UNIVERSITY OF ALBERTA

ARMY PHYSICAL FITNESS PERFORMANCE STANDARDS BASED ON BODY COMPOSITION, MUSCULAR STRENGTH AND ENDURANCE

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF PHYSICAL EDUCATION AND SPORT STUDIES

EDMONTON, ALBERTA

SPRING, 1993

ISBN 0-315-81979-0

UNIVERSITY OF ALBERTA

RELEASE FORM

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TITLE OF THESIS: ARMY PHYSICAL PERFORMANCE STANDARDS BASED ON MUSCULAR STRENGTH, MUSCULAR ENDURANCE, AND BODY COMPOSITION

DEGREE: DOCTOR OF PHILOSOPHY

YEAR THIS DEGREE GRANTED: 1993

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DATED Jan. 16, 1993

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled ARMY PHYSICAL PERFORMANCE STANDARDS BASED ON MUSCULAR STRENGTH, MUSCULAR ENDURANCE, AND BODY COMPOSITION submitted by HARSUKHPAL (PAUL) SINGH CHAHAL in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY

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Abstract

The purpose of this investigation was to develop task related physical performance standards based on muscular strength and endurance fitness components, and body composition, for male combat soldiers in the Canadian Army. Previously physical fitness standards for the Army have been based on norm reference approach and on fitness tests scores (non relevant to occupations) of the normal army population. In the process of developing the task related standards it was agreed that instead of selecting representative tasks from the Armoury, Artillery, Infantry and Combat Support groups of the Army and developing individual common tasks for each of these occupational specialty, one factor that all groups had in common was that they could be called upon to carry out the duties of an Infantry soldier at some point in the battle scenario. It was also agreed that the Infantry soldier's physical job requirements were the most demanding in the Combat Arms groups.

Representative selected common tasks for the study were casualty evacuation, ammunition box lift, maximal effort jerry can task, maximal effort slit trench dig, and weight load march. Following laboratory test batteries were selected and developed based on the physical requirements of the chosen common field tasks: (a) static and dynamic muscular strength test battery; (b) static and dynamic muscular endurance test battery; and (c) body composition variables.

Laboratory data on 116 randomly selected male infantry soldiers and field task data on 88 soldiers from the Canadian Forces Base in Calgary, Alberta, was gathered. Isometric and isokinetic strength levels of male soldiers were in agreement with the values reported by other authors for civilian male population of similar age

groups. Soldiers had lower strength levels in comparison to highly trained individuals and greater than relatively less trained male civilian population. Based on the size of multiple correlation coefficients, digging performance had the greatest degree of relationship with laboratory tests followed by casualty evacuation, ammunition box lift, and jerry can task respectively. Weight load march did not relate to the performance of any laboratory test. Canonical correlation coefficient between the selected laboratory and field task variables was 0.73, indicating a good overall relationship between the two.

Recommended performance standards for the field tasks were based on: (a) cutoff performances suggested by the panel of subject matter judges 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 discriminant 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 discriminant analysis results did not support or refute any of the cutoff performances suggested by the expert judges or the researcher. Based on the results of the study, recommended standards for the Canadian Army were those cutoff performances as suggested by the panel of subject matter judges and the researcher: a 13 km weight load march in full fighting order at 5.33 km/h in 2:26:20 h; a slit trench digging task, shifting ½ m^3 of gravel from one standardised container to another, with standard shovel, in 360 s or less; a casualty evacuation test, carrying (using fireman's carry) an individual of similar height and weight over a 100 m course in 60 s or less, both parties carrying weapons and in fighting order without back pack; an ammunition box lifting task involving loading 48 standard ammunition boxes from ground to standard truckbed height (1.3 m) in 300 s or less at a heart rate of 80% of maximum; a maximal effort jerry can task, carry and emptying three jerry cans (one at a time) into a gas tank simulator in 300 s or less.

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CHAPTER I. STATEMENT OF THE PROBLEM

A. Introduction

In the modern army many arduous jobs that used to require muscle power are now being handled by machines. Heavy equipment is now used to move guns, ammunition and other supplies. Instead of marching into battle, today's soldier often rides in an armoured personnel carrier. However, there are still many jobs in the army that demand a high level of physical fitness, in terms of both muscular strength and endurance. Today's soldier, like those in the past, must be prepared to fight any where in the world in all types of terrain and weather. This concept was demonstrated in the Falkland situation when in inclement weather and over very difficult terrain British soldiers were forced to march as far as 60 km, on foot, carrying full combat loads of up to 60 kg and were expected to be fit to fight on the same day (Time Magazine, 1982). In addition to carrying weapons, he must also carry many new pieces of gear such as special electronic equipment for communication and for detection of the enemy which did not exist 30 years back (Marston et al., 1981). Trucks, armoured personnel carriers, tanks, and other heavy equipment used in the battle field may break down and require repairs that may involve lifting of heavy parts. "New weapons in the radiological, chemical and biological fields mean that today's soldier must be prepared to carry the weight of additional protective equipment" (Marston et al., 1981). Modern equipment such as night vision goggles has made the 24 h battle day a reality. Nowadays, a soldier must have the stamina to fight for longer periods of time without rest and sleep than in past. Therefore, the need for a physically fit soldier may even be greater today than ever before (Marston et al., 1981).

The Canadian Forces (CF) defines fitness as "the physical ability and energy to accomplish assigned tasks, to meet unforeseen emergencies with vigour and alertness... the ability to effectively withstand stress and persevere under difficult operational circumstances" (CF EXPRES Operations Manual, 1981). As Daniels et al. (1979) defines, "the physical fitness is a state of the body which permits a person to respond and adapt instantly and efficiently to physical and/or emotional demands with a minimum of discomfort, and to return quickly to a normal and healthy state once the demand has been removed." They further emphasized that physical fitness, as it relates to army, can be defined as those factors which determine one's ability to perform heavy physical work and contributes to maintenance of good health and appearance. Jette and Kimick (1986) state that fitness readiness not only implies the ability to perform difficult tasks under hazardous conditions but also the ability to sustain a high degree of emotional strain without suffering psychological breakdown.

In the Falkland, British commanders had described the fitness and "esprit de corps" as their "secret weapon" (Time Magazine, 1982). Traditionally, the belief of being physically fit for the army was based on such factors as low body fat, high relative VO_2 max, able to run fast for extended period of times, do a large number of push-ups, sit-ups, and/or chin-ups. It was thought that the individuals who are successful in these tasks would be ideal soldiers having very high fitness level to perform their duties in the battle field. However, the Falkland experience proved this to be false. The soldiers who were lean and had a body build similar to that of a typical marathon runner were least successful in carrying out their battle duties (such as weight load marching for distance). Being successful, in the above mentioned performance tests does not mean that one is fit to perform the specific occupational requirements of the related army jobs. Most of the army tasks may or may not have similar physical demands of the muscles as would such tests. The individuals most successful in the Falkland situation were those who had a mesomorphic body type, with high upper and lower bodily strength. One of the major task of infantry soldiers involves carrying 20 to 30 kg of extra equipment. In order to successfully carry this extra load for an extended period of time one must posses adequate strength and muscular endurance capacities. Currently, the consensus of opinion of army personnel appears to be that a high level of muscular strength and endurance is more important than just having high level of relative oxygen consumption alone. Marching while carrying heavy external loads places extra demands on skeletal musculature as compared to marching with minimal or no equipment.

Mayo (1984) stated that the need for fitness of Canadian Forces personnel has never been questioned. The evaluation of performance of an individual in his specific job situation is complicated not only by the diversity of work situations but is also greatly influenced by fatigue, health, environment and psychological factors. Fitness of CF personnel is largely an individual responsibility. However, the CF requires its personnel to be alert, responsive, and physically as well as mentally prepared for the unexpected. The new soldiers are recruited into the services from a population which is largely inactive. The sedentary civilian life-style tends to carry over into the military population (Mayo, 1984). The soldier in a combat situation is required to perform a spectrum of physical activities including long and short marches as well as variety of other tasks (Murphy et al., 1984). The military person may be called upon to change jobs and environments quite often during his career. Traditionally, military personnel have had more active jobs to fulfil in emergency situations. Soldiers in these trades may be called upon to assist civil powers or the community. In the past, the military has been called upon to perform tasks like:

(a) charge a prison yard full of rioting prisoners

(b) assist in fighting forest fires

(c) build sand bag dikes for flood control (Mayo, 1984).

During these emergency situations, the individuals are expected to perform more physically demanding tasks. They are expected to demonstrate strength and endurance levels for the required tasks.

Other than meeting the physical requirements of the occupational tasks physical fitness has many other benefits. These include improved job efficiency, decreased accidents, injuries and sick leaves, increased productivity and alertness as well as a more positive work attitudes (Mayo, 1984).

Other countries such as the United States, Britain, Norway and France have also conducted internal fitness studies of their military forces. Overall, their findings are reported to be similar to those of Canada's (Allen, 1981). Personnel working in physically demanding jobs and participating in compulsory fitness training programs were fit while the remaining demonstrated a fitness level similar to the civilian population. For majority of CF personnel, poor fitness does not immediately appear to interfere with day to day job performance and a certain degree of obesity has been often tolerated (Allen, 1981).

A great majority of CF personnel are unfit and significant percentage are also reported to be fat (Mayo, 1984). Some of the persons who complained about any testing programs reasoned that fitness was not a requirement when they first entered the military and therefore, poor fitness should not be a cause for dismissal or compulsory fitness training. However, if through task specific standards an individual fails to demonstrate ability to carry out the duties of his job then the dismissal or compulsory training to attain the required fitness level appears to be justifiable regardless of the past selection criterion inadequacies. The current minimal physical fitness standards of the CF are set for the entire military forces. These standards do not appear to meet the needs of soldiers in combative roles. The subgroups of combative forces, in the Canadian Army, consist of Infantry, Armoury, Artillery, and Combat Support groups. The physical demands placed on these soldiers exceed those in the other trade specialties of the CF. Therefore, there was a need to set task specific performance standards for the combative forces in the Canadian Army.

B. Purposes of the Study

The main purposes of this study were:

1. to investigate a new approach in establishing physical fitness performance standards based on job requirements and physiological working capabilities of the Canadian soldiers
2. to develop task related physical performance standards for the Canadian Army based on the performance of selected representative common tasks of the army in conjunction with selected laboratory measures
3. to investigate relationship between physical performance, body fat, fat free weight and physical performance requirements of the army.

This study was part of a larger project which also included the aerobic, anaerobic, body composition and performance enhancement components.

C. Significance of the Study

Traditionally, Canadian Army physical performance standards for large part have been based on fitness test scores (non-specific to task performance) of certain upper percentile of the normal army population. This approach had been based on normative criteria having separate standards for each age group and job classification (Lee et al., 1990). This study investigated a new approach in establishing performance standards which were based on rating of soldiers by army commanders, physical job requirements and physiological working capabilities of soldiers.

D. Null Hypotheses

The following null hypotheses were tested ($p < 0.05$) that there would be no significant relationships:

a. between the field and laboratory measures;

b. between the field measures;

c. between the laboratory measures; and

d. of soldiers' rating by commanders with field and laboratory measures.

E. Limitations

1. The field measures of common tasks were obtained indoor, at room temperature of 18 to 22 °C
2. Subject motivation level during field and laboratory measures could not be fully controlled nor monitored
3. No assessment of subject skill level was made

F. Delimitations

1. The standards were based on data obtained from male combat infantry soldiers of the Canadian Army.
2. Field measures of the study were delimited to the following common tasks, representative of soldiers' job requirements as specified by the Army Command Council:
    - A. Execute Rescue Duties:
        1. Casualty Evacuation
    - B. Live and work in army environment:
        1. Lift and carry ammunition boxes at a submaximal effort
        2. Transport jerry cans (water and gasoline containers) at maximal effort
    - C. Execute survival duties:
        1. Maximal effort slit trench digging
        2. Weight load marching in full fighting order
3. The laboratory measures were delimited to the following body composition, muscular strength and endurance variables:
    - A. Body Composition:
        1. Percentage of body fat
        2. Fat free weight
    - B. Muscular strength:
        1. Maximal isometric handgrip strength
        2. Maximal isometric arm flexion strength at an elbow angle of 105°
        3. Maximal isometric trunk flexion strength at a hip angle of 160°

4. Maximal isometric trunk extension strength at a hip angle of 160°

5. Maximal isokinetic-concentric arm flexion strength through a full range of motion

6. Maximal isokinetic-concentric trunk flexion strength within the hip angle range of 150 to 170°

7. Maximal isokinetic-concentric trunk extension strength within the hip angle range of 150 to 170°

8. Maximal isokinetic-concentric bench press strength through full range of motion

9. Maximal isokinetic-concentric leg extension strength through knee angle of 90 to 180°

10. Maximal isokinetic-concentric knee flexion torque through knee angle of 180 to 90°

11. Maximal isokinetic-concentric knee extension torque through knee angle of 90 to 180°

12. Maximal isokinetic-concentric trapezius lift strength

C. Muscular endurance:

1. Isometric handgrip endurance capacity

2. Isometric arm flexion endurance capacity at an elbow angle of 105°

3. Isotonic-concentric trapezius lifting endurance capacity

G. Definition of Terms

1. **Task:** A task is any single part of work, such as lifting a box to the truck bed or digging a slit trench.

2. **Position:** It is a group of tasks performed by one person. Every employed worker fills a position (Hanman, 1951: in Marston et al., 1981).

3. **Job:** A job is a group of similar positions in one establishment. Usually several persons work on one job. Sometimes only one person may work at a given job (Hanman, 1951: in Marston et al., 1981).

4. **Occupation:** An occupation is a group of similar jobs throughout a nation or the world (Hanman, 1951: in Marston et al., 1981).

5. **Common Tasks:** The representative physical tasks required for the Infantry Occupational Specialty.

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

7. **Commander FMC (Forces Mobile Command):** Lieutenant-General responsible for the Canadian Forces Land Component (Army).

8. **Command Council:** Committee chaired by Commander FMC with senior representatives from all elements of Combat Arms.

9. **Minimum Physical Fitness Standard:** It is the lowest acceptable fitness level at which an individual may be reasonably expected to successfully undertake standing army orders.

10. **Laboratory Tests:** Tests of muscular strength and endurance, and body composition under controlled conditions in a laboratory setting.

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

12. **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 (Sharkey, 1988).

13. **Percentage of Body Fat:** It is that percentage of body weight that is actually adipose tissue, estimated from Brozek's formula (Brozek et al., 1963).

14. **Fat Free Weight:** The body weight minus the weight of body fat (Buskirk and Mendez, 1984).

15. **Residual Volume:** The amount of air that remains in the lungs after a maximum expiration (Harris, 1986).

CHAPTER II. REVIEW OF LITERATURE

A. Introduction

The establishment of task related performance standards, for the Canadian Army, based on occupational physical demands and physical capability to do work, has become a requirement both from an operational point of view as well as human rights legislature perspective. The use of these standards is a relatively new concept. Most military around the world do not have such standards but the concept is gaining popularity (Patton et al., 1978). Currently, most nations have fitness standards established for their armies by a process of normative referencing i.e., based on the achievement on general fitness test scores (not specific to task) of certain upper percentile of the normal army population. Such standards are based on age and type of group assignment (combative or support). These factors are known to influence the physical performance. The norm referencing approach does not account for individuals' ability to meet the specific physical requirements of the jobs. Many jobs assigned to soldiers can be physically very demanding. Therefore, some men are believed to lack the physical capacity required to fulfil the requirements of their jobs. To satisfy issues raised by human rights tribunals and in order to provide equal opportunity for individuals' to demonstrate their ability to fulfil the physical requirements of the jobs, task related, age free performance standards should be established. These standards should be based on the representative physical requirements of army's occupations.

B. Purposes of the Task Related Physical Performance Standards

The purpose of performance standards is to ensure that soldiers have the physical capabilities to meet the physical demands of their occupations. Some of the relevant components of occupational physical performance in this regard include body composition, muscular strength and endurance. Through the use of performance standards, the key physical attributes necessary to perform the jobs are stated in clear, measurable terms. When used for employee selection purposes, performance standards also can be helpful in screening people who would have difficulties in meeting the physical demands of jobs. In the initial phase of establishing the standards many factors are taken into consideration in determining the appropriate tests that would be used as screening tools to aid in personnel management. These factors include test reliability, validity, safety, cost and time constraints. Perhaps the most important factor is the measure of content validity between the actual occupational demands and the tests used to assess an individual's capabilities (Nottrodt and Celentano, 1984; Nottrodt and Celentano, 1984: Report (Rp.) #60)).

Improper screening can result in injury to workers (Arnold et al., 1982). In purely economic terms, injuries may result in increased medical and rehabilitation costs, workers compensation benefits, and decreased productivity. In human terms, individuals who are physically unsuited for their jobs run an increased risk of injury to themselves, and to other workers. Thus, tests of physical ability are important in both human and economic terms.

More than half of the lost work time in manufacturing and office jobs is reported to be associated with overexertion (e.g. low back pain, sore hands, wrists, arms, and shoulders). Low back pain is a major medical problem in industry. It is primarily related to overexertion and/or poor back fitness (Pransky et al., 1988; Himmelstein, 1988). Himmelstein et al. (1988) indicated that 21% of all compensable work injuries and 33% of workers compensation costs are attributable to low back pain, resulting in approximately 400,000 back injuries in the United States per year. The incidence is reported to be eight times greater for workers in jobs requiring high lifting strength compared to those requiring little or no lifting. In fact, material handling is believed to be the most hazardous act in industry. A great amount of work time is lost because of low back pain, and it ranks as the eleventh highest reason for total number of days spent in the hospital in the United States (Pransky et al., 1988; Chaffin, 1974). For these reasons, the ammunition box lift task, for the present study, was conducted at a submaximal level (70% of VO_2 max).

Derr (1988) stated that many of the most difficult ethical problems associated with worker fitness and risk evaluation programs are raised by efforts to identify the so-called "susceptible" or "high-risk" workers. Such workers run greater risk of occupational injuries. Even though they be technically qualified yet they may not be physically fit to do the job. Most of these problems can be avoided by proper development and implementation of suitable task related performance standards (Pransky et al., 1988).

In assessing physical capability of an individual for a specific job, the performance test battery should be a simulation of the most physically demanding tasks (Pransky et al., 1988). It is necessary, especially from a human rights point of view, to show that one needs the capacity to do work, and that those who lack this capacity cannot do the job satisfactorily. From a legal perspective, one must demonstrate content validity. Face validity and predictive validity alone would be insufficient for applicant's rejection (Rodgers, 1988; Kerlinger, 1986).

Once an individual is selected for a job, performance standards serve as the basis for the job orientation and induction process. The later refers to learning and experience required to perform all aspects of a job comfortably and satisfactorily (Schell and Kieshauer, 1987). When an individual has completed the induction phase, performance standards become baseline expectations. They also serve the purpose of giving feedback to the workers which may result in further improvement of their performance. Feedback is given with regards to: (a) workers' strengths, (b) areas needing improvements, (c) areas showing improvements, (d) attainment of previous objectives, and (e) new objectives and time lines (Schell and Kieshauer, 1987). The strategies to achieve new objectives also should be discussed.

C. Assessment of Physical Fitness in the Military - a Canadian Perspective

In the military, personnel physical fitness has been assessed by health oriented tests rather than task related tests based on the physiological working capabilities of the soldiers. Many military organizations around the world assume that if soldiers are physically fit for activities such as running, push-ups or other similar strenuous events then they are also fit to perform their jobs effectively (Jette and Kimick, 1986).

After 1972, the evaluation procedure used to assess the fitness level of CF personnel was the performance of a timed 1.5 mile run. This test had age and gender related standards based on Cooper's work (Mayo, 1984). Many military personnel who attempted to complete this test did not have adequate training. Administrators introduced a compulsory conditioning program to train those who failed the test. This program was poorly run and often ignored at some units. As a result of health related implications stemming directly from participation in the test, the Surgeon General concluded that this method of fitness assessment carried an unacceptable health risk for participants aged 30 years and over. All fitness testing was subsequently stopped for those above 30 years of age in September, 1980 (Mayo, 1984). The CF EXPRES Program was then introduced in 1983 to safely assess the basic fitness level of CF personnel.

The 1.5 mile run was an inappropriate test of general physical fitness evaluation since the minimum standard of performance could be achieved by individuals who were basically sedentary but spent a few weeks each year preparing for the run or even worse, did not prepare at all. Further more, it gave little or no indication of success with which the soldiers could fulfil their occupational duties (Mayo, 1984).

The CF EXPRES (Exercise Prescription) program was derived from the civilian Canadian Standardized Test of Fitness (Fitness Canada, 1981). The program consists of four components:

1. A pretest screening process to ensure the absence of health risk factors prior to testing. This includes a health appraisal and analysis of resting blood pressure and heart rate.
2. A physical fitness evaluation consisting of muscular strength, upper and lower body muscular endurance capacity, and body composition measurements.
3. An exercise prescription consisting of an individually prescribed physical fitness training program of sufficient frequency, duration, and intensity, to ensure improvement in fitness level (Participaction, 1986). In addition, unit training programs could be used as part of the prescription.
4. The major emphasis is to promote habitual participation in a effective physical training.

For assessment purposes the measurement of muscular strength is the sum of the right and left hand maximal handgrip force as measured with an isometric handgrip dynamometer. Muscular endurance is measured by the number of push-ups and sit-ups that can be completed in one minute.

The CF EXPRES is reported to be appropriate for gross fitness evaluation but is not sensitive enough to monitor specific physiological changes through physical training. As indicated in a study by Bell and Jacobs (1986), after 12 weeks of hydraulic resistance training the laboratory tests suggested significant gains in the measured fitness variables. However, the EXPRES test did not detect these changes.

The selection of occupational tasks for the development of performance standards as they apply to the CF EXPRES test were not based on the most physically demanding tasks but rather the minimum fitness requirements within the military. In investigator's opinion the test battery of the CF EXPRES program does not accurately assess soldiers' task related performance. The formation of the CF EXPRES program, age related standards did not take into account the physiological capabilities unique to soldiers and the physical requirements specific to their jobs. It appears that the performance standards also lack face validity among different military functional groups. The CF combative forces clearly required a higher level of physical fitness than can be demonstrated by the EXPRES program.

In the Canadian Forces, there are, at present, no officially sanctioned and standardized tests of physical fitness to assess the operational readiness of field units other than the Battle Efficiency Test (BET). This test has its own inherent limitations. It appears to measure one's ability to march, jump and evacuate a soldier for 200 m, and gives no indication of how successful he would be in performing various other military tasks (Myles et al., 1985).

