP-P-REL	64.5	5.57	106.5	4.41

D4. The Rankings and Raw Data for the Laboratory Measurements of the Third Place and Third Last Place Finishers in the Maximal Dig Field Test

Table 30 lists the complete laboratory measurement rankings and raw scores for the third place and third last place finishers in the Ammunition Box Field Test. If a soldier did not participate in a specific laboratory test, no rank or raw score for the related measurements was listed in the table. Full names of the laboratory measurements represented by the abbreviations are available in Appendix A1.

Table 30. Lists the Laboratory Measurement Abbreviations and Corresponding Rankings and Raw Scores for Third and Third Last Place Finishers in the Maximal Dig Field Test.

Laboratory Measurement Abbreviation	Results for Third Place Finisher: Soldier #51 Maximal Dig		Results for Third Last Place Finisher: Soldier #63 Maximal Dig	
	Rankings	**Raw Score**	**Rankings**	**Raw Score**
LP-P	80	702.27	14	896.83
LP-E	28	663.5	41	631.89
STE-E	74	135.6	28	165.32
STE-M	63	166.33	30.5	188.23
VO2-AB	14	4.97	78	4
AT-AB	3.5	4.6	30.5	3.91
DTE-M	56	163.59	23	181.84
DAF-E	10	74.95	9	76.82
DLE-M	55.5	254.16	46	263.29
AP-E	20	350.22	36	331.66
DAF-M	6	118.27	2.5	127.86
DTE-E	51	145.19	18	163.4
DLE-E	32	207.07	50	184.29
LEAN-WT	58	64.23	23	70.87
KF-L	87.5	98	14.5	141
KE-L	60	153	16	188
LP-P-REL	64.5	9.71	58.5	9.83
LP-E-REL	2	9.18	92	6.93
AP-E-REL	3	4.84	77	3.64

AT-REL	1	63.5	77	42.8
SAF-END	35.5	125	52	107
VO2-REL	1	68.6	105.5	43.7
TRAP-END	48.5	100	48.5	100
DTF-E	64	62.2	61	62.42
STF-E	65	61.17	101	52.48
STF-M	49	71.88	71.5	65.72
HGE-R	16	172	24	155
BP-M	46	121.91	4	169.54
WEIGHT	85	72.3	17.5	91.2
DTF-M	83	66.63	59	72.79
HGS-R	61.5	55	3.5	70
BODYD	9	1.08	85.5	1.05
BF%	9	10.42	85	21.43
DTL-M	96	44.73	6	89.6
BP-E	47	81.91	6	105.02
KF-R	73	106	24	133
SAF-M	89	30.94	15	63.8
AP-P	52	449.01	21	513.09
HGS-R	54	53	2.5	68
KE-R	74	146	12	193
HGE-L	10	167	53.5	108
DTL-E	81	32.09	7	58.21
SAF-E	93	25.79	14	52.85
AP-P-REL	28	6.21	57.5	5.63

APPENDIX E. WEIGHT LOAD MARCH FIELD TEST INFORMATION

1. Laboratory Measurements and Significant Values

2. The Rankings and Raw Data for the Laboratory Measurements of the First Place and Last Place Finishers in the Weight Load March Field Test

3. The Rankings and Raw Data for the Laboratory Measurements of the Second Place and Second Last Place Finishers in the Weight Load March Field Test

4. The Rankings and Raw Data for the Laboratory Measurements of the Third Place and Third Last Place Finishers in the Weight Load March Field Test

APPENDIX E1. LABORATORY MEASUREMENTS AND SIGNIFICANT VALUES

Table 31. Weight Load March Field Test T-Test Results for All Laboratory Measurements.

LABORATORY MEASUREMENT	SIGNIFICANT VALUE
leg mean power output	.000**
leg relative power output mpo	.002**
leg peak power output	.009**
leg relative power output ppo	.011*
static trunk extension mean	.014*
static trunk extension maximal	.015*
percent body fat	.028*
lean weight	.028*
body density	.029*
right handgrip strength	.031*
dynamic trunk flexion mean	.038*
absolute aerobic power	.039*
right handgrip endurance	.056
dynamic leg extension maximal	.058
dynamic arm flexion maximal	.059
static trunk flexion maximal	.061
static trunk flexion mean	.063
dynamic arm flexion mean	.065
dynamic trunk extension maximal	.082
relative aerobic power	.083
arm mean power output	.091
dynamic trunk extension mean	.111
left handgrip endurance	.115
dynamic leg extension mean	.133
arm relative power output - mpo	.141
absolute anaerobic threshold	.154
trapezius lift endurance	.156
height	.198
left handgrip strength	.205
dynamic trunk flexion maximal	.279
left knee extension	.301
arm peak power output	.354
right knee extension	.491

relative anaerobic threshold	.497
arm relative power output ppo	.506
left knee flexion	.590
dynamic trapezius lift maximal	.619
static arm flexion endurance	.636
weight	.718
body weight	.768
dynamic trapezius lift mean	.777
bench press mean	.786
bench press maximal	.842
right knee flexion	.902
static arm flexion maximal	.986
static arm flexion mean	.993