The BET consists of two 16 km route marches, in full fighting order, and is conducted in two consecutive days. The first march must be completed in less than two hours and 45 min and includes scaling a 1.33 m wall, jumping a 2.44 m ditch and carrying a soldier for 200 m. The second day's march must be completed in less than two hours and 30 minutes but does not include the two jumps and a carry. The test is performed in groups of 10 or more soldiers (Jette and Kimick, 1986). Myles et al. (1985) indicated that this test can be hampered by terrain and weather conditions. It lacks standardization and the norms are somewhat arbitrary. Furthermore, during the testing, the individuals can carry each others equipment, if necessary, and it is highly dependent on motivation and group encouragement (Jette and Kimick, 1986).

D. Muscular Strength and Endurance Requirements for Work

Rodgers (1988) states that a person's capacity for physical work is not a single value; it is determined by several factors including the time of continuous effort; the frequency of repeating the effort; the presence of environmental or mental stressors, such as heat, humidity and time pressure; individual characteristics, such as age, fitness, skill level for the task; and number and size of the active muscle groups. To determine the capacity needed to do a specific muscular activity, one needs to:

(1) define the active muscle groups

(2) rate of the effort intensity

(3) measure the time of continuous activity

(4) measure the recovery time between contractions

(5) determine the duration of muscular effort over the work-period

Physical fitness measurement provides an indication of the ability to perform physical work (Knuttgen and Kraemer, 1987). By estimating the physical capability, a rational selection of personnel for various occupations in military services can be facilitated (Tornvall, 1963). A common military belief for the CF appears to be that personnel should meet the minimum standards for physical fitness. Less emphasis is placed on the measurement of maximal capabilities (Myles and Toft, 1980).

The successful performance for various tasks appears to require general rather than specific physical abilities (Arnold, 1982). This indicates that the selection instruments should tap general physical abilities rather than the specific. However, assessment of these abilities would require quantification of some specific physical fitness characteristics of the involved muscle groups. The measures that are chosen require that the individuals being examined make motions and exert force, in a simplified and standardized form much as they would in performing the actual on-the-job tasks (Arnold, 1982). The task to be tested should be representative of the work.

For determination of optimal task performance the following points should be taken into consideration:

(a) the time it takes a worker to perform a given task

(b) the loss in productivity associated with hiring weaker workers

(c) the increased safety risks of physically weak workers (Arnold et al., 1982).

The optimal rate at which an individual works in relation to his physical capability is very crucial. Anything below or above this optimal level may reduce his total working output.

Two of the important components of physical fitness related to task efficiency are muscular strength and endurance. Individuals possessing high levels of muscular strength and endurance are generally believed to be more productive and less likely to get injured. The studies of Glesser and Vogel (1973), and Monod (1985) suggest that work rates which can be sustained are best expressed as a percentage of physical capability. The individuals with greater physical capability can sustain a higher work rate than the ones with a lesser ability.

The maximal weight that can be lifted is related to maximal muscular strength. For strength demanding tasks the effort intensity can be related to the strength of the muscle groups involved in the task. It is expressed as a percentage of the maximum strength for that working posture. Timing of the continuous contractions and recovery times for a given set of muscles can be used to assess the onset of fatigue. The strength aspects of fitness are very specific for the task considered. It is reasonable to require an individual's maximal lifting capacity to exceed, by a certain percentage, the requirements of the task (Arnold, 1982).

Arnold et al. (1982) indicated that past a certain strength level, performance no longer improved: time, rather than strength, apparently became the limiting factor for the number of bags (each weighing 22.7 kg) lifted and carried. Jorgensen and Poulsen (1974) demonstrated that in repetitive submaximal lifting both the capacity of the oxygen transport system and the back muscle strength acted as limiting factors. Probably the most practical consideration showed was that nothing was gained by increasing the weight of the burden above 50% of the maximum lifting capacity. The work output per unit time above this value did not increase. There are also increased injury risks and back pain associated with lifting tasks approaching the maximal capacity of the individual. The work of Monod (1985) indicated that, for intermittent static work, such as that performed in carrying tasks, the maximal safe load for a 10 min performance with muscle contractions maintained 50% of the time is 45% of an individual's maximal voluntary contractile force. He further stated that it might be reasonable (after trying to compensate for injury incidence rate) to permit 80% maximum lifting capability as a guideline for infrequent single lifts.

It is important to note that when developing performance standards for continuous work-tasks, lasting approximately 30 min or longer, any minimum fitness requirement above 50% of group mean score should be considered unacceptable as a desirable fitness level (Sharp et al., 1988). This could create a demand for a fitness level that may be unattainable by some individuals, regardless of how hard they train to improve their physical capabilities.

Taller individuals have been shown to lift greater amounts of load to the same height (Switzer, 1962: in Marston et al., 1981). A review of literature reveals that a number of anthropometric measurements (such as body mass, lean body mass, stature and different girth and circumference measures) are significantly correlated with various measures of strength (McDaniel et al., 1983: in Nottrodt and Celentano, 1984, Rp. #60). However, many of these correlations are too low for practical use in prediction of strength related performances.

The Relationship of Strength Between Regions of the Body

The static endurance is reported to be well correlated with isometric strength (Tuttle et al., 1955). The correlation between dynamic endurance and isometric strength is relatively low (Clark, 1954). Tornvall (1963) reported that good correspondence of strength is normally found between right and left side values of body musculature as well as between synergist and antagonist muscles. Muscle groups belonging to the same region appear to be more closely related to one another than those in other parts of the body. The correlation between neck musculature and the strength of other upper extremities and trunk was found to be rather low. This was also the case for the power of the trunk musculature compared with that of the upper extremities. Correspondence between trunk and leg muscular strength was, on the other hand, stronger. A relatively high correlation was also indicated between the values of the upper and lower extremities (Tornvall, 1963).

Different Components Contributing to Muscular Strength and Endurance

Theoretically each individual is assumed to have a certain range of muscular strength and endurance capability, which is genotypically determined. The actual phenotypical value may be divided into two factors: basic or minimal strength; and strength superimposed thereupon by training. Basic or minimal strength is considered to be the characteristic for each individual. The training component of strength may vary according to the demands of the environment. "The basic muscle strength is presumably well correlated in different parts of the body, since it is genotypically determined" (Tornvall, 1963).

Muscular Strength and Endurance Testing

For selection of a strength test, as suggested by Nottrodt and Celentano (1984, Rp. #61), the following points should be considered:

1. the test should be safe, reliable and quantitative
2. practical in terms of cost, time consumption, administration, data collection and interpretation

There is evidence that static strength tests may be potentially hazardous to individuals with high blood pressure (Goldberg et al., 1982; Chaney, 1981: in Nottrodt and Celentano, 1984, Rp. #61). However, static tests have been considered to be safer by some researchers, partly because they are less time consuming and less susceptible to fatigue (Chaffin, 1975; Asmussen, 1967: in Nottrodt and Celentano, 1984, Rp. #61). As reported by Nottrodt (1984, Rp. #62), they are also safer for the following reasons:

1. the dynamic stresses imposed by the motion of lifting an object are considered hazardous
2. the risk of dropping a lifted object increases as an individual approaches maximum capability
3. the repeated lifts of incrementally increasing weights create greater fatigue which can enhance the probability of the two previous risks

In addition, static tests have also been reported to be easier to standardize, leading to more reproducible results. As represented by calisthenic procedures it has been reported that static strength measures were better predictors than dynamic strength tests of tasks involving lifting, pulling or pushing heavy objects (Robertson and Trent, 1983: in Nottrodt and Celentano, 1984, Rp. #60; Celentano et al., 1984). Nottrodt and

Celentano (1984, Rp. #61) reported that the static strength tests, particularly maximal voluntary exertions which modelled lifting actions, had the greatest potential as useful predictors of various task performances.

However, isotonic strength gains are reported to be less noticeable on static tests. In early strength training studies, simple and quick isometric tests were used to evaluate isotonic strength gains and vice versa. The relationship between isometric and isotonic strength ($r = 0.77$) accounts for less than 60% of shared variance (Sharkey, 1988; Sharkey, 1966). Thus, the gains in isotonic training may not show up on an isometric test or vice versa. For this reason, dynamic strength and endurance testing may also be essential in order to predict dynamic occupational performances.

For prediction of general strength a combined testing of both arm and leg-muscle strength is suggested to result in a higher accuracy than the measurements confined to the upper or lower extremity alone (Sharkey, 1988).

Isotonic Free-Weight Endurance Testing: In the traditional free-weight endurance testing several areas of primary concerns existed:

1. Safety was the primary concern especially when lifting heavy weights. Often to overcome this weakness one or more spotter(s) were required to assist during testing.
2. Difficulty existed in isolating concentric contractions. Physiologically, the maximal tension generated by the skeletal muscles is greater for the isometric and the eccentric contractions than the concentric (Johnson et al., 1976; Doss and Karpovich, 1965). Therefore, the isometric and eccentric contractions normally could not be performed closer to maximal loads since the weight lifted would not

exceed the maximum for the concentric phase of the exercise.

A new Isotonic Free-Weight Dynamometer, developed by Singh et al. (1989), overcomes these problems and maintains all of free-weight's advantages. It allows an individual to isolate the concentric contraction. Most of the physical tasks of army tend to be concentric or isometric in nature. Physiologically, the loads which can be handled through the isometric and eccentric phases are relatively higher than the concentric phase. Therefore, the concentric strength and endurance may be the limiting factors in task performance and thus quantification of the eccentric variables are not applicable for standard development. The dynamometer is built so that during a exercise repetition the active phase (concentric phase) is controlled by the subject and the passive (eccentric phase) by the exercise apparatus. The predetermined speed at which the weight loaded bar returns to the starting position is controlled by the gear reduction box connected to an electrical motor. The speed once adjusted cannot be altered by the amount of force on the weight loaded bar (Singh et al., 1989). For multi-repetitions, as soon as the weight loaded bar comes back to the starting position, an individual lifts it again using the musculature under testing (e.g. trapezius lifts). This cycle continues until the desired number of repetitions is achieved. During concentric contraction if the subject is not able to complete the lift, the weight does not drop. Instead, it returns, at the preset speed, to the starting position.

Recently the free-weight dynamometer has been modified to function isokinetically (Singh et al., 1991; Figure 1). This change allows strength measurement for bench press, in a single maximal voluntary contraction. Previously, the subjects had to do series of contractions to reach one repetition maximum. These submaximal contractions

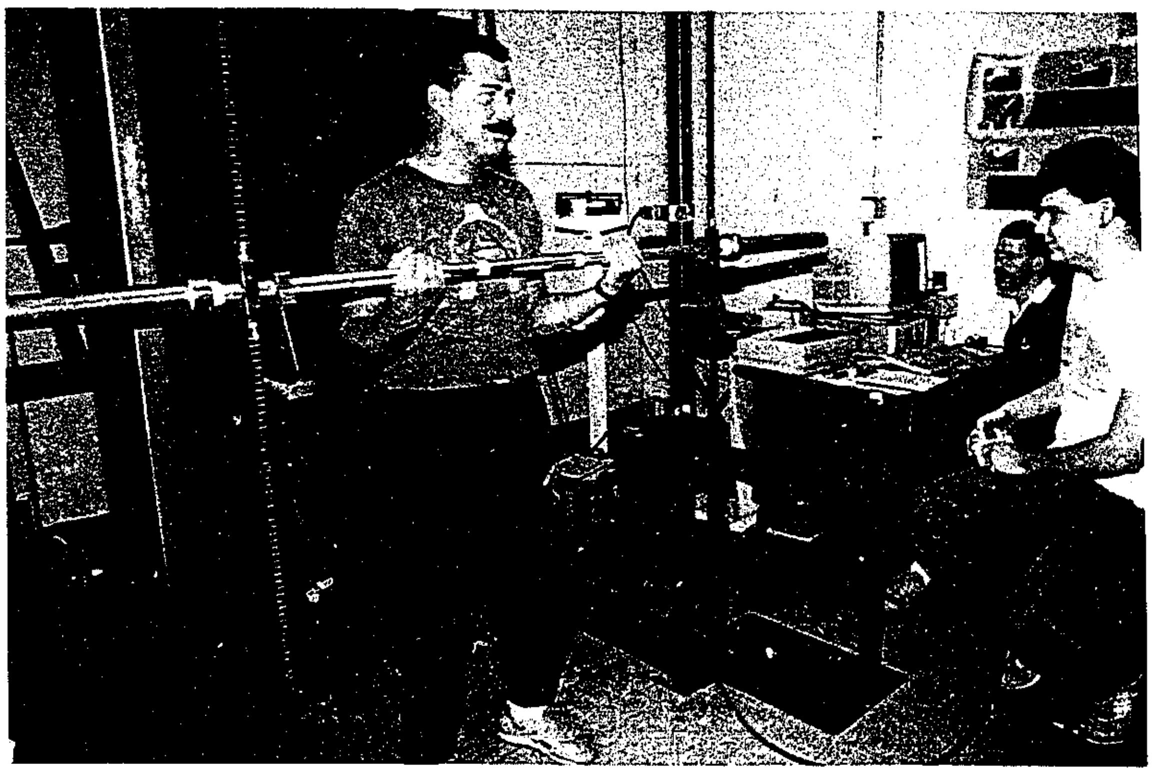

Figure 1. Subject Performing a Static Arm flexion Strength Test with Isotonic\Isokinetic Dynamometer.

would result in muscle fatigue and thus underestimation of the true strength.

Effect of Age on Muscular Strength

After 30 years of age the maximal strength of the Canadian soldier is reported to be minimally affected till the age of 60 years (Allen et al., 1980). A decline of about five percent in maximal strength occurs from 55 to 65 years. Allen et al. (1980) stated that soldiers who actively participated in any extra physical curricular activities achieved significantly higher scores on vertical jump height, number of push-ups and sit-ups than those who did not. There was a significant decline in performance with increasing age in all three tests for both groups. Based on the results of their study, Allen et al. (1980) reported that VO_2 max did not discriminate between these two groups and would not detect the differences in performance related to muscular strength.

Lifting Tasks in the Army

In the tasks used to develop occupational physical selection standards for all Canadian Forces trades, lifting strength was identified as the predominant physical requirement (Celentano and Nottrodt, 1984, Rp. #58; Nottrodt and Celentano, 1984, Rp. #59). One hundred CF trades were analyzed, in an occupational physical selection standards (OPSS) study, and 131 criterion tasks were identified of which 95% involved lifting and carrying (Allen et al., 1984, Rp. #57). Analysis indicated that most of these lifting tasks begin at floor (ground) level and end between waist and shoulder level (104 cm and 145 cm). Fifteen percent of the tasks required lifting above shoulder level. Trades were grouped by task demands using a five level lifting classification system developed by the U.S. Department of Labour and modified by the U.S. Army (Table 1). This revealed that 73% of trades accounted for 80% of CF personnel having a

Table 1. U.S. Army Job Classification System (Allen et al., 1984, Rp. #57).

Category	Criteria
Light	Lift 20 lbs maximum with frequent lifts of 10 lbs
Medium	Lift 50 lbs maximum with frequent lifts of 25 lbs
Moderately Heavy	Lift 80 lbs maximum with frequent lifts of 40 lbs
Heavy	Lift 100 lbs maximum with frequent lifts of 50 lbs
Very Heavy	Lift in excess of 100 lbs with frequent lifts of more than 50 lbs

Table 2. Distribution of CF Trades and Personnel by the U.S. Army Job Classification System (Allen et al., 1984, Rp. #57).

Demand Category	Number of Trades	Percent of Trades	Number of Personnel*	Percent of Personnel
Light	13	13.0	3301	5.1
Medium	11	11.0	6688	10.3
Moderately Heavy	57	57.0	40228	62.2
Heavy	13	13.0	9489	14.7
Very Heavy	3	3.0	4133	6.4
Unaccounted	3	3.0	844	1.3
TOTAL	100.0	100.0	64688	100.0

* Personnel as of November 1983.

Moderately Heavy (ability to lift 36 kg) or heavier requirement (Table 2).

Research has shown that the amount of weight an individual is able to lift decreases as lifting height increases. This weight decreases dramatically if the lift exceeds the person's chest or shoulder height (Chaffin et al., 1975; Snook and Ciriello, 1974; Snook and Irvine, 1967). Lifts from ground level are reported to involve whole body effort: legs, back, abdominal region and the arms. For most persons, lifting capability is reported to be limited by upper body strength.

Trunk Muscle Strength

A study concerning trunk muscle strength during constant velocity movement was conducted by Thorstensson and Nilsson (1982). The effects of gravity were removed by performing the movements in a horizontal plane (side lying position). The forces produced during flexion and extension movements varied with velocity and position. The typical recordings obtained in the study are shown in Figure 2. The strength of abdominal musculature was demonstrated to be less than half of the back extensors through most of the range of motion. The abdominal muscles have been shown to be more susceptible to fatigue than the back extensors (Smidt et al., 1983; Hasue et al., 1980).

Physical Requirements of Digging

One of the specified selected common tasks, representing soldiers' job requirements for the present study, was digging slit trenches. Intensity of digging, in the related literature, have been primarily reported in terms of submaximal aerobic power (Stevenson et al., 1987, 1988; Chakraborty et al., 1974). For optimal performance, muscular strength and endurance of arms, trunk and leg musculature is also necessary.

Figure 1. goes on this page. This page has been removed due to copy right restrictions. Information contained in this figure was from (Thorstensson and Nilsson, 1982) showing trunk flexion and extension force output readings.

However, from a research point of view the role of this musculature, for digging, is not well understood nor investigated. The fastest digging times, for equivalent amount of gravel to the present study (0.5 m^3), for males were two to four minutes (Stevenson et al., 1987, 1988).

Physical Requirements of Marching

Work intensity for marching has been largely reported as a percentage of the aerobic power. The role of muscular strength and endurance in marching capabilities is not well understood. Dziados et al., (1987) conducted a study to investigate some of the physiological determinants of load bearing capacity during marching in full combative gear. Because this task is largely aerobic in nature, the maximal aerobic capacity is believed to be an important determinant of load bearing ability. To assess the role of muscular strength and endurance of the lower extremities in load bearing activity, 49 infantry soldiers were measured for:

a. muscular strength of the quadriceps and hamstrings

b. muscular endurance capacity of the quadriceps and hamstrings

c. body composition

Following these measures, the infantry soldiers made a maximal effort 16 km road march with battle dress equipment weighing 18 $\pm$ 1 kg. The hamstring muscle strength was a significant factor in marching time. It emerged as the only significant predictor of march time when step-wise multiple regression was performed (multiple R = 0.45; r = 0.21).

One way of improving load bearing performance of an infantry soldier is through the reduction of the load he carries. The tactical and logistical requirements of battle limit the degree to which this strategy is possible, eventually resulting in diminishing return (Dziados et al., 1987).

The study, by Soule et al. (1978), indicates that as long as the load is axially placed (close to the spine), the additional energy cost attributable to the load carried is approximately equivalent to the weight distributed over the body as subcutaneous fat.

Greater muscle strength and endurance of the hamstrings and quadriceps are likely to be beneficial with respect to load bearing performance. The relative contribution of upper versus lower extremity muscular strength and endurance to load bearing performance is unknown. In some respects, the marching load, in the study by Dziados et al. (1987), was too light to represent the burden expected in actual combat. The intention was to employ a weight which could allow the soldiers to run if they were capable of doing so. Levine et al. (1982), in a study on self-paced load carriage, found that absolute predicted energy expenditure between fit and unfit subjects did not differ significantly, and hypothesized that fit subjects were limited by their inability to walk any faster. Dziados et al. (1987) suggested that if the selective strength training of the hamstring muscles could significantly improve specific load bearing performance then the changes in the methods for soldier training can be modified.

E. Models Related to Task Oriented Performance Standards

There is very little evidence, in military, which supports the use of muscular strength and endurance fitness factors for formation of task related performance standards (Arnold et al., 1982; Vogel et al., 1980; Patton et al., 1978).

United States Army Model

The United States (U.S.) Army has made an attempt to establish, age free, minimal fitness standards (Vogel et al., 1980; Daniels et al., 1979; Patton et al., 1978). The model used by this army can be of great value in future development of standards for other professional groups and organizations. It is based on clustering of occupations into five groupings based on levels of physical requirements (Table 3). Each representative task of every cluster was measured in terms of muscular strength requirements. The minimum requirement for each cluster was based on peak force demand measured among all the representative tasks of that cluster (Table 4). Based on field measures of strength the physical fitness standards for each cluster were determined by desirable levels of performance.

The common soldiering tasks, used by the U.S. Army, consisted of:

1. eight kilometre march in two hours
2. dig a one-man emplacement in 45 min
3. lift and carry: move 50 lb bag 50 m, repeat eight times within 10 min.
4. low and high crawl, for total of 75 m in 90 s
5. grenade throw: 15, 25 and 35 m
6. rush: sprint 75 m with two intermediate stops of two seconds each, within 25 s (Patton et al., 1978)

Adequate performance of these common tasks was originally specified for all soldiers to be completed by the end of basic training. They have been developed by the U.S. Army Infantry School. The standards established for these tasks were based on expert judgement by a panel of military veterans. The infantry trade was classified in the alpha cluster.

Table 3. U.S. Military Trade Clusters (Vogel et al., 1980).

Cluster Designations	Strength Demands
alpha	high
bravo	high
charlie	high
delta	medium
echo	low

Table 4. U.S. Military Trade Clustering Criteria (Vogel et al. 1980).

Intensity Rating	Strength Demands (kg weight lifted to waist height)
low	< 30
medium	30-40
high	> 40

A question arises that whether the performance standards, developed for the U.S. Army, can be applied to the needs of the Canadian Army? From structural and functional perspectives of the two armies, the answer is no. Firstly, the Canadian Army consists of only about 23 thousand personnel whereas the U.S. contain approximately 2.5 million. This size of the Canadian Army represents less than a one hundredth that of the U.S. Army. Most of the trade specialities are not exactly the same among the two nations which presents further problems of using the same standards. Secondly, the requirements and expectations of Canadian soldiers are different from those of the United States. Depending on the needs, Canadian soldiers can be expected to perform many roles in the army structure other than what is normally required for their day to day job requirements. For example, depending on demand of a situation such as during peace keeping duties, each soldier in the Canadian Army can potentially become an infantry soldier. Therefore, the physical demands placed on the Canadian soldier are different from those of the American. For this reason the clustering of the military occupational specialties for the Canadian Army, is not feasible since many of the expectations of the soldier can lie outside of his daily job requirements. Thirdly, the performance standards for the Canadian Army must relate to the combat equipment currently in use. All of the battle equipment used by two nations is not the same. Finally, some of the laboratory tests may not correlate with the performance of the army tasks. Therefore a combination approach of laboratory type of tests (where the correlation is high) and the task related performance standards may be required to validly predict the capabilities of soldiers to perform their job requirements.

Based on what is reported in the literature the U.S. Army model, for most soldiers, would theoretically impose higher performance standards than what is required by their occupations. The variability of fitness requirements within clusters could be greater than that of the occupations at high and low fitness requirement levels between the consecutive clusters.

LIFTAN Model

A knowledge-based expert system, called LIFTAN, for lifting has been developed by Karwowski et al. (1986). Since most tasks in industry and military involve lifting and carrying, the use of this system may provide some promising results. It allows a novice in the field of manual lifting to utilize the relevant knowledge and apply it to analyze specific work situations to determine individual's ability to perform the lifting requirements of jobs. LIFTAN is not a complete stand-alone risk analyzer. Further work is needed to be carried out to augment the present knowledge base (Karwowski et al., 1986). Currently, this model may be used to enhance the development of task related physical performance standards. However, since many military and industrial activities also tend to be aerobic in nature the model has a limited use.

Standardized Obstacle Courses

The Canadian Forces, as well as the Soviet Military, have developed standardized obstacle courses to asses the performance of their personnel (Jette and Kimick, 1986). Based on the assessment of subject matter experts, the obstacles consist of similar physically demanding events which are normally encountered during military duties. The advantages of these courses are that they can be administered in standardized conditions. Their use as a practical and valid measure of the field situations needs to be established. These courses do not appear to take into account individuals' physiological capabilities required to do work. Since these tests are performed at near maximal effort the energy systems utilized may not be representatives of the field tasks.

F. Steps for Development of Task Related Physical Performance Standards (Chahal et al., 1991)

Following are five main steps in the development of standards:

1. Identification of most physically demanding common tasks, in a job, based on the

operational requirements

2. Identification of physical capabilities required to successfully complete the selected work tasks, and development and\or selection of appropriate laboratory tests which predict the capability to complete these tasks

3. Quantification of physical capacities required for completion of laboratory test and field task performances

4. Statistical analysis of data to determine population performance characteristics on different tests and predictive relationships among laboratory and field task variables

5. Determination of acceptable level for the performance standards.

Stage 1: This phase deals with identification of tasks and their subcomponents for the organization as a whole. The organizational structure may consist of many occupational specialties. Each occupation tends to consist of several jobs. For example the Canadian Army, an occupation within the military organization, consist of four main job classifications: armoury, infantry, artillery, and support staff. A job may involve several tasks. Some of the tasks involved in a job of an infantry soldier consist of digging, casualty evacuation of an other soldier of equivalent height and weight, weight load marching, jerry can lifting and carrying, and ammunition box lifting. Each task then can be subdivided into subtasks which further consist of basic physical elements. For example, the casualty evacuation task can be broken down in subtasks: lifting an other soldier and then running 100 m while carrying the assumed to be an injured soldier on shoulders and back. Elements consist of such factors as the loads involved in lifting or carrying, the frequency, duration, body postures, percent participation, and environmental factors which may be associated with the working conditions (Ayoub et al., 1987; Marston et al., 1981).

The procedures for identification include survey questionnaires, interviews, observation, and physical measurements. The survey questionnaire is used to rank order tasks according to qualitative task demands. Then the tasks are classified according to the physical demands such as strength, muscular endurance, anaerobic and aerobic demands (Ayoub et al, 1987; Teves et al., 1985).

After task and component identification, most physically demanding common tasks representative of the work situation are selected in consultation with the subject matter experts. The subject matter experts are experienced supervisors of the jobs who have excellent working knowledge from a practical point of view as well as extensive observation of other workers' performances. It is assumed that if the individual soldiers are able to demonstrate their ability to perform more physically demanding tasks then they can also perform relatively less taxing tasks (e.g. lifting 30 and 20 kg). The selected tasks also should receive approval of most senior administrators. Feedback from the subject matter experts and approval of the senior administrators allows greater face validity to the selected tasks and also ensures acceptability of the set standards within an organization.

Stage 2: This stage involves identification of various physical fitness components required to perform the selected tasks. The factors most related to the work capacity are muscular strength and endurance, aerobic power and capacity, anaerobic power, and anaerobic threshold. Once these components are identified, appropriate laboratory tests should be developed and/or selected to quantify these components of physical performance. These tests should emphasize those components of fitness that are involved in the performance of the selected field (work) tasks (Myles et al., 1985). The purpose of the laboratory tests is four fold: (i) to validate the field tasks with the known valid laboratory tests of physical components; (ii) to validate the laboratory tests against field tasks (cross validation); (iii) to predict field task performance based on the laboratory measures; and (iv) based on the relationships between the field tasks and laboratory tests establish training programs for the soldiers who do not meet the requirements of the set standards.

Stage 3: In this phase, the quantification procedures involve measurements of laboratory test and field task performances. Representative workers, selected to develop the standards, perform these tests under simulated working conditions. The time to complete the task along with intensity of effort are the most important variables in determining ability to work.

The maximal strength and muscular endurance should be determined for those muscle groups which are most commonly used in actual working situations. The muscular endurance should be determined based on the load normally carried in the working situation. For example, if soldiers lift a 21 kg ammunition box, the relevant laboratory test (such as a trapezius lift endurance test) should be performed with a similar load. This would result in maximal predictability of a field task performance.

Stage 4: This phase involves statistical analysis of data. Descriptive data such as frequency distribution, mean, standard deviation, and range of scores should be determined and compared to other populations reported in the related literature.

The next step is the Pearson Product Moment Correlation Coefficients between laboratory and field variables. The raw data should be plotted to make sure linear combinations exist before computation of correlation coefficients. If they are non-linear, then appropriate data transformation procedures should be utilized before computing these coefficients. These correlation coefficients determine the relationship among variables. They also are helpful in reducing number of variables for multiple correlations and canonical correlations to ensure adequate subject/variable ratio to have the confidence in the results (Kerlinger, 1986).

After elimination of the non-relevant variables, the multiple correlations and stepwise regressions equations should be obtained. Multiple correlations are determined by relating a set of laboratory variables with a given field task variable. Similarly the multiple correlation and stepwise regression equations should be determined for field tasks predicting performance of each laboratory test. The main purpose of this analysis is to determine individual laboratory performance profiles based on the suggested performance standards of the field tasks. These profiles should be examined in order to ascertain that the workers have the physiological capabilities to meet the job requirements.

The canonical correlation between the set of laboratory and field tests should also be obtained. This gives an indication of how the selected laboratory tests relate to the performances of all the field tests combined.

Stage 5: This stage involves setting up desirable physical fitness performance standards. One way of setting the task related standards is through establishment of predictive relationship between laboratory and field variables. If the laboratory tests relate highly to the field task performance then they may be of most practical use. Such tests may be easy to administer, less time consuming, and require very little or no extra equipment. However, if the laboratory tests show no or minimal relationship with the field task performance, then task specific standards must be utilized. Where only a few of the tests show high correlations with the field task performance a combination of two approaches could also be utilized.

To determine a cutoff point for an acceptable performance standard a combination of two approaches should be used. When collecting the data a panel of experienced subject matter expert judges should be established. This panel should watch the performance of each field task very carefully and determine, based on the occupational requirements, which they believe are pass or fail performances. Once this process is completed, then the panel of judges should decide collectively if they unanimously agree on possible standard performances. If an agreement is reached, then these suggested performances should serve as a guide to establish cutoff points for task related standards. However, if they do not agree then they follow the observation procedures again and evaluate their pass and fail performances until a collective agreement is reached. This procedures is necessary to establish criterion (non-normative) related task standards.

The cutoff performance time suggested by the panel should be checked using discriminant analysis (Kerlinger, 1986) for correct classification of data into pass and fail groups. The suggested performances also should be validated against the data collected for the laboratory tests and compared against the related literature to make sure that the soldiers can physiologically meet these requirements. If the suggested level of acceptable performances by the expert panel is in agreement with the discriminant analysis and physiological findings then these are the set standard performances. However, if discriminant analysis and physiological data do not support the findings of panel of experts then some subjective adjustments to the cutoff performances needs to be made until there is an agreement among all three.

G. A Suggested Theoretical Model for Development of Task Related Physical Fitness Standards

From a physical performance point of view, to meet the total needs of an organization, as shown in Figure 3, the minimal standards ideally could be set at three levels. If all members in the organization are required to perform certain common physically related tasks then part of the standards can be set at LEVEL 1A. These standards apply to all personnel within the organization. In situations, where some occupations have similar physically related tasks but they are not common across occupations, then the standards could be set at LEVEL 1B. These standards apply to all members within each cluster of occupations. They do not apply to the individuals belonging to other occupational clusters. Depending on the structure of an organization, a combination of both, LEVEL 1A and 1B, may have applicability. Within each occupation, the standards set at LEVEL 2 are job related. The tasks for which they are set are not contained in any other occupation within the organization. If all jobs within a occupation have some common tasks or physical demands then the standards at LEVEL 2A are of most practical use. But if some jobs have unique common tasks or physical demands then the LEVEL 2B also may be applicable. Depending on the structure of an occupation, a single level or combination of both levels may have applicability.

The standards at LEVEL 3 are set for a specific job level. These standards may apply only if a given job has unique physical demands within the organization. These standards only apply to the personnel responsible for a specific job.

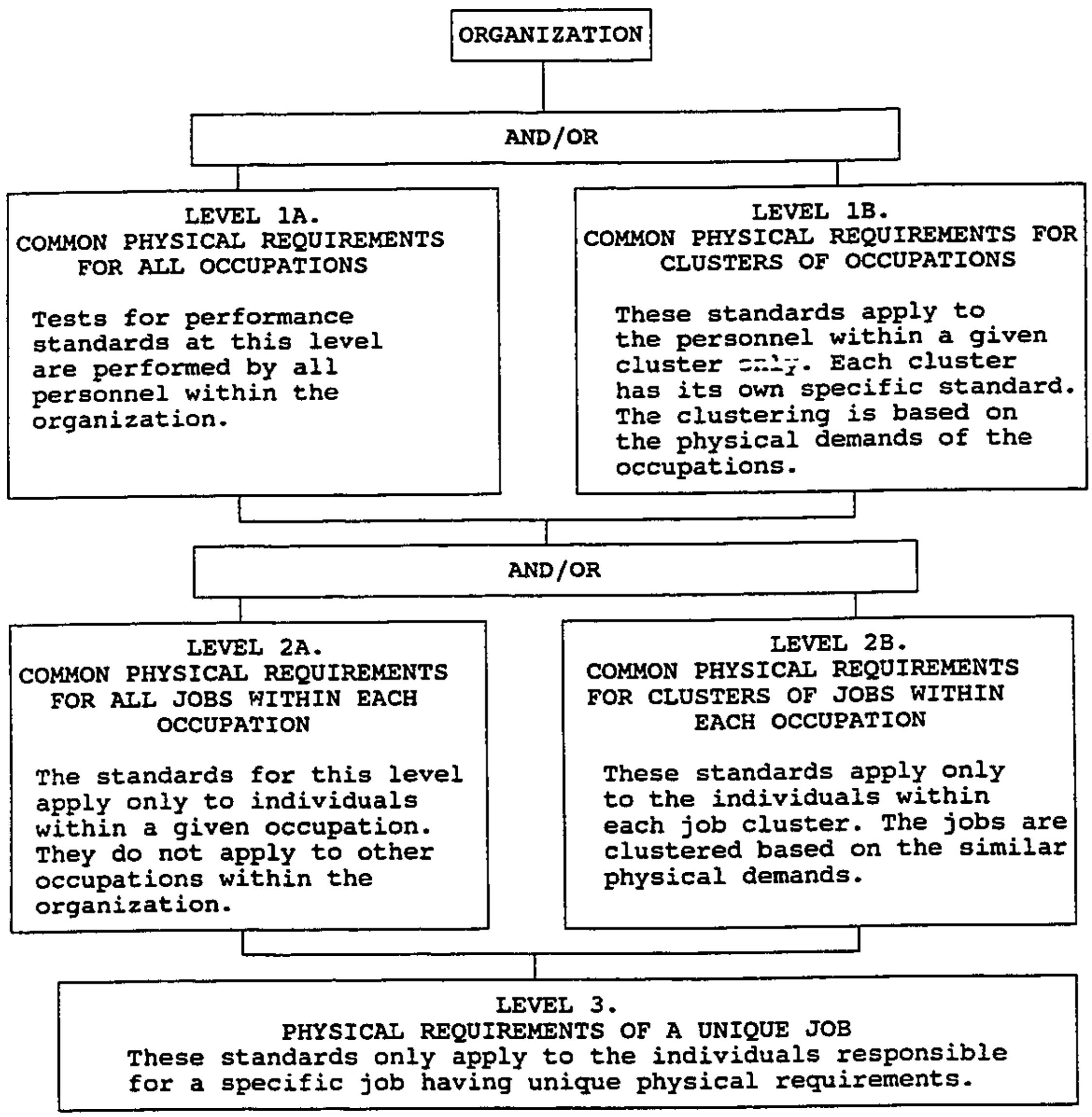

Figure 3. A Suggested Theoretical Model for Establishing Task Related Physical Performance Standards.

The use of this proposed model can be limited by its complexity, financial and time constraints both from standard development and administration points of view. Certain standard models used by organizations to meet their needs, such as the Mdl fr the U.S. Army, can be viewed as a part of the current model (LEVEL 1B). However, when a component of the suggested model is disregarded at the expense of financial or time constraints the set standards may not be as effective. They may determine higher or lower levels of physical capacities in certain situations than the optimal. The optimal level of physical capacity is the one which allows an individual to fulfil the job requirements with reasonable physical effort, without experiencing undue stress. In other situations the standards may play a limited role in predictability of ability to carry out the desired physical tasks.

There may be certain jobs within an organization, e.g. the executive positions, in which the physical requirements may be very low and thus the use of physical performance standards may not be as relevant. For personnel in such jobs optimal level of physical fitness is still important for many health related benefits. These include decreased accidents and health related problems, and increased alertness as well as a more positive work attitudes (Mayo, 1984).

Development of Performance Standards for the Canadian Army

All of the Canadian Army personnel sometimes in their career may have to function as infantry soldiers. So therefore, every soldier in the CF combative forces, in addition to performing the requirements of his own occupational specialty, must also be capable of performing all the job requirements of an infantry soldier. This means that the minimal fitness standard set for the infantry personnel must also apply to soldiers in the other occupational specialties within the army. These occupational specialties are artillery, armoury, and combative support groups.

Job Requirements of the Infantry Soldier: As described by Jette and Kimick (1986), "these soldiers must be able to work outdoors in all types of weather and geographical locations, and for long periods, without rest, food or shelter". They are expected to perform efficiently when suffering from extreme mental and physical fatigue. Considerable physical exertion is required by these individuals as well as a high degree of manual dexterity and coordination. They may be required for special air mobile or amphibious type of operations and could serve in arctic, mountainous, jungle or desert environments (Jette and Kimick, 1986; CF Manual of Other Ranks, 1983). To determine the specific job requirements, Directorate of Military Occupational Structures (1983) analyzed each trade of the infantry on a periodic basis. Five hundred and seventy one different infantry tasks were identified as a result of this process. Some of the more physically demanding tasks are outlined in Table 5.

H. Body Composition and Physical Performance

Fat-free Body Weight and Physical Performance

Fat-free body weight is calculated by total body weight minus the fat weight. It is known to affect some physiological performance functions. Although fat-free weight and lean body mass are not the same, most investigators calculate fat-free weight but report it as lean body mass. Many authors use these terms interchangeably. Lean body mass includes the concept of an essential amount of lipid necessary for membrane and nerve as well as other physiological functions, whereas, the fat-free weight excludes all lipid (Buskirk and Mendez, 1984). Further confusion is wrought when lean body mass is equated with body weight minus weight of adipose tissue. The adipose tissue contains not only stored lipid, but a cellular matrix that contains protein, water, minerals, and a small amount of membrane lipid. In most procedures the fat-free weight is determined by subtracting fat or lipid weight from the total body weight (Buskirk and Mendez, 1984).

Table 5. Physically Demanding Tasks of the Infantry Men (Jette and Kimick, 1986).

1. Performing individual movements (leopard crawl, etc.)	11. village clearing operations
2. digging trenches	12. woods clearing operations
3. constructing bunkers/fortifications	13. house clearing operations
4. route marches	14. range ammunition party
5. obstacle course training	15. construction of obstacles
6. combat swimming	16. clearing/breaching obstacles
7. unarmed combat	17. laying mines
8. mountain climbing/repelling	18. nuclear, biological and chemical warfare drills
9. mountain warfare training	19. changing tires
10. approach and assault operations	20. fighting floods, and
	21. fighting forest fires

Total body potassium, nitrogen, creatine, and 3-methylhistidine excretion have been used to estimate the total muscle mass. It may be stated that greater the muscle mass the higher concentration of phosphagens, thereby, increase in the capability to generate maximal strength (Ergen et al., 1983). As stated by Ergen et al. (1983) significant correlations have been demonstrated between maximal strength, work output and lean body weight (LBW).

Percentage of Body Fat and Physical Performance

Considering other factors constant, the percentage of body fat is believed to be related to physical performance. For master swimmers, Harris (1986) showed that percentage body fat values increased with age ($r = 0.51$, $p < 0.05$). Subjects consisted of 20 females and 40 males in the age range of 20 - 49 years. The performance levels for swimming were reported to decline one percent per year from age 25 to 35 years. They showed a high degree of negative correlation (-0.72) between body fat and treadmill running time.

Jette and Kimick (1986) demonstrated high performers to have lower percentage of body fat on a 19-item Indoor Standardized Obstacle Course (ISOC). It consisted of running, crawling, scaling, pulling, lifting, carrying and pushing events arranged in a sequential order. The purpose of the course was to assess soldiers fitness by execution of tasks similar to those encountered under combat conditions. The events were selected to assess the major components of fitness related to the performance of military tasks. These events were reported to require minimal skill levels. Forty-three healthy male subjects between the ages of 21 to 31 years underwent a series of intensive laboratory testing. The scores of 10 top and bottom performers were compared in relation to the percentage of body fat. The total percentage of body fat estimation was obtained from the skinfolds measurements. The mean scores for each group were computed. The individual scores for the subjects were not reported. The results indicated that the high performer group had a mean of 10.7% of body fat whereas the low performers had a mean of 19.5%. One of the reason for their performance differences may have been a poor physical fitness level of the low achievers in relation to the high achievers. The second possible factor is that they were carrying excess fat weight which may have required greater physical effort and thus had slowed them down. Buskirk and Taylor (1957) stated that excess fat does not have any significant effect on the ability of the cardiovascular and respiratory system to deliver oxygen to the muscles under maximal conditions. However, the individuals with greater percentage of body fat than the optimal level are at a disadvantage because extra load of fat which does not contribute to performance. The excess fat does increase the oxygen uptake and thus the cardiovascular load during a submaximal external load. It also increases muscular strength and endurance demands to perform a task (Buskirk and Taylor, 1957). The empirical observation of many activities indicates that the high achievers, for activities placing high muscular strength and endurance demands, tend to have lean and mesomorphic body build.

Methods of Assessing Body Density

Many methods are available for measuring body composition. Some of the most common laboratory methods are underwater weighing, volume displacement, radiographic analysis, potassium-40, isotopic dilution, Bioelectrical Impedance Assessment (BIA), tomography, nuclear magnetic resonance, and ultrasound techniques (Caton et al., 1988; Roche, 1984; Jackson and Pollock, 1982). These methods have a higher degree of validity than the field tests such as the skin folds and are considered appropriate for research purposes.

Limitations of Equations used for Measurements of Body Fat

Lohman (1981) showed that equations developed on one group will be bias when applied to subjects who differ in gender, age and fatness. Equations developed on younger subjects will underestimate the body density and thus overestimate the body fat of older subjects (Jackson and Pollock, 1982).

The interpretation of the density of the human body as fat and fat-free body percentages is where the greatest source of variance lies. This variation results when any of the following assumptions, as outlined by Lohman (1984), do not hold:

1. The fat-free body composition and density is relatively stable with little interindividual variability in water, protein, mineral content or muscle and bone content.
2. The fat composition and density is similar among individuals.
3. The differences between populations in the mean fat-free body composition has little effect on body composition estimates, and thus reference man is a good standard for all populations.
4. The environmental influences including nutritional effects are of minor importance in affecting fat-free body composition.

Estimates of biological variation in the fat-free body composition from animal and human studies support the concept that errors of three percent fat arise from converting body density, water, and potassium content into body fat weight within a given population especially for white, adult, college-age males (Lohman, 1984). The equation developed by Siri (1961) for converting body density to body fatness is based on fat-free body density of 1.100 g/cc and fat density of 0.900 g/cc. Brozek et al. (1963) proposed that fat be estimated from body density using the equation based on the chemical composition of a reference man.

Hydrodensitometry

Some of the assumptions and problems in utilizing hydrodensitometry in the calculation of body fatness remain unresolved. These include the true densities of different gross components of body composition in the young, aged, and physically fit. Due to many problems associated with measurement of body density by underwater weighing alternative methods have been developed (Buskirk and Mendez, 1984). Garrow et al. (1979) reported that the standard deviation was no greater than 0.3 kg fat for repeated measurements on three subjects who varied considerably in body fatness.

Bioelectrical Impedance in Assessing Body Composition (BIA Method)

This method measures the body impedance with a low level current conducted through the tissues (Abu-Khaled et al., 1988). Because the fat-free mass contains electrolytes, it behaves like an electrical conductor with electrical properties highly dependent on the ionic states. The whole-body resistance is dependent primarily on the configuration such as geometry of the body, the length of the conductive path, the amount of body water, electrolyte concentration, and the compartmental distribution of body water and electrolytes (Caton et al., 1988). Factors which alter the route of electrical current through the body are not well understood. It is possible that changes in distribution of body water relative to BIA electrodes, such as those occurring with a change in skin blood flow, could alter the resistance and therefore affect the estimation of body fat (Caton et al., 1988). The BIA method compared with hydrostatic densitometry was found to overestimate fatness in lean males and underestimate it in overweight subjects (Segal et al., 1985). State of dehydration or hydration may affect the resistance and thus the results. In humans over hydration would likely give relatively higher resistance measurements whereas dehydration should result in relatively lower resistance values (Abu-Khaled et al., 1988). The problem of dehydration may be controlled to some degree by having the subjects drink one to two glasses of water one hour and urinating about five minutes prior to testing. In this time period the body is assumed to eliminate any excess water or replenish any deficits.