* $p \leq .05$ ** $p \leq .01$

E2. The Rankings and Raw Data for the Laboratory Measurements of the First Place and Last Place Finishers in the Weight Load March Field Test

Table 32 lists the complete laboratory measurement rankings and raw scores for the first place and last place finishers in the Weight Load March Field Test. If a soldier did not participate in a specific laboratory test, no rank or raw score for the related measurements was listed in the table. Full names of the laboratory measurements represented by the abbreviations are available in Appendix A1.

Table 32. Lists the Laboratory Measurement Abbreviations and Corresponding Rankings and Raw Scores for First and Last Place Finishers in the Weight Load March Field Test.

Laboratory Measurement Abbreviation	Results for First Place Finisher: Soldier #160 Weight Load March		Results for Last Place Finisher: Soldier #77 Weight Load March	
	Rankings	**Raw Score**	**Rankings**	**Raw Score**
LP-E	17	698.41	111	493.33
LP-E-REL	14	8.56	109	6.16
LP-P	7	931.04	102	625.72
LP-P-REL	4	11.41	95	8.78
STE-E	22	172.3	112	85.94
STE-M	4.5	221.99	112	121.16
BF%	22	13.19	112	32.13
LEAN-WT	27	69.36	115	47.85
BODYD	21.5	1.07	112	1.02
HGS-R	29.5	60	61.5	55
DTF-E	2	86.61	97	54.54
V02-AB	17	4.88	115	2.71
HGE-R	18	170	109.5	57
DLE-M	3	414.77	96	195.3
DAF-M	1	133.71	101	47.15
STF-M	3	93.55	93	60.02
STF-E	5	84.7	93	53.66
DAF-E	28	59.44	92	36.25
DTE-M	1	233.17	112	109.75
VO2-REL	18	59.7	115	38

AP-E	23	347.35	111	225.31
DTE-E	1	210.33	112	98.77
HGE-L	23	142	108	41
DLE-E	1	318.68	105	139.64
AP-E-REL	19	4.26	105.5	3.16
AT-AB	17	4.08	112	2.42
TRAP-END	48.5	100	106	35
HGS-L	64	51	57.5	52
DTF-M	3	97.2	88	65.49
KE-L	5	203	95	129
AP-P	49	454.36	109	315.45
KE-R	705	201	103.5	122
AT-REL	28	49.9	112	33.9
AP-P-REL	64.5	5.57	105	4.42
KF-L	26.5	140	95	94
DTL-M	5	90.15	74	51.45
SAF-END	49.5	113	106.5	55
WEIGHT	77	81.6	29	71.3
DTL-E	2	66.21	95	29.23
BP-E	40	86.53	20	94.73
BP-M	29	131.39	32	129.74
KF-R	30	130	77.5	104
SAF-M	1	107.24	69	39.21
SAF-E	1	88.82	68	33.34

E3. The Rankings and Raw Data for the Laboratory Measurements of the Second Place and Second Last Place Finishers in the Weight Load March Field Test

Table 33 lists the complete laboratory measurement rankings and raw scores for the second place and second last place finishers in the Weight Load March Field Test. If a soldier did not participate in a specific laboratory test, no rank or raw score for the related measurements was listed in the table. Full names of the laboratory measurements represented by the abbreviations are available in Appendix A1.

Table 33. Lists the Laboratory Measurement Abbreviations and Corresponding Rankings and Raw Scores for Second and Second Last Place Finishers in the Weight Load March Field Test.