The measurement taken under different ambient temperatures also alters the resistance values (Caton et al., 1988). Predicting the fat mass has been demonstrated to be significantly lower in warm than cool conditions (24 °C vs. 33.4 °C). Caton et al. (1988) demonstrated that varying skin temperature by altering ambient temperature significantly changes resistance measurements and the estimation of total body water and percent fat. The temperature induced change in resistance was assumed possibly due to alterations in cutaneous blood flow and/or compartmental distribution of body water. Therefore, Caton et al. (1988) recommended that the BIA measurements should be taken only under well-standardized ambient conditions. Despite all these limitations, this method, as demonstrated by Khaled et al. (1988), showed very high correlation ($r = 0.97$) with the hydrostatic method for estimation of the percentage of body fat. However, its superiority over the hydrostatic method was not demonstrated nor claimed.

CHAPTER III. METHODOLOGY

A. Subjects

A sample of 116 full-time male Infantry Soldiers, in age range of 18 to 44 years, was randomly selected from the Canadian Forces Base in Calgary. Prior to testing all subjects were medically examined and screened within the month preceding the data collection. An information package containing description of the tests was sent to each subject.

Testing Sessions

The subjects were administered a laboratory test battery at the University of Alberta, Faculty of Physical Education and Recreation. A field test battery was given at the Canadian Forces Base (CFB) in Calgary. Prior to testing, the subjects were familiarized with the test procedures and equipment. All testing sessions were supervised by a medical assistant trained and equipped to handle emergencies. During the testing, the temperature was maintained between 18 to 22 °C. Subjects were requested not to smoke nor consume caffeine beverages at least four hours prior to testing. They were also advised not to engage in any strenuous activity nor consume alcoholic beverages for a period of at least 24 h prior to testing (Appendix A1).

Before testing subjects were required to fill and sign the following:

a. Physical Activity Readiness Questionnaire (PAR-Q: Appendix A2)

b. a Health Appraisal Form (Appendix A3)

c. a Laboratory Consent Form (Appendix A4i).

d. a Field Consent Form (Appendix A4ii)

B. Testing Protocols for Laboratory Tests

Muscular Strength and Endurance Testing Equipment

Isotonic Electronic Free-Weight Dynamometer: This apparatus was designed and built to eliminate the eccentric contraction phase which is a feature in isotonic endurance testing (Singh et al., 1989, Chahal and Singh, 1988). When the subject was required to do more than one repetition, eg. for trapezius lift endurance capacity test, the weight loaded bar came back to the starting position at a preset speed eliminating the eccentric phase; the subject then lifted the bar. This cycle continued until termination of the test.

Isokinetic Electric Trunk and Leg Dynamometer: The electric trunk and leg dynamometer measured isokinetic-concentric, and isometric maximal strength (Singh et al., 1991; Chahal, 1988; Singh, 1972). The isokinetic strength tests performed on this apparatus consisted of concentric leg extension, trunk extension and flexion tests. The isometric strength tests conducted on this apparatus included trunk extension and trunk flexion (Figure 4).

The dynamometer consisted of an electric motor connected to a chain from which a cable passed over ball bearing pulleys and emerged at a point between the subject's feet and in front of him (for leg extension and trunk extension tests). For leg extension testing the cable was connected to a steel bar which was firmly attached to a four-inch webbed belt (Singh and Bucks, 1975, Figure 5). Sewn to the webbed belt was an automobile seat belt with a buckle. By adjusting the buckle, the belt could be securely fastened around the subject's waist (Okoro, 1987).

For trunk extension a bar was hooked at the end of the cable (Chahal, 1988). This allowed the subject to stand and do the back-lifting motion. For trunk flexion testing the

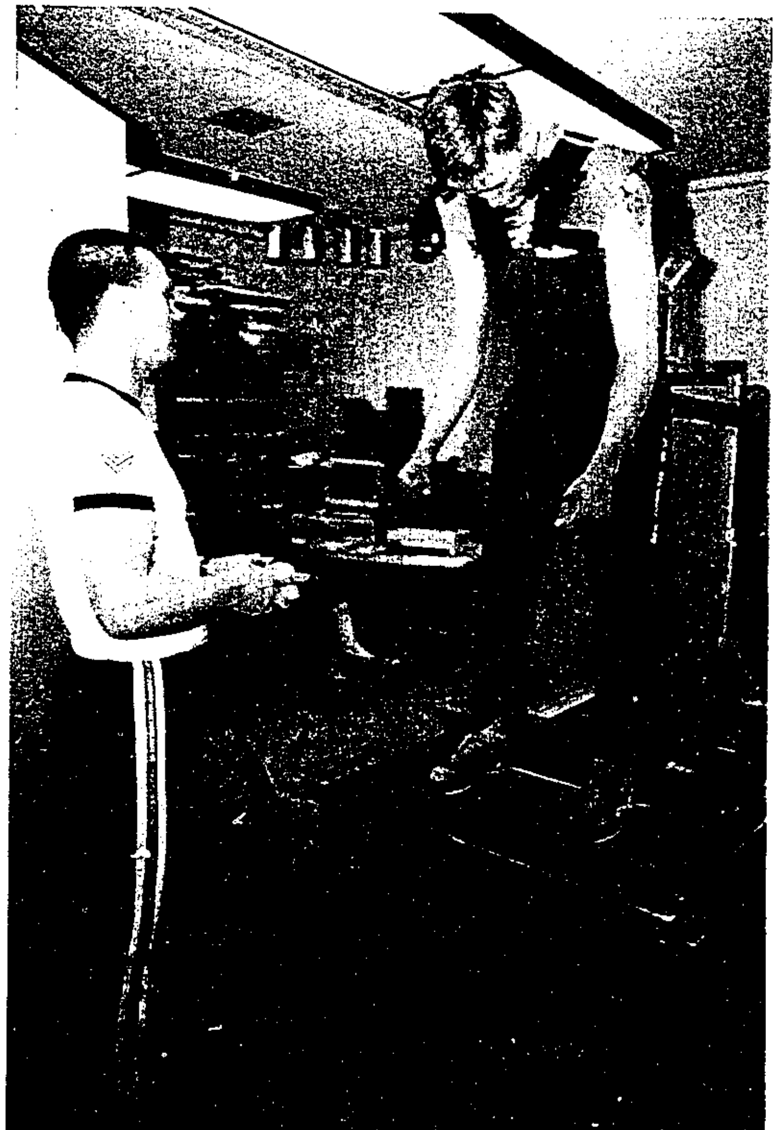

Figure 4. Maximum Isometric Trunk Flexion Strength Test Being Conducted on the Electric Trunk and Leg Dynamometer.

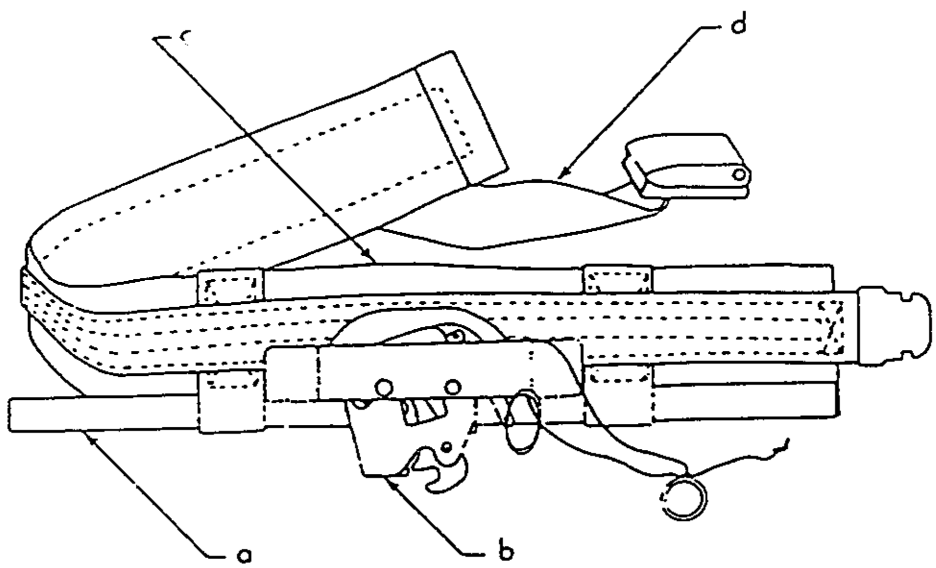

Figure 5. Special Belt used for Leg Extension Strength Test: (a) Steel Bar, (b) Release Mechanism, (c) Webbed Belt, (d) Automobile Seat Belt (Singh & Bucks, 1975).

cable was connected to two pulleys located on posterior aspect of the back board (Chahal, 1988). The cable was then connected to the shoulder harness through the back board.

The electric dynamometer and load cells were checked prior to every testing session. Since the legs can produce considerable force in leg extension test (up to 11,133 N has been observed for a isometric test) a 13,377 N capacity load cell was used. The subjects were instructed not to produce any bouncy movements during the test. Jerking movements during testing can result in artificial increases in peak force output. For other tests the 4,459 N capacity load cell was sufficient to record force outputs. The load cell was connected to an IBM computer to record, plot and store data.

Other Equipment and Human Resources:

1. A Cybex Dynamometer
2. Two handgrip dynamometers
3. Two goniometers
4. Three stop watches
5. Two IBM computers
6. Bench (for bench press activity)
7. Five testers

Isometric Strength Tests

All of these tests were conducted at joint angles relevant to the chosen field tasks requirements. The isometric test battery consisted of handgrip, arm flexion, trunk flexion and extension tests (Appendix B1). For each test, before attempting maximal contractions, the subjects performed a warm-up contraction at a intensity of 50 to 60%

of the maximal voluntary effort. Following this, subjects performed two maximal voluntary contractions of five seconds duration each. A rest period of three minutes was given after each contraction. Maximal force recorded was used for data analysis. During each test, subjects were instructed to breathe normally. Verbal encouragement was given to subjects during testing.

Isometric Handgrip Strength Test: This test was conducted with a handgrip dynamometer (Carolina Biological Supply Company, Burlington, North Carolina, U.S.A.). Maximum grip strength of each hand was recorded. The testing procedures were the same as described by Stevenson et al. (1988).

Isometric Arm Flexion Strength Test: This test was conducted at an elbow angle of 105°. It represented the elbow angle at which soldiers generally carry ammunition boxes while transporting them. The bar was grasped at a shoulder width (the outside edges of hands being shoulder width apart).

Isometric Trunk Flexion Strength Test: To measure trunk flexion strength the cable was connected to a shoulder harness via two pulleys located on the posterior of the back board. Each subject executed this test at a hip angle of 160° (Figure 4). The placement of the harness hook, on the subject's upper back, was standardized at a height parallel to the inferior border of the upper arms at the armpit level. The upper pulley of the dynamometer was adjusted to the height parallel to the hook elevation while the subject was standing (Chahal, 1988). A chain was used to adjust the cable length according to the height of the subject. Position of feet was standardized with the lateral borders being shoulder width apart.

Isometric Trunk Extension Strength Test: Each subject completed a maximal

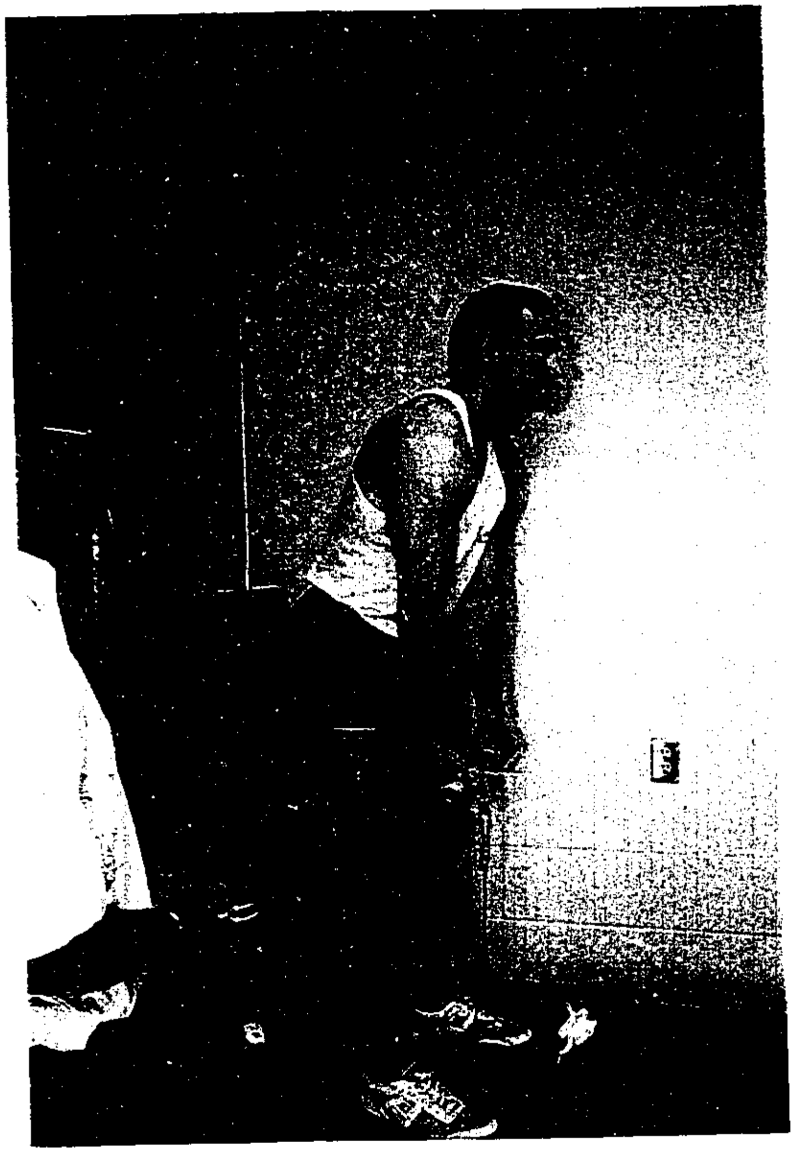

Figure 6. Trunk Extension Strength Testing on the Electric Trunk Dynamometer.

isometric trunk extension test at a hip angle of 160° (Chahal, 1988; Figure 6). Hip angle was measured with a manual goniometer before testing during the submaximal warm-up contraction. The placement of the goniometer was as follow: (a) the center of the goniometer was placed on the trochanter major; (b) the upper arm parallel to the supine; (c) and the lower arm of the goniometer war placed parallel to the shaft of femur. While performing the test the subject was instructed to keep his upper back straight. For safety reasons, this procedure was standardized for all subjects. An over and under hand grip was used to perform the test. The feet positioning, throughout the test, was the same as for the trunk flexion strength test.

Isokinetic-Concentric Strength Tests

The isokinetic-concentric strength test battery consisted of:

1. arm flexion
2. leg extension
3. trapezius lift
4. bench press
5. trunk flexion
6. trunk extension
7. knee flexion and extension tests

The first four tests were conducted at a cable velocity of 13 cm/s. This speed corresponded to an angular velocity of 30°/s (Okoro, 1987). The trunk flexion and extension tests were conducted at a cable velocity of 6.5 cm/s corresponding to an angular velocity of 15°/s (Ashton, 1973). It is well known that trunk movements tend to occur at slower velocities than those of peripheral joints such as those of legs and arms. The knee extension and flexion tests were conducted at an angular velocity of 180°/s as this speed is specific to knee angular velocity in weight load marching (Dziados et al., 1987).

Subjects performed six warm-up contractions at 50 to 60% of their maximal voluntary effort. Following warm-up contractions each soldier was asked to perform two sets of two maximal voluntary contractions (Appendix B1). A three minute rest interval was given after each set of contractions. The maximal force recorded was used for data analysis.

Isokinetic-Concentric Arm Flexion Strength Test: The arm flexion contraction was performed through a full range of motion, from approximately 180 to 40° of elbow flexion. The subject grasped the bar at shoulder width apart and during the test flexed his arms maximally by pulling it upward. Once full flexion was reached the arms were extended slowly without any resistance. The cable was lowered by the electric motor of the dynamometer to the starting position for another repetition.

Isokinetic-Concentric Leg Extension Strength Test: At the start of this test, the subject stood on the dynamometer platform so the cable could be adjusted to his waist height. The cable was then connected to a webbed belt fastened securely around the waist. For greater stability, the subject grasped at each end of the bar which attached to the webbed belt.

The test was conducted from a knee flexion angle of 90 to 180°. At the start of the test the subject assumed a 90° knee flexion and then pulled upward as the cable was released by the dynamometer at a preset speed. Once standing height was reached the subject returned to the starting position of 90° knee flexion to repeat another maximal contraction.

Isokinetic-Concentric Trapezius Lift Strength Test: This test was conducted in a standing position, feet shoulder width apart. Special handles on the weight bar were designed to simulate the handles of an ammunition box which were 38.5 cm apart. At the start of the test, from full arm extension, the subject lifted the bar upward until the top part of the grip handles reached a height parallel to subject's clavicle height (sternal end). He then relaxed while maintaining the grips as the bar returned automatically to the starting position. The subject then repeated the maximal contraction.

Isokinetic-Concentric Knee Flexion and Extension Torque Tests: These tests were conducted on a Cybex Dynamometer (Cybex, 1983; Moffroid et al., 1969) within a range of 90 to 180° knee flexion (Figure 7). Upon the "Start" command, the subject maximally extended the knee. Once full extension was reached then he maximally flexed the knee. This procedure consisted of one repetition. The test was conducted on each leg.

Isokinetic-Concentric Trunk Flexion Strength Test: The trunk flexion strength test was conducted through a hip angle range of 170 to 150°. The body positioning was similar to that during the isometric trunk flexion strength testing. From the starting position the subject pulled forward and downward while the cable was released by the dynamometer at a preset speed. Once 150° of hip flexion was reached the subject relaxed as the cable brought him back to the starting position automatically.

Isokinetic-Concentric Trunk Extension Strength Test: This test was performed through a hip angle range of 150 to 170°. The body positioning and handgrip was the same as for the isometric trunk extension strength test. While maintaining legs and back

Figure 7. Knee Flexion and Extension Torque Testing on the Cybex Dynamometer.

straight, the subject pulled up on the bar while the cable was released at a preset velocity. Once a hip angle of 170° was reached the subject assumed the starting position to perform another maximal contraction.

Isokinetic-Concentric Bench Press Strength Test: This test was conducted on the Isokinetic Electric Dynamometer. It was performed in a supine position on a bench. The bar height was preset two inches above the chest, at mid sternal level. The subject grasped the bar at shoulders width apart. At the start of the test he pushed it upwards reaching full extension of the elbow joints. He then relaxed while maintaining a grip on the bar as it returned automatically to the starting position. Once the starting position was reached the subject repeated another maximal contraction.

Muscular Endurance Tests

Isometric Handgrip Endurance Test: This test was designed to simulate the grip endurance requirement while transporting jerry cans (Appendix B2). It was conducted on each hand using the handgrip dynamometer. The subject maintained the force output needle at 205.8 N for as long as possible. Feedback to the subject was provided by the tester when the force needle started to deviate from 205.8 N. When the subject was unable to maintain the required force for two seconds, after feedback from the tester, the test was terminated. The endurance scores of each hand were recorded in seconds.

Isometric Arm Flexion Endurance Test: This test was conducted at an elbow angle of 105° (Appendix B2). This represented the elbow angle at which soldiers generally carry ammunition boxes while transporting them. The test was performed using a free-weight bar weighing 20 kg. A goniometer was used to monitor the constant elbow angle. The subject grasped and held the bar at a shoulders' width. Continuous feedback was provided to the subject throughout the test. The test was terminated when the subject failed to maintain the elbow angle for two seconds. The time sustained at the standardized angle was recorded in seconds.

Isotonic-Concentric Trapezius Lift Endurance Test: The body positioning and lifting technique, for this test, was similar to that during the isokinetic-concentric trapezius lift strength test. It was conducted on the free-weight dynamometer with a load encountered in the repeated performances of the ammunition box lifting task (Appendix B2). The rationale for choosing the free-weights over the isokinetic procedures was that the weight that a soldier needed to lift was the same, irrespective of the joint angle. Subjects performed 10 contractions per minute with a 21 kg load on the bar (including weight of the bar). Each contraction required approximately three seconds followed by a three second rest interval. During the passive phase of exercise the weight bar returned to the starting position in three seconds. The pace was set with a metronome. When the subject was unable to keep up with the pace or did 100 repetitions the test was terminated. The total number of completed repetitions was recorded.

Hydrostatic Weighing

A rectangular tank six feet in height, four feet in width and 10 feet in length was used for hydrostatic weighing (Figure 8; Appendix B3 and B4). Within the tank an aluminum chair was suspended from a load cell. This load cell was connected to an IBM computer. Prior to each test, the subject in a bathing suit was weighed on a balance scale to the nearest tenth of a kg. Before entering the tank the subject was instructed to shower. Once he was in the tank, sitting on a chair, a 9.45 kg diver's weight belt was placed across his thighs, close to the waist. Vital capacity was measured in this position.

Residual volume was estimated as a 24% of vital capacity. Then the hydrostatic weight was determined. The procedures for hydrostatic weighing were as follow (Appendix B3):

1. Air bubbles were dislodged from the swim suit, hair, and the body.
2. The subject maximally inhaled and closed the nasal passages. He was instructed to remain motionless in order to obtain a steady accurate computer weight reading.
3. The subject was slowly submerged in the water. Once a steady motion less state was observed by the tester, a six second underwater weighing reading was recorded. The chair was then pulled up, by the tester, so that subject's head and neck raised from the water.
4. The percent of body fat (based on the formula of Brozek et al. (1963)), and fat free body weight was then calculated by the computer.

This procedure was repeated until two similar readings, within a half percent of body fat, were recorded on the computer (Appendix B4).

Sequence and Scheduling of Laboratory Tests

The subjects were randomly divided into 10 testing groups (A - K), each containing up to 12 soldiers. Each group was tested over a two day period (Table 6 and 7). The laboratory testing was completed in two weeks.