Laboratory Measurement Abbreviation	Results for Second Place Finisher: Soldier #108 Weight Load March		Results for Second Last Place Finisher: Soldier #19 Weight Load March	
	Rankings	**Raw Score**	**Rankings**	**Raw Score**
LP-E	59	601.01	83	550.54
LP-E-REL	47	7.92	111	6.02
LP-P	34	827.56	98	660.22
LP-P-REL	13	10.9	113	7.22
STE-E	21	172.79	81	131.29
STE-M	32.5	187.77	45	176.37
BF%	97	24.31	114	32.45
LEAN-WT	92	56.96	68	61.94
BODYD	97	1.04	114	1.02
HGS-R	14.5	64	47	57
DTF-E	30	70.69	25	72.12
V02-AB	86	3.82	83	3.86
HGE-R	5	242	20.5	161
DLE-M	53.5	257.13	42	268.99
DAF-M	24.5	90.92	59	72.23
STF-M	54	69.83	17	80.32
STF-E	41	67.38	32	70.87

DAF-E	21	61.77	29.5	59.38
DTE-M	59.5	162.22	28	177.05
VO2-REL	82	50.2	109.5	42.1
AP-E	108	236.74	9	375.76
DTE-E	53	144.62	23	161.5
HGE-L	11.5	165	14.5	161
DLE-E	67	172.29	55	181.67
AP-E-REL	109	3.12	30	4.11
AT-AB	73	3.44	69	3.46
TRAP-END	48.5	100	48.5	100
HGS-L	12	62	24	59
DTF-M	50.5	74.39	15	84.88
KE-L	53.5	157	17	183
AP-P	97	374.78	10	550.84
KE-R	47.5	163	28.5	176
AT-REL	67	45.2	104	37.7
AP-P-REL	92	4.94	33.5	6.02
KF-L	53	114	38.5	122
DTL-M	66	55.31	2	99.49
SAF-END	53.5	106	9.5	181
WEIGHT	46	75.9	100	91.5
DTL-E	73	33.94	6	60.28
BP-E	29	91.17	9	103.69
BP-M	34	128.96	5	164.78
KF-R	46	449	20	136
SAF-M	62.5	41.64	26	56.17
SAF-E	50	39.84	22	48.03

E4. The Rankings and Raw Data for the Laboratory Measurements of the Third Place and Third Last Place Finishers in the Weight Load March Field Test

Table 34 lists the complete laboratory measurement rankings and raw scores for the third place and third last place finishers in the Weight Load March Field Test. If a soldier did not participate in a specific laboratory test, no rank or raw score for the related measurements was listed in the table. Full names of the laboratory measurements represented by the abbreviations are available in Appendix A1.

Table 34. Lists the Laboratory Measurement Abbreviations and Corresponding Rankings and Raw Scores for Third and Third Last Place Finishers in the Weight Load March Field Test.

Laboratory Measurement Abbreviation	Results for Third Place Finisher: Soldier #113 Weight Load March		Results for Third Last Place Finisher: Soldier #70 Weight Load March	
	Rankings	**Raw Score**	**Rankings**	**Raw Score**
LP-E	25	668.42	114	431.31
LP-E-REL	77.5	7.33	114	5.05
LP-P	21	881.31	113	540.36
LP-P-REL	66.5	9.66	114	6.33
STE-E	10	183.94	101	118.07
STE-M	17	198.95	101	135.76
BF%	105	25.76	98	24.37
LEAN-WT	42	66.52	60	63.98
BODYD	105	1.04	98	1.04
HGS-R	67	54	112.5	41
DTF-E	6	82.31	75	60.42
V02-AB	42	4.34	104	3.54
HGE-R	94.5	70	114	33
DLE-M	4	410.89	93	208.53
DAF-M	15	100.3	75	64.9
STF-M	[illegible]	91.73	63.5	66.63
STF-E	2	88.48	76	57.28
DAF-E	12	73.55	82	41.84
DTE-M	3	219.03	103	134.16

VO2-REL	95.5	47.5	111	41.3
AP-E	52	302.42	106	239.4
DTE-E	3	196.63	95	123.34
HGE-L	87	72	113	24
DLE-E	5	249.3	90	156.4
AP-E-REL	99	3.32	113	2.8
AT-AB	38	3.83	92	3.14
TRAP-END	48.5	100	104	44
HGS-L	12	62	102	40
DTF-M	10	87.16	60.5	72.34
KE-L	45	162	86	134
AP-P	54	447.84	94	376.95
KE-R	24.5	182	89	136
AT-REL	81	41.9	108	36.7
AP-P-REL	93	4.91	106.5	4.41
KF-L	68.5	107	95	94
DTL-M	31.5	72.4	50	61.49
SAF-END	89.5	76	97	66
WEIGHT	98.5	91.2	89	85.4
DTL-E	34	45.38	44	42
BP-E	46	82.14	63	73.73
BP-M	39	125.66	75	99.53
KF-R	41.5	122	88.5	99
SAF-M	31	54.21	46	47.92
SAF-E	28	45.87	36	43.03