Day One: On day one, each group left CFB Calgary by 0700 h and arrived at the University, in Edmonton, by 1100 h. Upon arrival they received a briefing of the study and the tests that they would complete. A light box lunch was provided; subjects reviewed the testing advisory (Appendix A1) and were allocated a subject number (1 - 12). This information, group and subject number, was written on a sticker and placed

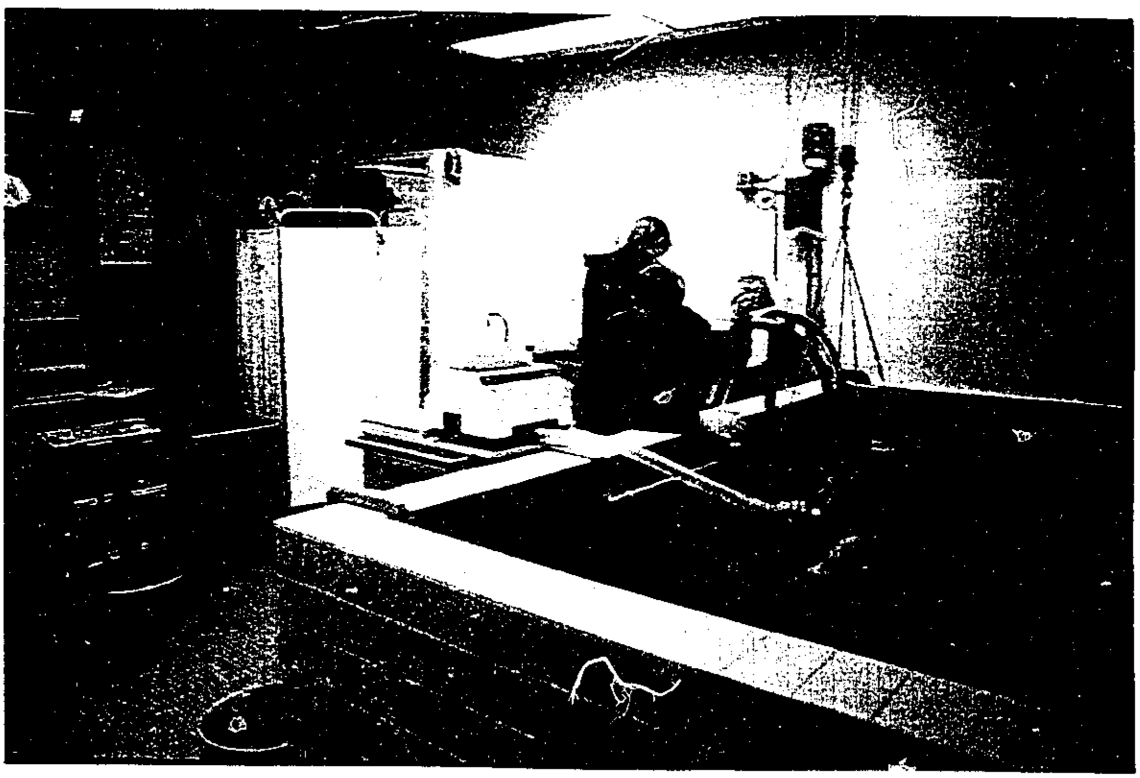

Figure 8. Hydrostatic Weighing in a Water Tank.

on right pocket of their uniform. The punctuality and adequate rest between testing sessions was emphasized. During introductory briefing each subject completed an informed consent form, a PAR-Q and a EXPRES health appraisal questionnaire (Appendix A2, A3, and A4i). Testing for this group commenced at 1300 h and terminated at 1900 h (Table 8).

Day Two: On day two, testing continued from 0700 h and terminated at 1200 h (Table 9). Day two of first group represented day one schedule for the next incoming group. For example, day two of group A was day one of group B. They received a briefing similar to Group A on day one. On day two group A was provided with a box lunch and departed for CFB Calgary at 1300 h This process continued for a six day cycle as shown in Table 6 and 7. Two six day cycles, for total of 12 days, resulted in the laboratory testing of 116 subjects.

C. Testing Protocol for Field Tests

Criteria for Selection of Common Tasks for the Canadian Armed Forces

From potentially hundreds of physical tasks which could have been chosen, a series of representative common tasks were selected by the researcher and a committee of army experts. The selection of common tasks was based on:

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 Forces Base (CFB) Wainwright, Alberta; and, at the headquarters of #1 Combat Brigade Group in Calgary, Alberta; and
3. interviews and special meetings at Forces Mobile Command (FMC)

Headquarters in Montreal, Quebec.

Table 6. Week One, Laboratory Group Testing Schedule.

Time (h)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
0700 to 1100	Group A Travel Intro.	Group A Test Set #2 Group B Travel Intro.	Group B Test Set #2 Group C Travel Intro.	Group C Test Set #2 Group D Travel Intro.	Group D Test Set #2 Group E Travel Intro.	Group E Test Set #2
1100 to 1300	Lunch, Rest or Test for Selected Individuals					
1300 to 1900	Group A Test Set #1	Group A Travel Group B Test Set #1	Group B Travel Group C Test Set #1	Group C Travel Group D Test Set #1	Group D Travel Group E Test Set #1	Group E Travel

Table 7. Week Two, Laboratory Group Testing Schedule.

Time (h)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
0700 to 1100	Group F Travel Intro.	Group F Test Set #2 Group G Travel Intro.	Group G Test Set #2 Group H Travel Intro.	Group H Test Set #2 Group J Travel Intro.	Group J Test Set #2 Group K Travel Intro.	Group K Test Set #2
1100 to 1300	Lunch, Rest or Test for Selected Individuals					
1300 to 1900	Group F Test Set #1	Group F Travel Group G Test Set #1	Group G Travel Group H Test Set #1	Group H Travel Group J Test Set #1	Group J Travel Group K Test Set #1	Group K Travel

Table 8. Day One, Individual Time Schedule for Laboratory Tests. Set One of Muscular Strength and Endurance Test Consisted of: Isometric Strength of Arm and Trunk Extension; Isokinetic-Concentric Strength of Leg Extension, Arm Flexion, Trunk Extension, Trapezius Lift, and Bench Press.

Day One		
0700-1100	Group travelled to the University of Alberta	
1100-1300	Study briefing, assignment of subject numbers, light lunch, rest (before and between tests)	
TIME (h)	Muscular Strength Tests (Set 1). Subject No.	Underwater Weighing Test. Subject No.
1300-1330	12	
1330-1400	11	
1400-1430	10	12
1430-1500	9	11
1500-1530	8	10
1530-1600	7	9
1600-1630	1	8
1630-1700	2	7
1700-1730	3	
1730-1800	4	
1800-1830	5	
1830-1900	6	

Table 9. Day Two, Individual Time Schedule for Laboratory Tests. Set Two of the Muscular Strength and Endurance Test Consisted of: Isometric Strength of Trunk Flexion; Isokinetic-Concentric Strength of Trunk Flexion, and Knee Flexion and Extension; Isometric Endurance of Arm Flexion; Isotonic-Concentric Endurance of Trapezius Lift.

Day Two		
0600-0645	Subjects Eat Before 0630 h, Boarded Bus 0645	
TIME (h)	Muscular Strength & Endurance Tests (Set 2). Subject No.	Underwater Weighing Test. Subject No.
0730	12, 11, 10	
0830	9, 8, 7	
0845		6
0900		5
0915		4
0930	6, 5, 4	3
0945		2
1000		1
1015		
1030-1130	3, 2, 1	
0700-1100	Next group travels to University of Alberta	
1100-1300	Study briefing, assignment of subject numbers, light lunch, rest (before and between tests)	
1200-1300	Testing group had lunch and departed for CFB Calgary	
1300-1900	New group started testing as per day one above	

As a result of the field observations and interviews, it was agreed that instead of picking representative tasks from the Armoury, Artillery, Infantry and Combat Support Groups that the one thing all groups had in common was the fact that they all could be called upon to carry out the duties of an infantry soldier at some point in the battle scenario. It was agreed that the infantry soldier's physical tasks were the most demanding in the Combat Arms groups. Accordingly, the common tasks for the Canadian Army were recommended by field officers and subject matter experts, and accepted and approved by the most senior army authority. The army experts included Lieutenant-General Foster (Commander of the Canadian Army) and his Command Council Staff, consisting of Brigadier-Generals from Combat Arms Staff. In addition, each of the Generals was provided input by their senior staff officers based on previously held meetings under the chairmanship of Major Lee at CFBs' Calgary, Wainwright and FMC Headquarters Montreal. Thus, the common tasks were verified and approved by Command Council as representative of the most demanding physical tasks for all Combat Arms personnel. Selected common tasks for the study were as follow:

1. **Execute Rescue Duties:**

    a. **Casualty Evacuation:** A soldier must lift another soldier or a mannequin (of a given weight) using Fireman's Carry and evacuate him for a given distance in a specified time.

2. **Live and Work in Army Environment:**

    a. **Handle Material Manually:** Lift a box equivalent in size and weight to a box of 5.66 mm ammunition unassisted to a level of a truck bed (at a given height).

b. **Transport Jerry Cans:** Carry a full jerry can of water (of a given weight for a given distance). Lift and empty jerry can into a container. Continue with the task for a given time.

3. **Execute Survival Duties:**

   a. **Digging Slit Trenches:** Scoop, lift and/or throw a given amount of standardized gravel out of a slit trench, in a given time using an issue shovel.

   b. **March:** March cross country a given distance in a specified time at a given pace in full fighting order in all weather and light conditions.

All tasks were to be completed individually, using current equipment and without assisting aids.

(I) Casualty Evacuation: In a battle situation an individual may need to evacuate a wounded soldier in the shortest possible time. Depending on circumstances in a realistic condition the time taken for one soldier to evacuate an other may mean a life and death situation for either or both of them. For this reason, the casualty evacuation task was performed at a maximal voluntary effort (Figure 9).

Each subject was required to evacuate an other soldier of equivalent height and weight at a maximal effort using a fireman's carry for a distance of 100 m (Appendix C1).

Equipment and Human Resources:

1. An other soldier of an equivalent height and weight
2. A gymnasium with 100 m indoor track
3. Light fighting order equipment
4. Two stop watches

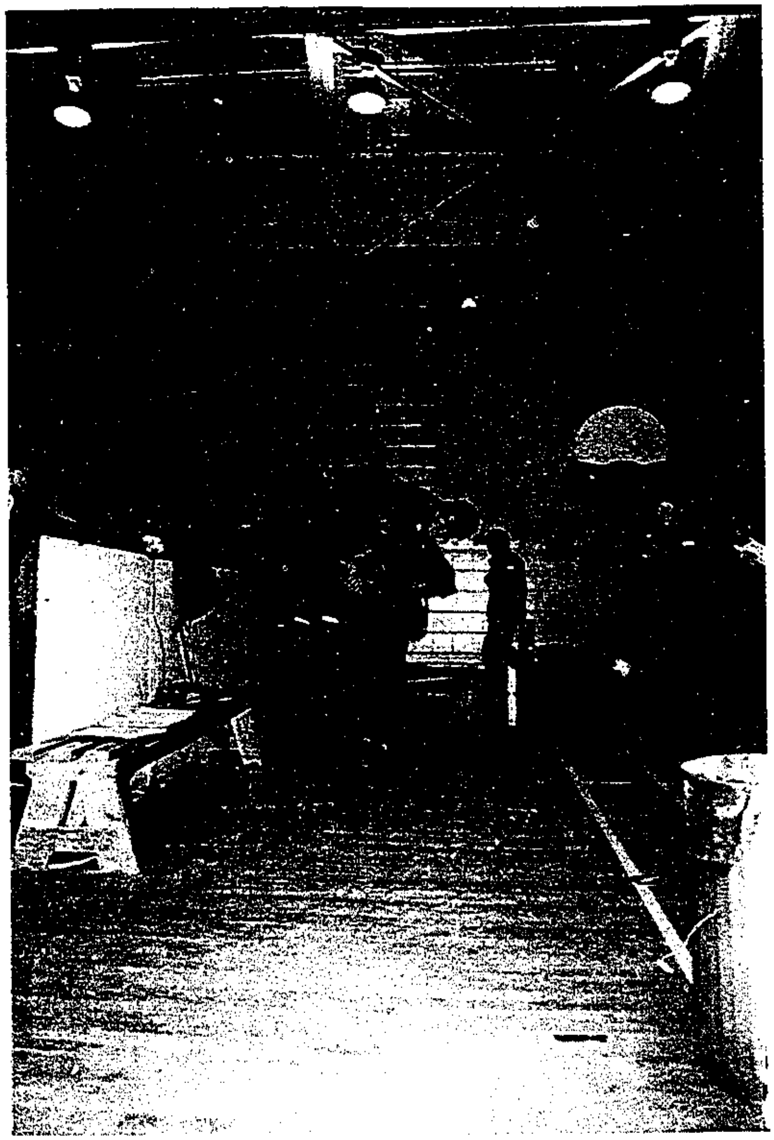

Figure 9. Casualty Evacuation Task in a Gymnasium.

5. Ten pylons

6. A measuring tape

7. Two testers

(II) Manual Material Handling (Ammunition Box Lift): This task involved lifting ammunition boxes, each weighing 20.9 kg. The task was performed at submaximal effort of 70% maximal aerobic power (Figure 10; Appendix C2). The task duration, as demonstrated in the pilot study ranged between 3:30 to 10:00 min. Each subject lifted a box from the floor and placed it on a truck bed simulator table at a height of 1.3 m. This procedure was repeated for total of 48 boxes.

<u>Equipment and Human Resources</u>:

1. Ten ammunition boxes
2. A truck bed simulator table (1.33 m in height)
3. Two stop watches
4. Two sport testers
5. Six pylons
6. Three testers

(III) Transport Jerry Cans: Often in military a soldier needs to transport fuel and water. In combative situation the task may require moving full jerry cans from one vehicle to an other and/or carrying them into the field. Two tasks were proposed: one at the maximum voluntary effort and the other at 70% maximal aerobic lower. However, the pilot study showed that the submaximal test had low reliability and was very cumbersome to administer. Therefore this task was eliminated form the test battery. As agreed by Subject Matter Experts, the standard set for this task was to be based on

Figure 10. The Ammunition Box Lift and Carry Task.

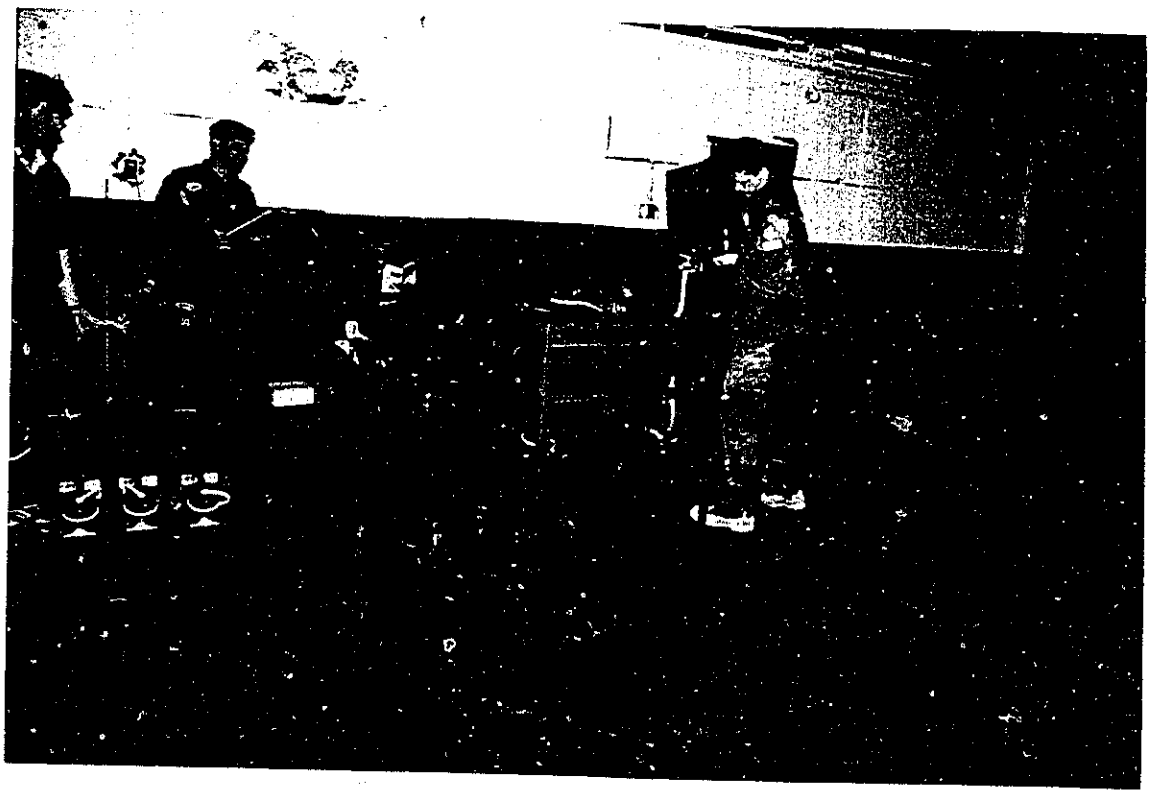

Figure 11. Gas-tank Simulator Table for the Jerry Can Task.

transportation of a single jerry can at a time.

Maximal effort jerry can task was designed to assess the maximal ability to lift, carry and empty jerry cans for duration of about two minutes (Figure 11; Appendix C3). The subject carried one full jerry can weighing 21 kg for distance of 35 m and then emptied it into a gas-tank simulator table, at a height of 1.3 m. Then he ran back and picked up another can and repeated the procedures. After three shuttle runs and emptying the cans into a funnel, the subject ran back to the starting line. As soon as his foot was over the line the task was terminated. The total time to complete the task was recorded.

<u>Equipment and Human Resources</u>:

1. Six jerry cans
2. Two jerry can gas-tank simulator tables
3. Floor mats (to put around gas-tank simulator tables)
4. Two stop watches
5. Ten pylons
6. One water bucket, jug and a mop
7. Two testers

(IV) Digging Slit Trenches: Each subjects was instructed to dig at the maximum rate possible (Figure 10; Appendix C4). This task simulated digging trenches to build defensive positions which provide personnel protection against incoming enemy fire.

A box dig, 1.8 m (length) x 0.6 m (width) x 4.5 m (depth) representing standard gravel of 0.5 m^3, was utilized (Figure 12). It was placed on the floor. The box dig, as reported in the literature, provides greater experimental control and safety of the subjects

(Stevenson et al., 1988). The confines of the box ensured that all soldiers removed identical volume of the standardized gravel. The consistency of the crushed rock soil was always uniform. The size of the crushed rocks was less than one centimetre in diameter. The crushed rock was dampened with water to prevent dust suspension and thus breathing discomfort. A second box of the same dimensions was placed along side the first one. Using the standard military shovel, the subject dug from one box and put the rock soil into the other. The subjects were allowed to use heavy hand gloves for protection against blisters. On the command "Start", the subject commenced digging and was free to move from one side of the box to the other. The task was considered complete when the tester overseeing the task said "Stop". In order to achieve uniformity among subjects, test personnel judged when the box was empty. This required subjects to scoop out the final bit of soil by hand until one could no longer pick up a handful of gravel, particularly from tight corners where it was difficult to reach with the shovel. The total time to complete the dig was recorded.

Equipment and Human Resources:

1. Two 0.5 m^3 gravel boxes
2. Four issue shovels
3. A fan for ventilation
4. Mats to put around the boxes
5. A water sprinkler to moisten the rock soil for keeping the dust under control
6. Data recording sheet
7. Six pairs of leather work gloves
8. Three stop watches

9. A water-hose

11. Two testers

(II) Weight Load March: The application of this task can be seen when in the battle situation the soldiers have to maintain sustained operations for several hours (two to three). A distance of 10 to 16 km was agreed upon by the subject matter experts to be the most appropriate marching length. Factors involved in the choice of this distance included test adequacy, ease of administration, safety, and amount of time to administer the test evaluation. As a result of the present study, based on the objective measures of the physical capabilities, the army required to know the most appropriate marching distance in the above mentioned range. Traditionally, for assessment of marching capabilities, the soldiers have been marching 16 km at 120 paces per minute with their full gear (20 kg). This pace is equivalent to a marching speed of 5.33 km/h. In order to determine the adequate distance within this range, a 16 km march at the above given speed, with full fighting order (24.5 kg), was included in the test battery.

The weight load march was performed on a 100 m indoor track (Figure 13; Appendix C5). A group of 15 soldiers marched at a time in a line formation. The distance between each soldier was five meters. The subject and group number was labelled on the soldier's helmet.

Equipment and Human Resources:

1. One hundred meter indoor track
2. Sixteen sets of full fighting order equipment
3. Two metronomes (one spare)
4. One loud speaker (for metronome)

5. Two testers

Figure 12. The Maximal Effort Slit Trench Digging Task. Subject is digging from the box he is standing in the adjacent box.

Figure 13. Weight Load March in a Gymnasium.

Sequence of Field Testing

Field task data was gathered on 99 subjects. Inevitably, for unforeseen work and health related reasons, some subjects dropped out between laboratory and field testing.

For the field tests, the subjects were randomly assigned to one of six testing groups (#1 - 6), each consisting of 30 or less soldiers. Each group was divided into A and B sub-groups with an equal number of subjects. Each soldier was assigned a subject number within the subgroup. For example, subject #5 in Group 2A read Group 2A5. This information was placed on the soldier's right shirt pocket. All testing for each respective group was completed within a single day (Table 10 and 11). Testing of all groups was completed within six days.

D. The Pilot Project

In order to determine the internal consistency or stability of the test measures, the test retest reliability coefficients were computed for each of the field tasks and selected laboratory tests during a pilot study. All the reliability coefficients were computed using Pearson Product Moment Correlational procedures (all reliability coefficients are reported with results, in Chapter IV).

E. Statistical Analysis of Data

1. The statistical procedures used in the study were sensitive to outliers in the data. Therefore, the first step in the data analysis process was to identify any multivariate outliers in the data set and to remove them from the remaining analyses.
2. Means, standard deviations, and range of scores for each variable was determined. Wherever applicable, a dependant t-test was utilized to determine significant differences between means.

Table 10. Daily Field Test Schedule of Each Subgroup.

Time	Type of Activity
0730-0800	Administration and Briefing
0800-0830	Casualty Evacuation (Started with Group B immediately followed by Group A)
0900-1340	Group A started on station one to three
0900-1200	Group B did Weight Load Marching
1400-1840	Group B started on station one to three
1500-1800	Group A started on Weight Load Marching

Table 11. Station Type and Subject Assignment at Start of Each Field Testing Session.

STATION:	Casualty Evacuation: Every one was tested from 0800 to 0830 h
STATION #1:	Maximal Effort Jerry Can Task Subject #1, 2, 3, 4 & 5 started at this station in the stated order.
STATION #2:	Maximal Effort Digging Task Subject # 6, 7, 8, 9 & 10 started at this station in the stated order.
STATION #3:	Ammunition Box Lift Task Subject # 11, 12, 13, 14 & 15 started this task in the stated order.
STATION #4:	Weight Load Marching: Group A started in the morning and Group B in the afternoon.
NOTE:	On each station, for Stations 1 to 3, each subject was tested in numerical order. For example at Station #1 the testing order of subjects was 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15 . Subject finishing the test at Station # 1 moved to Station 2, 2 to 3, and 3 to 1. At each station testers made sure that each subject got least 30 min rest before starting the next test.

3. Pearson Product Moment Correlations amongst all the field and laboratory tests were generated. Correlation coefficients were also computed between the laboratory variables to determine their relationship among themselves. Similar procedures were also used for the field variables. The correlation procedures assumes that a linear relationship exists between the variables. This was confirmed by graphing raw data.
4. Multiple Stepwise Correlations and Regressions equations were computed for each field task. The multiple correlation determined the relationship of several laboratory tests combined with a given field test. Multiple regression equations allowed predictability of a field task performance using several laboratory test performances (Kerlinger, 1986).
5. Canonical correlation was computed to determine over all relationship between the laboratory and field task variables.
6. For each field task, a panel of subject matter expert judges had classified all individuals into pass and fail groups. A discriminant analysis was used to determine the linear combination of field tests that maximally discriminated between the two groups. The resultant classification table was examined to determine the percentage of correct classifications. The assumptions of discriminant analysis are that the two populations are multivariate normal and have the same covariance matrix. This model is compensatory: that is a strength in one test may compensate for a weakness in another test.

F. Selection of Physical Performance Standards

The cutoff points for all field task performances were based on a combination of two criteria:

(a) the performance cutoff points suggested by the panel of subject matter judges

(b) the physical capabilities of the soldiers

The time suggested by the panel of judges determined the minimal physical requirements of the job. A panel of five subject matter expert judges observed each of the field task performances. They were experienced army officers who had worked in the environment, performing and supervising similar tasks for years. These experts were appointed from across Canada. After observing each task, the judges came to a consensus on the cutoff point for acceptable performance of each field task with the exception of weight load march. The cutoff distance for weight load march was selected by the researcher based on the physiological capability of the subjects. All of the field tasks were rank ordered by the expert judges in terms of what they considered to be the most appropriate tasks to measure the physical requirements of a soldier in the field. The performance cutoff points suggested by the judges and the researcher, and other possible cutoff points were submitted to discriminant analytic procedures. The purpose of this analysis was to observe the effect of different performance cutoff points on the classification of the soldiers into pass and fail groups. This procedure provided a validity check of the performance cutoff points suggested by the judges and the researcher. It could also have identified other possible cutoff points for the standards.

In the discriminant analytic procedure a linear combination of the laboratory variables was found that produced the maximal separation between the pass and fail groups. The canonical discriminant function coefficients along with the correlations between the discriminant function and the original variables were used to interpret the discriminant functions.

CHAPTER IV. RESULTS AND DISCUSSION

A. Descriptive Laboratory Results

Age, Weight, and Height of Soldiers

One hundred and sixteen male volunteer infantry soldiers participated in the study. The soldiers age range was from 18 to 44 years with a mean of 25.6 years. Their mean weight and height was 78.6 kg ± 10.5 kg (s.d.) and 177.4 cm ± 7.6 cm in range of 61.2 to 112.0 kg and 159.2 to 198.4 cm respectively (Table 12).

Body Composition

The mean body fat for the whole sample was 18.4% ± 5.9%, ranging from 5.2 to 35.4% (Table 12). The mean fat free weight was 63.9 kg ± 8.0 kg,

Table 12. Descriptive Results for Anthropometry and Body Composition Related Variables.

Variable	n	Mean	Median	Std.Dev.	Minimum	Maximum
Age (years)	116	25.6	25.0	5.4	18.0	44.0
Weight (kg)	115	78.6	77.8	10.5	61.2	112.0
Height (cm)	116	177.4	177.2	7.6	159.2	198.4
Body Fat (%)	115	18.4	18.3	5.9	5.2	35.4
Fat Weight (kg)	115	14.7	14.1	5.9	4.2	37.3
Fat Free Weight (kg)	115	63.9	64.2	8.0	47.9	83.7

ranging from 47.9 to 83.7 kg. In a similar study on body composition Martin and Nelson (1985) reported a mean percentage of body fat 16.8%, ± 3.0% for male soldiers, age 20.9 ± 1.5 years. The difference between results may have been due to differences in methodology and/or age. It is generally accepted that with an increase in age percentage body fat increases (Harris, 1986). On average the soldiers of the present study were older in comparison to those in the Martin and Nelsons study. Based on observations of the data the subjects in the upper age range had a higher percentage of fat than the younger individuals.

Reliability of Laboratory Measures

Test-retest reliability coefficients were computed for the laboratory variables which did not have literature reported values. These values as shown in Table 13 ranged from 0.85 to 0.99. For each test, they were computed utilizing 15 subjects.

Muscular Strength

(A) Isometric Handgrip Strength: Handgrip strength measures were obtained for both hands. The purpose of this was to investigate if the left hand had a higher relationship with the field task performances than the right. This hypothesis was based on fact that, on average, the left handgrip strength is less than that of the right (Petersen et al., 1988) and therefore it could be a performance limiting factor due to a greater chance of muscular fatigue during the field task performances. The average of both hands was also obtained to investigate if it contributed any additional information.

The mean right and left handgrip strength was 541.9 N $\pm$ 80.4 N and 508.6 N $\pm$ 84.28 N, ranging from 343.0 to 833.0 N and 215.6 to 695.8 N respectively. The average handgrip strength of both hands was 522.3 N $\pm$ 80.4 N, ranging from 274.4 to 715.4 N (Table 14). A dependent t-test revealed a significantly higher grip strength for the right hand in comparison to the left. The soldiers in this investigation had higher handgrip strength than that reported by other researchers for male civilian populations

Table 13. Reliability Coefficients for the Investigated Variables.

Test	Reliability Coefficient
Isometric Handgrip Strength	0.91
Isometric Trunk Flexion Strength	0.99
Isometric Trunk Extension Strength	0.98
Isometric Arm Flexion Strength	0.92
Isokinetic Arm Flexion Strength	0.85
Isokinetic Trunk Flexion Strength	0.93
Isokinetic Trunk Extension Strength	0.97
Isokinetic Leg Extension Strength	0.97
Isokinetic Trapezius Lift Strength	0.95
Isokinetic Knee Flexion Torque (Ross, 1988)	0.97
Isokinetic Knee Extension Torque (Ross, 1988)	0.95
Isokinetic Bench Press Strength	0.92
Isometric Arm Flexion Endurance	0.90
Isometric Handgrip Endurance	0.97
Isotonic Trapezius Lift Endurance	0.96
Slit Trench Digging	0.86
Casualty Evacuation	0.85
Jerry Can Task	0.83
Ammunition Box Lift	0.90

All reliability coefficients were significant at $p \leq 0.05$ level.

(Petersen et al., 1988; Mathiowetz et al., 1985; Fike and Rousseau, 1982; Swanson et al., 1970). Petersen et al. (1988) reported a mean handgrip strength of 51.7 kg, range 29.0 to 81.8 kg for right hand and 48.3 kg, range 27.3 to 76.4 kg for the left hand for 125 male civilian subjects (college students and faculty members), age 17 to 50 years. The differences in results can be explained possibly due to the trained state of the soldiers. All soldiers were required to do some sort of physical training or physically demanding tasks in their day to day occupational requirements which may have contributed to their higher grip strength.

Table 14. Descriptive Results for Maximal Isometric Strength Tests (N).

Variable	n	Mean	Median	Std.Dev.	Minimum	Maximum
Right Handgrip	116	541.3	543.9	80.4	343.0	833.0
Left Handgrip	115	508.6	509.6	84.3	215.6	695.8
Average Handgrip	116	522.3	534.1	80.4	274.4	715.4
Arm Flexion	107	457.7	446.9	154.8	201.9	1050.6
Trunk Flexion	116	616.4	669.3	104.9	453.7	928.1
Trunk Extension	112	1675.8	1671.9	246.0	1187.8	2193.2

(B) Isometric and Isokinetic-Concentric Arm Flexion Strength: The mean isometric arm flexion strength was 457.7 N $\pm$ 154.8 N, ranging from 201.9 to 1050.6 N (Table 14). The mean isokinetic-concentric arm flexion strength was 756.6 N $\pm$ 199.9 N, ranging from 307.7 N to 1310.3 N (Table 15). The concentric strength was significantly higher than the isometric strength.

(C) Isometric and Isokinetic-Concentric Trunk Flexion and Extension Strength: The mean isometric trunk flexion and extension strength was 616.4 N ± 104.9 N and 1675.8 N ± 246.0 N, ranging from 453.7 to 928.1 N and 1187.8 to 2193.2 N respectively (Table 14). The mean strength for isokinetic-concentric trunk flexion and extension movement was 715.4 N ± 103.9 N and 1584.7 N ± 242.1 N, ranging from 460.6 to 979.0 N and 985.9 to 2285.4 N respectively (Table 15).

Table 15. Descriptive Results for Maximal Isokinetic-Concentric Strength Tests.

Variable	n	Mean	Median	Std.Dev.	Minimum	Maximum
Right Knee Flexion (Nm)	113	115.4	114.0	19.3	64.0	165.0
Left Knee Flexion (Nm)	113	114.1	113.0	22.4	60.0	171.0
Average Knee Flexion (Nm)	113	114.7	114.0	20.1	65.0	168.0
Right Knee Extension (Nm)	113	157.7	157.0	26.6	106.0	240.0
Left Knee Extension (Nm)	113	156.1	156.0	25.5	105.0	212.0
Average Knee Extension (Nm)	113	156.9	155.5	24.9	107.5	224.5
Arm Flexion (kg)	105	756.6	737.0	199.9	307.7	1310.3
Trunk Flexion (kg)	116	715.4	717.4	103.9	460.6	979.0
Trunk Extension (kg)	114	1584.7	1597.4	242.1	985.9	2285.4
Leg Extension (kg)	116	2527.4	2458.8	616.4	1446.5	4267.5
Trapezius Lift (kg)	107	614.5	586.0	152.9	343.0	975.1
Bench Press (kg)	106	1140.7	1155.4	258.7	628.2	1993.3

The isokinetic-concentric trunk flexion strength was significantly higher than the isometric trunk flexion. For the isokinetic test, the higher strength may have occurred at other than 160° hip angle (hip angle for isometric test). The isometric trunk extension strength was significantly higher than the dynamic trunk extension strength. This finding agrees with that reported by Johnson et al. (1976). These authors stated that the isometric force produced by a given muscle group is higher than its concentric force.

The ratio between the isometric trunk flexion and extension strength was 1:2.7 and for concentric trunk flexion and extension strength it was 1:2.2. These results were consistent with those reported in the literature for healthy men (Chahal and Singh, 1989; Nordin et al., 1987).

(D) Isokinetic-Concentric Knee Flexion and Extension Torque: The mean knee flexion and extension torque was obtained for both limbs. The mean torque for right and left knee flexion movement was 115.4 Nm ± 19.3 Nm and 114.1 Nm ± 22.4 Nm, ranging from 64 to 165 Nm and 60 to 171 Nm respectively. The average torque for both limbs was 114.7 Nm ± 20.1 Nm, ranging from 65 to 168 Nm (Table 15).

The mean torque for right and left knee extension was 157.1 Nm ± 26.5 Nm and 156.1 Nm ± 25.5 Nm, ranging from 106 to 240 Nm and 105 to 212 Nm respectively (Table 15). The average score for both limbs was 156.9 Nm ± 24.9 Nm, ranging from 107.5 to 224.5 Nm. The average torque ratio of knee flexors and extensors was 1:1.37.

Torque values found in this investigation were on average lower than those reported by Ross (1988) using a similar testing protocol. For his subjects, the mean for maximal torque output was 132 Nm for knee flexion and 181.3 Nm for knee extension. Differences between the results could be due to small sample size (n = 11) tested by

Ross (1981) or possibly higher strength trainability of his subjects in comparison to the soldier population.

(E) Isokinetic-Concentric Leg Extension Strength: The mean strength score for leg extension was 2527.4 N ± 616.4 N, ranging from 1446.5 to 4267.9 N (Table 15). These scores were higher than those reported by Okoro (1987) for male subjects 18 to 28 years of age (n = 44). His testing protocol was identical to that of this investigation. The mean leg extension strength score for Okoro's subjects was 172.2 kg. His subjects had never done leg extension training whereas many of the soldiers in the present investigation did weight training regularly. The soldiers day to day occupational activities were also more rigorous.

(F) Isokinetic-Concentric Trapezius Lift Strength: The mean strength score for trapezius lift was 614.5 N ± 152.9 N, ranging from 343.0 to 975.1 N (Table 15). Trapezius lift strength is important for the ammunition box lift task.

(G) Isokinetic-Concentric Bench Press Strength: The mean bench press strength was 1140.7 N ± 258.7 N, ranging from 628.2 to 1993.3 N (Table 15). These findings are in agreement with those of Hortobagyi et al. (1989). Using a similar test protocol, the mean bench press score for their college male subjects was 117.0 kg ± 29.1 kg. Their subjects also performed the test at 13 cm/s cable velocity. According to Hortobagyi and Katch (1990), this cable velocity is approximately 36 degrees per second, comparable to that reported by Okoro (1987). Okoro stated that for the leg extension test, the cable velocity of 13 cm/s translated to an average angular velocity of approximately 30° per second. This speed permitted subjects to achieve a high force output to replicate the movement speed of the free weight bench press (Hartobagyi et al., 1989; and Lander et al., 1985). Force output was reported to be 29% greater than that achieved for one repetition maximum for an isotonic lift. This is an important finding since army tasks are usually isotonic in nature. The difference between the two modes of contractions can be explained due to muscular fatigue which may occur in isotonic lifts when doing several lifting trials in order to achieve one repetition maximum. For example, in a study by Hartobagyi et al. (1989) subjects took eight to 12 repetitions before achieving a one repetition maximum. Another possible factor that could account for this difference is that isokinetic maximal force output is usually recorded at or near the strongest point in the range of motion, whereas in free weight lifting one can only lift the weight which can be overcome through the weakest point in the range of motion.

Summary of Descriptive Muscular Strength Results

Isometric and isokinetic-concentric strength of male soldiers was in agreement with values reported by other authors for civilian male populations of similar age groups (Hortobagyi and Katch, 1990; Chahal and Singh, 1989; Hartobagyi et al., 1989; Beimborn and Morrissey, 1988; Petersen et al., 1988; Ross, 1988; Nordin et al., 1987; Okoro, 1987; Lander et al., 1985). Soldiers had lower strength in comparison to highly trained individuals (Ross, 1988), and greater strength than a relatively less trained male civilian populations (Petersen et al., 1988; Okoro, 1987).

Muscular Endurance

(A) Isometric Handgrip Endurance: The mean right and left isometric handgrip endurance was 119 s $\pm$ 52.3 s and 107 s $\pm$ 42.8 s, ranging from 24 to 318 s and 24 to 215 s respectively. For both hands the average mean endurance was 112 s $\pm$ 44.2 s, ranging from 24 to 266 s (Table 16). The right hand had significantly more endurance than the left ($p < 0.01$). This may have been due to most individuals being right hand dominant (Petersen et al., 1988).

Table 16. Descriptive Results for Muscular Endurance Tests.

Variable	n	Mean	Median	Std.Dev.	Minimum	Maximum
Static Right Handgrip (s)	115	119.9	116.0	52.3	24.0	318.0
Static Left Handgrip (s)	114	107.0	107.0	42.8	24.0	215.0
Static Average Handgrip (s)	116	112.0	107.8	44.8	24.0	266.5
Static Arm Flexion (s)	113	109.3	104.0	43.9	14.0	252.0
Dynamic Trapezius Lifts (Reps.)	112	92.5	100.0	20.1	16.0	100.0

Reps. = Repetitions.

(B) Isometric Arm Flexion Endurance: The mean score for isometric arm flexion endurance at an elbow angle of 105° was 109.3 s $\pm$ 43.9 s, ranging from 14 to 252 s (Table 16).

(C) Isotonic-Concentric Trapezius Lift Endurance: The mean score for trapezius lift endurance was 92.5 repetitions $\pm$ 20.1 repetitions, ranging from 16 to 100 repetitions (Table 15). This test was performed with 21 kg load concentrically only. The ceiling level of performance was set at 100 repetitions. It was determined that the subjects, in combat situation, would seldom lift more than 100 boxes at a time. In the pilot study the subjects demonstrated that if an individual was able to do this many repetitions then he could do close to another 100 or more without showing any symptoms of muscular fatigue.

Descriptive Field Task Performance Results

Out of the 116 subjects who completed the laboratory tests, 88 completed the field test battery. The results of field task performances are shown Table 17.

Table 17. Descriptive Results for Field Tasks.

Variable	n	Mean	Median	Std.Dev.	Minimum	Maximum
Casualty Evacuation (s)	94	46.8	44.4	8.5	32.3	68.9
Ammunition Box Lift (s)	99	164.3	154.0	50.6	78.0	409.0
Maximal Effort Jerry Can (s)	99	242.3	240.0	30.1	189.0	374.0
Maximal Effort Digging (s)	97	262.0	254.0	44.5	169.0	372.0
Weight Load March (m)	88	14461.4	16000.0	2992.8	5500.0	16000.0

B. Inferential Results

Correlation Between Body Composition and Field Task Variables

(A) Correlation Between Body Weight and Field Tasks: The body weight significantly correlated with ammunition box lift (r = -0.19) and maximal effort dig (r = -0.20), (Table 18). The negative correlation coefficients indicated that as the body weight increased the time to complete both tasks decreased. This may have occurred possibly due to the greater lean body mass of the heavier individuals.

(B) Correlation of Percentage of Body Fat with Field Tasks: The percentage of body fat significantly correlated with casualty evacuation (r = 0.20), ammunition box lift (r = 0.26) and maximal effort dig (r = 0.28), (Table 18).

Table 18. Pearson Product Moment Correlations Between Field Tasks and Body Weight, Percentage of Body Fat, and Lean Body Mass.

Variable	Casualty Evacuation	Ammunition Box Lift	Maximal Effort Jerry Can	Maximal Effort Digging	Weight Load March
Body Weight	-0.07	* (3.6%) -0.19	-0.02	* (4.0%) -0.20	-0.10
Percentage Body Fat	* (4.0%) 0.20	* (6.8%) 0.26	0.09	* (7.8%) 0.28	-0.01
Fat Weight	0.14	0.12	0.06	0.14	-0.03
Fat Free Weight	* (4.0%) -0.20	* (13.0%) -0.36	-0.07	* (13.0%) -0.36	-0.11

* significant at $p \leq 0.05$ level
(parentheses include shared variance)

Positive correlation coefficients indicated that as the percentage of body fat increased so did the completion time of each task. This indicated that as a soldier's percent of body fat increased the time to complete the task also increased.

As shown in Table 18 it is evident that the percentage of body fat had a greater bearing on the field task performances than the absolute quantity of fat. The absolute fat weight showed no significant correlations with any of the field task performances.

(C) Correlation of Fat Free Weight with Field Tasks: The fat free weight significantly correlated with the performance of casualty evacuation (r = -0.20), ammunition box lift (r = -0.36) and maximal effort dig (r = -0.36), (Table 18). Negative correlation coefficients indicated that as the fat free weight increased the performance times decreased. These results support that greater lean body mass contributes to faster task completion times.

Correlation Coefficients Between Muscular Strength and Field Task Variables

(A) Correlation Between Isometric Handgrip Strength and Field Tasks: The grip strength of each hand and the average of both were significantly correlated with maximal effort jerry can and maximal effort digging performances (Table 19). Correlation coefficients of right hand with maximal effort jerry can and maximal effort dig were -0.23 and -0.18 respectively, for left hand they were -0.23 and -0.20, and for average of both hands the coefficients were -0.25 and -0.18. As determined by t-tests for differences between dependent correlation coefficients, the respective coefficients for right and left hand were of similar magnitude. The negative coefficients indicated that as the grip strength increased the time to complete the task decreased.

Table 19. Pearson Product Moment Correlations Between Field and Maximal Static Strength Tests.

Variable	Casualty Evacuation	Ammunition Box Lift	Maximal Effort Jerry Can	Maximal Effort Digging	Weight Load March
Right Handgrip	-0.11	-0.13	* (5.3%) -0.23	* (3.2%) -0.18	0.05
Left Handgrip	-0.04	-0.16	* (5.3%) -0.23	* (4.0%) -0.20	0.07
Average Handgrip	-0.05	-0.13	* (6.3%) -0.25	* (3.2%) -0.18	0.04
Arm Flexion	-0.11	-0.16	-0.07	* (4.8%) -0.22	-0.05
Trunk Flexion	* (10.9%) -0.33	* (4.0%) -0.20	* (5.8%) -0.24	* (9.0%) -0.30	0.03
Trunk Extension	* (4.0%) -0.20	* (11.6%) -0.34	* (6.8%) -0.26	* (22.1%) -0.47	0.04

* significant at $p \leq 0.05$ level
(parentheses include shared variance)

Table 20. Pearson Product Moment Correlations Between Field and Maximal Isokinetic-Concentric Strength Tests .

Variable	Casualty Evacuation	Ammunition Box Lift	Maximal Effort Jerry Can	Maximal Effort Digging	Weight Load March
Right Knee Flexion	-0.14	-0.10	0.00	* (5.8%) -0.24	-0.11
Left Knee Flexion	-0.14	* (2.9%) -0.17	-0.10	* (12.3%) -0.35	-0.12
Average Knee Flexion	-0.15	-0.15	-0.06	* (9.6%) -0.31	-0.12
Right Knee Extension	* (6.3%) -0.25	-0.12	* (2.9%) -0.17	* (5.8%) -0.24	-0.12
Left Knee Extension	-0.17	-0.13	* (4.4%) -0.21	* (11.6%) -0.34	-0.09
Average Knee Extension	* (4.8%) -0.22	-0.13	* (4.0%) -0.20	* (9.0%) -0.30	-0.11
Arm Flexion	* (7.8%) -0.28	-0.12	-0.08	* (12.3%) -0.36	-0.01
Trunk Flexion	* (9.0%) -0.30	* (4.4%) -0.21	* (3.2%) -0.18	* (7.8%) -0.28	0.01
Trunk Extension	* (4.8%) -0.22	* (9.6%) -0.31	* (2.9%) -0.17	* (23.0%) -0.48	0.08
Leg Extension	* (5.3%) -0.23	* (5.3%) -0.23	-0.14	* (15.2%) -0.39	-0.09
Trapezius Lift	-0.11	* (3.6%) -0.19	-0.14	* (4.4%) -0.21	-0.01
Bench Press	-0.15	* (3.2%) -0.18	-0.09	* (5.3%) -0.23	-0.12

* significant at $p \leq 0.05$ level
(parentheses include shared variance)

(B) Correlation of Isometric and Isokinetic-Concentric Arm Flexion Strength with Field Tasks: Isometric arm flexion strength significantly correlated with the performance of maximal effort dig only (r = -0.22), (Table 19).

Dynamic arm flexion strength significantly correlated with the casualty evacuation (r = -0.28) and maximal effort dig (r = -0.36), (Table 20). Negative correlation coefficients indicated that the greater the static or dynamic arm flexion strength the lesser the time to complete the task. For casualty evacuation, dynamic arm flexion strength is important when lifting a soldier into a fireman's carry position. Both of these tasks seem to require greater dynamic force effort from the arm flexors than that in the other tasks. Based on the size of correlation coefficients, and number of variables each related to, dynamic arm flexion strength was a better predictor of the field task performance than the static arm flexion strength.

(C) Correlation of Isometric and Isokinetic-Concentric Trunk Flexion and Extension Strength with Field Tasks: Isometric trunk flexion and extension strength significantly correlated with all field task variables with the exception of the weight load march (Table 19). Dynamic trunk flexion and extension strength also significantly correlated with all the field task variables with the exception of the weight load march (Table 20). Results of dynamic test results were similar to those of static tests. The dynamic trunk extension strength correlated highly with maximal effort dig (r = -0.48). Based on empirical observations, this field task appeared to require a fair amount of back lifting during uplifting motion of a shovel.

Performance of the weight load march did not significantly correlate with any of the static or dynamic strength variables.

(D) Correlation of Isokinetic-Concentric Knee Flexion and Extension Torque with Field Tasks: Right and average knee flexion torque significantly correlated with the performance of maximal effort dig only (r = -0.24; -0.31), (Table 20). Left knee flexion torque significantly correlated with the performance of ammunition box lift (r = -0.17) and maximal effort dig (r = -0.35), (Table 20). Based on the results, it is a better predictor of the field task performance in comparison to that of the right knee flexion torque.

Right and average knee extension torque significantly correlated with the performance of casualty evacuation (r = -0.25; -0.22), maximal effort jerry can task (r = -0.17; -0.20), and maximal effort dig (r = -0.24; -0.30) tasks. Left knee extension torque was significantly correlated with the performance of maximal effort jerry can (r = -0.21) and maximal effort digging (r = -0.34) tasks (Table 20). As determined by the t-test for differences between two dependent correlation coefficients the superiority of right over the left limb or vice versa was not demonstrated. Negative correlational values indicated that higher knee flexion or extension torque is associated with lower task completion times.

(E) Correlation Between Isokinetic-Concentric Leg Extension Strength and Field Tasks: Dynamic leg extension strength significantly correlated with casualty evacuation (r = -0.23), ammunition box lift (r = -0.23), and maximal effort dig (r = -0.39; Table 20).

(F) Correlation Between Isokinetic-Concentric Trapezius Lift Strength and Field Tasks: Trapezius lift strength significantly correlated with the performance of ammunition box lifting (r = -0.19) and maximal effort dig (r = -0.21), (Table 20).

Both of these tasks had an upward lifting action similar to the trapezius lift strength test. Based on these results it appears that maximal trapezius lifting strength may not be an important factor related to the field task performances since the maximal weight to be lifted was only 20.9 kg.

(G) Correlation Between Isokinetic-Concentric Bench Press Strength and Field Tasks: Bench press strength significantly correlated with the ammunition box lift (r = -0.18) and maximal effort dig (r = -0.23), (Table 20). Significant but low correlations may be due to the fact that in field situation the physical exertion required was not similar to that during the maximal effort bench press test. For the ammunition box lift a soldier at most may be required to push a 20.9 kg box once it is lifted to a truck bed height. When a subject forcefully digs the shovel into the gravel also requires contribution of similar musculature as in bench pressing. This movement is more muscular endurance related. The extent of the force exerted by these muscles during digging is not known. However, it appears that stronger individuals have an advantage when digging the shovel into the gravel.

Correlation Coefficients Between Muscular Endurance and Field Task Variables

(A) Correlation Between Isometric Handgrip Endurance and Field Tasks: Isometric right handgrip endurance significantly correlated with the performance of ammunition box lift (r = -0.19) and maximal effort dig (r = -0.27). Left and average handgrip endurance significantly correlated with the performance of ammunition box lift (r = -0.24; -0.24), maximal effort dig (r = -0.23; -0.28), and maximal effort jerry can (r = -0.18; -0.22) tasks (Table 21). These field tasks appear to demand sufficient handgrip endurance for successful completion. Handgrip endurance is required while:

(a) lifting and carrying a jerry can; (b) lifting an ammunition box to a truck bed height; and (c) shovelling at a maximal effort. Statistical analysis (t-test for differences between dependent correlation coefficients) showed no superiority of relationship of one hand over the other.

(B) Correlation Between Isometric Arm Flexion Endurance and Field Tasks: Isometric arm flexion endurance at an elbow angle of 105° significantly correlated with the performance of ammunition box lift ($r = -0.24$), maximal effort jerry can task ($r = -0.17$), and maximal effort dig ($r = -0.34$), (Table 21). It was important while carrying a jerry can towards a gas tank simulator.

(C) Correlation Between Isotonic Trapezius Lift Endurance and Field Tasks: Trapezius lift muscular endurance significantly correlated with the performance of casualty evacuation ($r = -0.24$), ammunition box lift ($r = -0.20$), and maximal effort dig ($r = -0.35$), (Table 21). In casualty evacuation it appears to be important for support while carrying another soldier. For the ammunition box lift it is required for uplifting of the box to the truck bed height. The trapezius lift endurance may be more important for the short individuals since they must lift it to a greater height relative to their own body height (Switzer, 1962: in Marston et al., 1981). For the maximal effort dig the trapezius lift appeared to be used through upward lifting of a shovel while digging.

Correlation Coefficients Within Field Tasks

Simple Pearson Product Moment Correlation Coefficients were computed between all the field task performances. Casualty evacuation significantly correlated with the ammunition box lift ($r = -0.28$), maximal effort jerry can ($r = 0.20$), and maximal effort dig ($r = 0.34$), (Table 22). Maximal effort dig also significantly correlated with the ammunition box lift (r = 0.41) and maximal effort jerry can task (r = 0.18).

Table 21. Pearson Product Moment Correlations Between Field and Muscular Endurance Tests.

Variable	Casualty Evacuation	Ammunition Box Lift	Maximal Effort Jerry Can	Maximal Effort Digging	Weight Load March
Isometric Right Handgrip	-0.13	* (3.6%) -0.19	-0.15	* (7.3%) -0.27	-0.03
Isometric Left Handgrip	-0.09	* (5.8%) -0.24	*(3.2%) -0.18	* (5.3%) -0.23	-0.02
Isometric Average Handgrip	-0.11	* (5.8%) -0.24	*(4.8%) -0.22	* (7.8%) -0.28	-0.05
Isometric Arm Flexion	-0.16	* (5.8%) -0.24	*(2.9%) -0.17	* (11.6%) -0.34	-0.10
Isotonic Trapezius Lift	* (5.8%) -0.24	* (4.0%) -0.20	-0.05	*(12.3%) -0.35	-0.10

* significant at $p \leq 0.05$ level
(parentheses include shared variance)

Table 22. Pearson Product Moment Correlations Within Field Tasks.

Variable	Casualty Evacuation	Ammunition Box Lift	Maximal Effort Jerry Can	Maximal Effort Digging	Weight Load March
Casualty Evacuation	1.00				
Ammunition Box Lift	* (7.8%) 0.28	1.00			
Maximal Effort Jerry Can	* (4.0%) 0.20	0.07	1.00		
Maximal Effort Digging	* (11.6%) 0.34	* (16.8%) 0.41	* (3.2%) 0.18	1.00	
Weight Load March	-0.16	-0.03	-0.02	-0.18	1.00

* significant at $p \leq 0.05$ level
(parentheses include shared variance)

Multiple Correlations and Stepwise Regression Equations

The purpose of this analysis was: (a) to obtain measures of overall relationship between selected laboratory tests and individual field tasks, and (b) to determine how well field task performances could be predicted from laboratory results. Before carrying out the analysis, the laboratory tests which had the highest Pearson Product Moment Correlation coefficients with the field task(s) and low correlation with other chosen laboratory tests were selected for the multiple correlation and stepwise regression analysis (Table 25 to 33). When two or more laboratory tests were highly correlated with each other, only one of them was selected for inclusion into the analysis (Table 23). The purpose of these procedures was to reduce the number of laboratory variables so that the ratio of subjects per variable was adequate to have confidence in the results.

Table 24 provides a summary of the multiple correlation coefficients between the selected laboratory tests and each field task. The remaining tables 25 through 33 present the summary tables for the stepwise regression analyses. Each variable in the tables is presented in the order in which it appeared in the stepwise regression equation. All reported multiple correlations, except for the weight load march, were significant at $p < 0.05$ level.

The "B" and "Beta" coefficients shown in Table 25 to 33 are used for predicting the field task performance from the laboratory test scores. "B" regression coefficients are used with raw laboratory test scores and "Beta" coefficients are used with standardized laboratory scores.

Tables 26, 28, 30, and 32 shows the multiple regression results where only those laboratory variables which significantly contributed to the multiple correlation were included. These tables should be used when the goal is to predict the field tasks from the laboratory tests. The addition of the other laboratory variables, as shown in the tables 25, 27, 29, and 31 which include all the variables, would not contribute significantly to the prediction of the field task and would require extra testing time to obtain these measures.

Table 23. Pearson Product Moment Correlation Coefficients Between Laboratory Tests.

Variable Number

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2.	0.77															
3.	0.90	0.94														
4.	0.34	0.41	0.37													
5.	0.26	0.32	0.30	0.38												
6.	0.48	0.45	0.49	0.49	0.50											
7.	0.45	0.39	0.43	0.37	0.41	0.42										
8.	0.50	0.44	0.49	0.41	0.39	0.56	0.86									
9.	0.49	0.43	0.48	0.41	0.41	0.52	0.96	0.97								
10	0.43	0.44	0.47	0.43	0.53	0.48	0.73	0.66	0.72							
11.	0.49	0.46	0.52	0.45	0.50	0.58	0.66	0.74	0.73	0.83						
12.	0.48	0.47	0.52	0.46	0.54	0.55	0.73	0.73	0.76	0.96	0.95					
13.	0.33	0.33	0.32	0.45	0.35	0.46	0.25	0.25	0.26	0.37	0.32	0.36				
14.	0.30	0.36	0.33	0.46	0.88	0.49	0.43	0.44	0.45	0.53	0.49	0.54	0.33			
15.	0.43	0.46	0.46	0.53	0.52	0.83	0.47	0.54	0.53	0.55	0.59	0.60	0.54	0.51		
16.	0.30	0.31	0.31	0.34	0.37	0.24	0.37	0.45	0.43	0.35	0.41	0.40	0.38	0.36	0.62	
17.	0.41	0.39	0.40	0.56	0.35	0.50	0.40	0.45	0.44	0.38	0.45	0.43	0.47	0.43	0.56	0.40
18.	0.26	0.39	0.32	0.56	0.36	0.49	0.34	0.38	0.38	0.36	0.33	0.37	0.41	0.37	0.50	0.46
19.	0.53	0.45	0.46	0.24	0.25	0.44	0.41	0.45	0.45	0.36	0.44	0.42	0.37	0.32	0.41	0.25
20.	0.43	0.58	0.53	0.24	0.25	0.32	0.31	0.32	0.32	0.29	0.31	0.32	0.28	0.28	0.35	0.20
21.	0.51	0.54	0.55	0.27	0.28	0.45	0.40	0.43	0.43	0.37	0.43	0.42	0.37	0.33	0.43	0.27
22.	0.34	0.43	0.40	0.39	0.51	0.45	0.36	0.38	0.39	0.40	0.26	0.30	0.30	0.48	0.54	0.28
23.	0.01	0.18	0.09	0.13	0.40	0.29	0.21	0.22	0.23	0.27	0.49	0.47	0.21	0.39	0.30	0.14
24.	-0.06	0.00	-0.1	0.06	-0.08	0.00	-0.06	-0.10	-0.09	-0.16	-0.11	-0.14	-0.08	-0.08	0.06	-0.12
25.	0.33	0.39	0.35	0.28	0.49	0.40	0.46	0.50	0.50	0.50	0.53	0.54	0.07	0.55	0.38	0.21
26.	0.42	0.41	0.40	0.28	0.29	0.48	0.43	0.52	0.50	0.47	0.61	0.56	0.21	0.34	0.44	0.18
27.	-0.06	0.03	0.00	0.10	0.12	-0.05	0.06	-0.05	0.00	0.01	-0.17	-0.08	0.06	0.15	-0.07	-0.12
28.	0.03	0.13	0.09	0.15	0.22	0.06	0.18	0.09	0.14	0.14	-0.02	0.06	0.07	0.27	0.04	-0.07
29.	0.35	0.33	0.32	0.19	0.37	0.39	0.37	0.50	0.46	0.45	0.62	0.56	0.02	0.39	0.40	0.30

r ≥ 0.16 is significant at $p < 0.05$ level

	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.
18.	0.52											
19.	0.37	0.30										
20.	0.26	0.29	0.71									
21.	0.35	0.29	0.93	0.91								
22.	0.29	0.36	0.38	0.42	0.42							
23.	0.07	0.21	0.24	0.20	0.22	0.38						
24.	0.10	0.01	-0.07	-0.05	-0.04	-0.08	0.00					
25.	0.41	0.28	0.29	0.16	0.23	0.37	0.34	0.26				
26.	0.38	0.18	0.43	0.29	0.38	0.19	0.37	-0.12	0.60			
27.	0.07	0.03	-0.10	-0.06	-0.10	0.01	0.03	0.47	0.30	-0.07		
28.	0.17	0.08	-0.01	0.01	-0.01	0.10	0.11	0.42	0.53	0.17	0.96	
29.	0.32	0.25	0.34	0.18	0.27	0.33	0.29	-0.22	0.68	0.66	-0.49	-0.26

Variable numbers and their corresponding Laboratory Tests for Table 23 are as follow:

Variable Number	Variable Name
1.	Static Right Handgrip Strength
2.	Static Left Handgrip Strength
3.	Static Average Handgrip Strength
4.	Static Arm Flexion Strength
5.	Static Trunk Flexion Strength
6.	Static Trunk Extension Strength
7.	Dynamic Right Knee Flexion Torque
8.	Dynamic Left Knee Flexion Torque
9.	Dynamic Average Knee Flexion Torque
10.	Dynamic Right Knee Extension Torque
11.	Dynamic Left Knee Extension Torque
12.	Dynamic Average Knee Extension Torque
13.	Dynamic Arm Flexion Strength
14.	Dynamic Trunk Flexion Strength
15.	Dynamic Trunk Extension Strength
16.	Dynamic Leg Extension Strength
17.	Dynamic Trapezius Lift Strength
18.	Dynamic Bench Press Strength
19.	Static Right Handgrip Endurance
20.	Static Left Handgrip Endurance
21.	Static Average Handgrip Endurance
22.	Static Arm Flexion Endurance
23.	Dynamic Trapezius Lift Endurance
24.	Age
25.	Weight
26.	Height
27.	Body Fat
28.	Fat Weight
29.	Fat Free Weight

Table 24. Summary of the Multiple Correlation Coefficients of Each Field Task with the Selected Laboratory Variables.

Field Task	Multiple R	R Square
Casualty Evacuation	0.49 *	0.24
Ammunition Box Lift	0.43 *	0.18
Maximal Effort Jerry Can	0.36 *	0.13
Maximal Effort Dig	0.58 *	0.33
Weight Load March	0.29	0.08

* significant at $p \leq 0.05$ level

Casualty Evacuation

The multiple correlation coefficient for this task was 0.49 with the selected laboratory variables (Table 25). The variable contributing most toward the multiple correlation were static trunk flexion strength and percentage of body fat. These are the two variable which would be used for prediction purposes. The corresponding multiple correlation and regression equation to be used for prediction purposes is presented in Table 26. The multiple correlation for prediction was 0.43.

Ammunition Box Lift

The multiple correlation coefficient between the ammunition box lift and seven selected laboratory variables was 0.43 (Table 27). The laboratory tests which contributed the most to the multiple correlation coefficient were static trunk extension strength and percentage of body fat. The prediction table shows that once these variable were in the equation the other tests did not significantly contribute to the prediction of this task. The multiple correlation for prediction was 0.39

(Table 28).

Table 25. Multiple Correlation Between the Casualty Evacuation and the Selected Laboratory Variables.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.49	0.24	0.158	7.60	3.04	0.008	77

Variable	B	SE B	Beta	T	Sig T
Static Trunk Flexion Strength	-0.024025	0.011558	-0.301854	-2.08	0.041
Percentage of Body Fat	0.278036	0.151664	0.202621	1.83	0.071
Trapezius Lift Endurance	-0.086032	0.046039	-0.218168	-1.87	0.066
Static Trunk Extension Strength	0.003577	0.004698	0.112788	0.77	0.443
Dynamic Arm Flexion Strength	-0.002761	0.004847	-0.069652	-0.57	0.571
Dynamic Right Knee Extension Torque	-0.011281	0.042918	-0.036650	-0.26	0.793
Dynamic Leg Extension Strength	-0.000433	0.001663	-0.034439	-0.26	0.796
Constant	65.289678	7.539569		8.66	0.000

Table 26. Variables in Stepwise Regression Equation for Performance Prediction of Casualty Evacuation.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.43	0.19	0.165	7.57	8.50	0.000	77

Variable	B	SE B	Beta	T	Sig T
Static Trunk Flexion Strength	-0.031487	0.008372	-0.395614	-3.76	0.000
Percentage of Body Fat	0.288583	0.144342	0.210307	2.00	0.049
Constant	63.400879	6.178460		10.26	0.000

Table 27. Multiple Correlation Between the Ammunition Box Lift and the Selected Laboratory Variables.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.43	0.18	0.112	48.78	2.64	0.016	92

Variable	B	SE B	Beta	T	Sig T
Static Trunk Extension Strength	-0.052716	0.027894	-0.258765	-1.89	0.062
Percentage of Body Fat	1.836053	0.921486	0.208325	1.99	0.050
Trapezius Lift Endurance	-0.419263	0.318714	-0.144021	-1.32	0.192
Static Arm Flexion Endurance	-0.053194	0.149680	-0.045670	-0.36	0.723
Dynamic Leg Extension Strength	0.003752	0.010348	0.045430	0.36	0.719
Static Trunk Flexion Strength	-0.013739	0.062393	-0.027789	-0.22	0.826
Average Handgrip Endurance	0.018271	0.133662	-0.016316	-0.14	0.892
Constant	266.594883	47.430866		5.62	0.000

Table 28. Variable in Stepwise Regression Equation for Ammunition Box Lift Performance Prediction.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.39	0.15	0.133	48.19	8.00	0.001	92

Variable	B	SE B	Beta	T	Sig T
Static Trunk Extension Strength	-0.063743	0.020036	-0.312893	-3.18	0.002
Percentage of Body Fat	1.742303	0.866813	0.197688	2.01	0.048
Constant	239.768188	39.396897		6.09	0.000

Maximal Effort Jerry Can Task

The multiple correlation between the maximal effort jerry can task and the selected laboratory variables was 0.36 (Table 29). The variable contributing the most to the multiple correlation coefficient was static trunk flexion strength. This test would be the one used for prediction purposes. The multiple correlation coefficient, for prediction was 0.29 (Table 30). These correlation values were low indicating that the selected laboratory tests may not have been sensitive enough to relate to the physical demands of this task. The pause time to empty the can into a funnel could have been a factor which may have lowered jerry can task's relationship with the laboratory tests. The pause time provided rest, allowing soldiers to recover from the running part of the task, whereas the laboratory tests required maximal effort through out each test.

Maximal Effort Dig

The multiple correlation coefficient between the maximal effort dig and the selected laboratory tests was 0.58 (Table 31). Two variables which contributed the most to the multiple correlation coefficient were dynamic leg extension strength and trapezius lift endurance. These are the tests which would be used for prediction purposes. The multiple correlation coefficient for prediction was 0.53 (Table 32).

Weight Load March

The multiple correlation coefficient for weight load march (0.29) was not significant with any laboratory tests (Table 33). Low correlation coefficients of this task with any all laboratory tests and field tasks is most likely due to the factor that 73.5% of weight load march performances fell on a single point. In order to get a high correlation coefficient high variability is a necessity.

Table 29. Multiple Correlation Between the Maximal Effort Jerry Can Task and the Selected Laboratory Variables.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.36	0.13	0.078	28.75	2.56	0.033	93

Variable	B	SE B	Beta	T	Sig T
Static Trunk Extension Strength	-0.057227	0.033960	-0.202642	-1.69	0.096
Static Average Handgrip Strength	-0.060138	0.048736	-0.164266	-1.23	0.221
Static Trunk Flexion Strength	-0.018329	0.016077	-0.150320	-1.14	0.257
Dynamic Left Knee Extension Strength	0.077483	0.157088	0.068704	0.49	0.623
Static Average Handgrip Endurance	0.004243	0.081915	0.006397	0.05	0.959
Constant	329.793276	26.442765		12.47	0.000

Table 30. Variable in Stepwise Regression Equation for Maximal Effort Jerry Can Task Performance Prediction.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.29	0.08	0.072	28.84	8.25	0.005	93

Variable	B	SE B	Beta	T	Sig T
Static Trunk Flexion Strength	-0.096856	0.028367	-0.286039	-2.85	0.005
Constant	295.883025	19.515296		15.16	0.000

Table 31. Multiple Correlation Between the Maximal Effort Dig and the Selected Laboratory Variables.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.58	0.33	0.268	38.33	5.23	0.000	82

Variable	B	SE B	Beta	T	Sig T
Dynamic Leg Extension Strength	-0.017603	0.008625	-0.251846	-2.04	0.045
Trapezius Lift Endurance	-0.582428	0.276007	-0.225856	-2.11	0.038
Dynamic Arm Flexion Strength	-0.027695	0.023353	-0.128034	-1.19	0.239
Static Trunk Extension Strength	-0.021072	0.024521	-0.120409	-0.86	0.393
Static Arm Flexion Endurance	-0.115567	0.127406	-0.113321	-0.91	0.367
Static Trunk Flexion Strength	0.025178	0.053289	0.058105	0.47	0.638
Average Knee Flexion Torque	-0.064691	0.261632	-0.030233	-0.25	0.805
Constant	421.670342	38.369694		10.99	0.000

Table 32. Variables in Stepwise Regression Equation for Performance Prediction of Maximal Effort Dig.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.53	0.28	0.265	38.41	15.59	0.000	82

Variable	B	SE B	Beta	T	Sig T
Dynamic Leg Extension Strength	-0.026681	0.006829	-0.381722	-3.91	0.000
Trapezius lift Endurance	-0.761635	0.251955	-0.295349	-3.02	0.003
Constant	401.528382	26.406978		15.21	0.000

Table 33. Multiple Correlation Between the Weight Load March and the Selected Laboratory Variables.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.29	0.08	0.008	3000.94	1.11	0.368	79

Variable	B	SE B	Beta	T	Sig T
Static Arm Flexion Endurance	-16.640183	10.237983	-0.241835	-1.63	0.109
Dynamic Trunk Extension Strength	3.936119	2.460411	0.332424	1.60	0.114
Dynamic Leg Extension Strength	- 1.218750	0.733622	-0.260325	-1.66	0.101
Trapezius Lift Endurance	-20.753775	21.703709	-0.121621	-0.96	0.342
Static Trunk Flexion Strength	3.707793	4.103544	0.130153	0.90	0.369
Dynamic Arm Flexion Strength	-0.584579	1.954170	-0.041888	-0.30	0.766
Constant	12884.3132	2853.00615		4.52	0.000

Summary of Multiple Correlations Between the Laboratory and Field Task Variables

Based on the size of the multiple correlation coefficients, digging performance had the highest relationship with the selected laboratory tests, followed by casualty evacuation, ammunition box lift, and maximal effort jerry can task. Weight load march did not show any significant relationship with the laboratory variables. The main reason for not obtaining significant relationship of this field task with the selected laboratory tests may have been due to majority of the weight load march performances falling on a single point (a distance of 16 km). This effect is know as a "ceiling effect", where performance were not recorded above this distance. In order to have high correlation coefficient between any two variables the variability of the scores is a necessary condition. Another possible explanation for lack of relationship may be due to different effort intensity required by each test situation. The laboratory tests were performed at maximal efforts where as the weight load march test was restricted to a constant speed of 120 paces per minute (5.33 km per hour).

Canonical Correlation Between Laboratory and Field Task Variables

A canonical correlation coefficient was computed between selected laboratory tests and field tasks. This coefficient provided an overall relationship of laboratory tests with field tasks. It is a statistical procedure which finds two linear combinations or canonical variates (one for the laboratory tests and one for the field tasks) which have the maximum possible Pearson Product Moment Correlation. The canonical correlation coefficient between the laboratory and field tests was 0.73 (n = 63), indicating a good relationship between the two.

An examination of the canonical variables (Table 34 and 36) along with their respective correlations with laboratory tests (Table 35 and 37) determined the contribution of each laboratory and field task variable to the final canonical correlation coefficient. Based on these results, as shown in Table 34 to 37, static trunk extension strength, dynamic leg extension strength and trapezius lift endurance contributed most from the laboratory tests. Maximal effort dig, ammunition box lift, and casualty evacuation contributed most from the field tasks.

Table 34. Standardized Canonical Coefficients for Laboratory Variables.

Variable	Canonical Coefficient
Static Trunk Flexion Strength	-0.089
Static Trunk Extension Strength	-0.463
Dynamic Leg Extension Strength	-0.414
Trapezius Lift Endurance	-0.424
Static Arm Flexion Endurance	-0.328
Percentage of Body Fat	0.499
Average Handgrip Strength	0.266

Table 35. Correlations Between Laboratory Tests and Canonical Variable.

Variable	Correlation Coefficient
Static Trunk Flexion Strength	-0.552
Static Trunk Extension Strength	-0.777
Dynamic Leg Extension Strength	-0.745
Trapezius Lift Endurance	-0.650
Static Arm Flexion Endurance	-0.640
Percentage of Body Fat	0.509
Average Handgrip Strength	0.509

Table 36. Standardized Canonical Coefficients for Field Tasks.

Variable	Canonical Coefficient
Casualty Evacuation	0.330
Ammunition Box Lift	0.317
Maximal Effort Jerry Can Task	0.003
Maximal Effort Dig	0.788
Total Weight Load March Distance	0.411

Table 37. Correlations Between Field Tasks and Canonical Variable.

Variable	Correlation Coefficient
Casualty Evacuation	0.631
Ammunition Box Lift	0.643
Maximal Effort Jerry Can Task	0.188
Maximal Effort Dig	0.874
Total Weight Load March Distance	0.219

Cutoff Points for Performance Standards of Field Tasks

Cutoff points for field task performances were based on a combination of several criteria: (a) the performance cutoff points suggested by the panel of subject matter expert judges and the researcher; and (b) the physical capabilities of soldiers. The time suggested by the panel of judges determined minimal physical requirements of the job. A panel of five subject matter expert judges observed each of the field task performances. These judges were experienced army officers who had been performing and supervising similar tasks for years. After observing the tasks, the judges came to

a consensus on the cutoff point for acceptable performance of each field task. The suggested performance cutoff points were 60 s for casualty evacuation, 300 s for ammunition box lift and maximal effort jerry can tasks and
360 s for maximal effort dig (Table 38).

Before collection of data, based on day to day physical performances of jobs, the army officers (other than the panel of expert judges) have had classified the soldiers into fit and unfit categories. Unfit individuals were further classified into two subcategories: (a) soldiers who could perform the tasks successfully but needed further improvement in their physical fitness; and (b) individuals who would have difficulty in completing the tasks successfully. The results obtained from the laboratory and field tests did not significantly correlate with the officers performance categorizations. These results indicated that officers were unable to predict soldiers fitness related field performances. This may have been due to officers' subjective evaluation of soldiers and/or factors other than physical fitness (such as skill level, leadership qualities, motivation and personal biases) taken into account during their evaluation procedures.

Table 38. Panel of Subject Matter Judges Rating of Field Tasks and Suggested Times for Completion.

Task Rating	Suggested Times
Casualty Evacuation	60 s (1 min)
Ammunition Box Lift	300 s (5 min)
Maximal Effort Jerry Can Task	300 s (5 min)
Maximal Effort Dig	360 s (6 min)

Table 39. Pass and Fail Outcome of the Field Task Performances Based on the Cutoff Points Suggested by the Subject Matter Experts and the Researcher.

Test Outcome	Casualty Evacuation	Ammunition Box Lift	Maximal Effort Jerry Can	Maximal Effort Digging	Weight Load March
Pass (%)	87.2	98.0	98.0	97.9	73.5
Fail (%)	12.8	2.0	2.0	2.1	26.5

The expert judges were not required to set a cutoff point for the weight load march. The cutoff distance for weight load march was determined by the researcher on the bases of physiological capabilities and march performances of the subjects. The frequency distribution for the distance completed by the subjects is contained in Table 40. All subjects who completed 13,000 m were able to complete 16,000 m. Table 41 provides an overview of the pass and fail percentages based on different distances completed. From these results a clear point of delineation was observed at 13,000 m. This information was most valuable in considering the optimal distance for the completion of the weight load march test. Therefore, it was concluded that based on physiological data and research evidence, the cutoff performance point should be at a distance of 13 km. Based on this criteria, 73.5% of the sample passed this test (Table 39). It appeared that motivation and other psychological factors also play a crucial role in the performance of weight load march.

Based on the cutoff scores suggested by the judges 87.2% of the subjects passed the casualty evacuation, 98% the ammunition box lift and maximal effort jerry can tasks, and 97.9% the maximal effort dig (Table 39). These cutoff scores were further analyzed using discriminant analysis function.

Table 40. Frequency Distribution for the Weight Load March Distance Completed by the Subjects.

Distance in Meters	Frequency
5500	1
5900	1
6600	2
6700	2
8500	1
9200	1
9300	1
9600	1
10000	1
10100	1
10300	1
11000	1
11200	2
11400	1
11700	1
12500	1
13000	1
16000	68
TOTAL	88

Table 41. Pass and Fail Classification of Soldiers Based on Different Distance Cutoffs During the Weight Load March.

	Weight Load March Distance Completed				
	< 5,001m	< 8,001m	<10,001m	<13,001m	16,000m
Pass (%)	100	93.2	88.6	78.4	77.3
Fail (%)	0	6.8	11.4	21.6	22.7

All of the field tasks were rank ordered by the panel of expert judges in terms of what they considered to be the most appropriate tasks to measure the physical requirements of the soldier in the field. Maximal effort dig was ranked number one, followed by weight load march, casualty evacuation, ammunition box lift, and the maximal effort jerry can task.

Discriminant Analysis for Possible Cutoff Performance Points

Performance cutoff points suggested by the judges and the researcher, and other possible cutoffs were submitted to discriminant analytic procedures. The purpose of this analysis was to observe the effect of different performance cutoff points on the classification of the soldiers into pass and fail groupings. This procedure provided a validity check of the performance times suggested by the judges and the researcher. It could have also identified other possible alternative performance cutoffs for the standards.

In the discriminant analytic procedure a linear combination of the laboratory variables was found that produced the maximal separation between the pass and fail groups. The canonical discriminant function coefficients along with the correlations between the discriminant function and the original variables were used to interpret the discriminant functions.

As a result of the above procedures, as the cutoff point became more lenient, resulting in only a few subjects failing the test, the percentage of correct classification for the pass and fail group tended to increase. In such a case, the results obtained from the analysis, based solely on large percentages of correct classification, cannot be strongly argued to support nor refute the judges performance cutoffs.

The discriminant function for casualty evacuation was performed for possible cutoff points of 40, 45, 50, 55, 60, and 65 s. None of the selected laboratory tests used in the multiple regression and thus the discriminant analysis, was able to significantly substantiate the cutoff at 60 s. For ammunition box lift, maximal effort jerry can task, and maximal effort dig, due to few failures (Table 39) for each of these tests the results were not significant. For weight load march possible cutoff points of 10,000 m and 15,000 m were used for the analysis. Everyone reaching 13,000 m finished the total march, therefore any distance within the range of 13,000 to 16,000 m would have revealed the same results. The discriminant analytic results found for each cutoff point of weight load march were not significant.

Recommended Performance Standards For the Canadian Army

Based on the results of the study: i.e. cutoff performances suggested by the panel of subject matter expert judges and the researcher; discriminant analysis of the possible cutoff performances; and soldiers physiological capabilities to meet the requirements of the jobs; the recommended standards for the combat soldiers of the Canadian Army were 60 s for casualty evacuation, 300 s for ammunition box lift,
300 s for maximal effort jerry can task, 360 s for maximal effort dig, and 13 km for weight load march (Table 38). The percentage of pass and failures for each cutoff performance is shown in Table 39 and 41).

It is important to know that the cutoff suggested by the expert judges for all field tasks, with the exception of weight load march, represented the criteria (job requirements) of each field task. Other methods of determining performance cutoffs, in isolation from times suggested by the expert judges, would have resulted in establishing norm reference standards as discussed earlier.

Laboratory Physical Performance Characteristics of a Soldier Meeting the Minimal Requirements of Suggested Physical Performance Standards

Based on field task performances, laboratory test performances were predicted for the cutoff performances of field tasks. The predicted values for static muscular strength, dynamic muscular strength, muscular endurance, and body composition values are reported in Table 42, 43, 44, and 45 respectively. These values did not indicate the minimum requirement for each variable but rather provided some

Table 42. Static Strength Characteristics of Soldiers for Suggested Field Task Performance Standards.

Laboratory Variable	Performance Characteristic
1. Trunk Flexion Strength	574.0 N
2. Trunk Extension Strength	1420.6 N
3. Arm Flexion Strength	372.1 N
4. Right Hand Grip Strength	494.8 N

guidelines toward minimal scores which may be needed or expected for overall success on the field tasks (excluding the weight load march). However, a strength in one variable may compensate for a weakness in another. For each of the predicted laboratory variables, the regression equations are reported in Appendix D.

Table 43. Dynamic Strength Characteristics of Soldiers for Suggested Field Task Performance Standards.

Laboratory Variable	Performance Characteristic
1. Trunk Flexion Strength	580.8 N
2. Leg Extension Strength	1990.0 N
3. Trapezius Lift Strength	537.6 N
4. Bench Press Strength	1013.8 N
5. Right Knee Flexion Torque	104.28 Nm
6. R. Knee Extension Torque	140.67 Nm

Table 44. Muscular Endurance Characteristics of Soldiers for Suggested Field Task Performance Standards.

Laboratory Variable	Performance Characteristic
1. Right Hand Grip Endurance	83.9 s
2. Static Arm Flexion Endurance	66.4 s
3. Trapezius Lift Endurance	73.8 repetitions

Table 45. Body Composition Characteristics of Soldiers for Suggested Field Task Performance Standards.

Laboratory Variable	Performance Characteristic
1. Body Weight	72.11 kg
2. Percentage of Body Fat	23.40 %
3. Fat Free Weight	56.00 kg

CHAPTER V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this investigation was to develop task related physical fitness performance standards for male combat soldiers in the Canadian Army based on body composition, muscular strength and endurance. Canadian Human Rights Commission Bona Fide Occupational Guidelines (1978) suggested the use of a "task related" method in the development of physical fitness standards. Previously physical fitness standards for the Army have been based on norm reference approach. These standards were non relevant to occupational physical requirements.

In the process of developing task related standards, criteria for selection of common tasks and the basis for the recommended physical fitness performance standards that represent the Army's needs were reviewed. The outcome of this analysis was the recognition of a need to develop physical fitness performance standards based on physical requirements of the jobs, and soldiers physiological capacities as determined in performance of both laboratory and field testing situation.

As a result of field observations and interviews, it was agreed that instead of selecting representative tasks from the Armoury, Artillery, Infantry and Combat Support groups, developing individual common tasks for each, one factor that all groups had in common was that they could be called upon to carry out the duties of an Infantry soldier at some point in the battle scenario. It was also agreed that the Infantry soldier's physical job requirements were the most demanding in the Combat Arms groups. This concept was discussed during field visits, with senior staff officers, and ratified by the Canadian Army Command Council members. From hundreds of physical tasks which could have been chosen, a series of representative common tasks were selected by the researcher and a committee of army experts, both at headquarters and in the field, and eventually approved by the Command Council. The selection of common tasks was based on:

1. a comprehensive review of national and international military scientific literature data bases
2. interviews and field observations with subject matter experts in the field at Canadian Forces Base (CFB) Wainwright; and at the headquarters of #1 Combat Brigade Group in Calgary, Alberta
3. interviews, special meetings and briefings at Forces Mobile Command (FMC) Headquarters in Montreal, Quebec

Representative selected common tasks were:

(a) casualty evacuation

(b) ammunition box lift

(c) maximal effort jerry can carry task

(d) maximal effort slit trench dig

(e) weight load march

The following laboratory tests were selected and developed based on the physical requirements of the chosen common field tasks.

(a) static and dynamic muscular strength test battery

(b) static and dynamic muscular endurance test battery

(c) body composition variables

Laboratory data on 116 male infantry soldiers and field task data on 99 soldiers from Canadian Forces Base in Calgary, Alberta, was gathered. For unforeseen and valid work and health related reasons, some subjects could not complete the field testing.

All subjects were medically screened prior to testing. Subject also completed the CF EXPRES "pre-test" screen, a PAR-Q and consent forms. All subjects completed a laboratory test battery prior to collection of field task data in the research laboratories of the Faculty of Physical Education and Recreation, the University of Alberta. The field task battery was administered at the Canadian Forces Base (CFB) in Calgary.

Means, standard deviations, and range of scores for each variable were determined. Where applicable, the t-test for dependent measures was utilized to determine differences between means. Pearson Product Moment Correlations among all field and lab test results were calculated. Standard computer programs for computation of correlation coefficients were utilized.

Multiple Stepwise Correlations and Regression equations were computed for each of the field tasks. Multiple correlation determined the relationship of selected laboratory tests with a given field test. Regression equations permitted prediction of a field task performance from several laboratory tests. Canonical correlation was also computed to determine the overall relationship between the laboratory and field task variables.

Isometric and isokinetic strength levels of male soldiers were in agreement with the values reported by other authors for civilian male population of similar age groups. Soldiers had lower strength levels in comparison to highly trained individuals and greater than relatively less trained male civilian population.

Based on the size of multiple correlation coefficients, digging performance had the greatest degree of relationship with laboratory tests followed by casualty evacuation, ammunition box lift, and jerry can task. Weight load march did not relate to the performance of any laboratory test.

The canonical correlation coefficient between the selected laboratory and field task variables was 0.73, indicating a good overall relationship between the two. Static trunk extension strength, dynamic leg extension strength and trapezius lift endurance contributed most to the canonical correlation from the laboratory tests. Maximal effort dig, ammunition box lift, and casualty evacuation contributed most from the field tasks.

A panel of subject matter expert judges was asked to classify all individuals into pass and fail groups for all field tasks except for the weight load march. The cutoff distance for weight load march was determined by the researcher on the bases of the task performance and physiological capability of the subjects. Discriminant 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 discriminant analysis results did not support or refute any of the cutoff performances suggested by the panel of expert judges or the researcher.

Recommended performance standards for the field tasks were based on the following criteria:

(a) cutoff performances suggested by the panel of subject matter judges

(b) soldiers' physiological capabilities to meet job requirements.

Conclusions

Based on the results of the study, recommended standards for the Canadian Army were those cutoff performances as suggested by the panel of subject matter judges and the researcher. In conclusion, for male soldiers, it is recommended that the following field tasks be included in a field Physical Fitness Test Battery for the Canadian Armed Forces:

1. A 13 km weight load march in full fighting order at 5.33 km/h, in 2:26:20 h.
2. A slit trench digging task, shifting ½ m^3 of gravel from one standardised container to another, with standard shovel, in 360 seconds or less.
3. A casualty evacuation test, carrying (using a fireman's carry) an individual of similar height and weight over a 100 meter course in 60 seconds or less. Both parties carrying weapons and in fighting order without back pack.
4. An ammunition box lifting task involving loading 48 standard ammunition boxes from ground to standard military truckbed height (1.3 meter) in 300 seconds or less at a heart rate of 80% of maximum.
5. A Maximal Effort Jerry Can task, carrying and emptying three jerry cans, one at a time, into a gas tank simulator in 300 seconds or less.

Recommendations

1. This study investigated the relationships of field tasks and laboratory tests. Based on this data physical training programs need to be developed for those who do not meet the minimal requirement of the field task(s).
2. In order to develop task related performance standards for women, a similar study needs to be conducted on a comparable or a larger sample size.
3. The results of this study should be cross-validated utilizing new expert judges and a different representative sample of male soldiers at a later date.

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APPENDIX A. ADMINISTRATIVE FORMS

1. Testing Advisory Form
2. Physical Activity Readiness Questionnaire (PAR Q)
3. Health Appraisal Questionnaire Form
4. Consent Forms for the Project:
   i. Consent Form for The Laboratory Tests
   ii. Consent Form for The Field Tests

A1. FORCES MOBILE COMMAND PHYSICAL FITNESS STANDARDS TESTING ADVISORY

TO: ALL PARTICIPANTS

Prior to your testing sessions, please note the following:

1. Do not smoke within four hours to start of a testing session.
2. Do not drink coffee or tea (or other beverage containing Caffeine) within four hours prior to your testing session.
3. Do not eat at least two hours prior to a test session. If you cannot avoid eating, eat lightly.
4. Do not consume any alcoholic beverages at least 24 h prior to a test session.
5. Do not exercise strenuously within 24 h prior your test session.
6. Do be on time for your test session, if possible, be early.
7. If you have any question(s) talk to one of the test coordinators.

Participation Activity Readiness Questionnaire (PAR-Q) goes on this page (as Appendix A2). This questionnaire has been removed due to copyright restrictions. PAR-Q is issued by the Ministry of British Columbia, Canada.

A3. HEALTH APPRAISAL QUESTIONNAIRE
(CF EXPRESS, 1989)

Name: ______________________ Group #: _____ Subject #: _______

This questionnaire is a screening device to identify those members for whom physical activity might be inappropriate at the present time.

To best of your knowledge:

	Yes	No
1. Do you have a restricted medical category which may prevent you from being evaluated or participating in a progressive training program?	☐	☐
2. Do you have any recurring problems with your back, shoulders, hips, knees or ankles which may prevent you from being evaluated or participating in a progressive training program?	☐	☐
3. Do you suffer from such things as: High blood pressure, heart disease, asthma, bronchitis, emphysema, diabetes, epilepsy, arthritis or cancer?	☐	☐
4. In addition to the above is there anything which you feel should be discussed with a medical officer prior to assessment?	☐	☐
5. Are you taking medication (prescribed or otherwise) which may affect your ability to undertake a physical evaluation?	☐	☐

6. How are you feeling today?

Excellent ☐ Good ☐ Physically tired ☐ Mentally tired ☐

Don't feel good at all ☐

Other (please specify) ☐

____

____

____

____

A4-i. THE INFORMED CONSENT FORM FOR THE LABORATORY TESTS

I,______________ ________________authorize Dr. M. Singh and P. Chahal, the University of Alberta, to administer and conduct testing of laboratory measures. These tests are designed to assess my physiological fitness abilities related to the performance of selected army tasks. These measures consist of body composition, muscular strength and endurance tests.

The muscular strength and endurance capacity test battery consists of:

1. The isometric strength test battery consisting of handgrip, arm flexion at elbow angle of 105 degrees, trunk flexion and extension at hip angle of 160 degrees. For each test, before attempting maximal contractions, I will be required to perform a warm-up contraction at an intensity of 50 to 60% of the maximal voluntary effort. After a warm-up contraction for five seconds, I will perform two maximal voluntary contractions. Each contraction will be five seconds in duration. The maximal force generated during the either contractions will be recorded. A rest period of three minutes will be given between each contraction.

2. The isokinetic-concentric strength test battery consists of arm flexion, leg extension, trapezius lift (similar to the movement of lifting an ammunition box from waist to shoulder height), bench press, trunk flexion and extension in hip angle range of 170 to 150 degrees, knee extension and flexion. The first four tests are to be conducted at a cable velocity of 13 cm/s. This speed corresponds to an angular velocity of 30 degrees per second (Okoro, 1987). The trunk extension and flexion tests will be conducted at a cable velocity of 6.5 cm/s (Ashton, 1973). Empirical observations of various task performance indicates that these trunk movements tend to occur at slower velocities than that of the peripheral joints such as those of legs and arms. The knee extension and flexion tests will be conducted at an angular velocity of 180 degrees per second. This speed is specific to the knee movements seen in weight load marching (Dziados et al., 1987). For each of these tests a warm-up set of six repetitions at a submaximal intensity will be conducted at 50 to 60% of my maximal voluntary effort. Following the warm-up contraction, I will perform two sets of two maximal voluntary contractions.

3. The isometric endurance capacity test battery consist of handgrip, and arm flexion endurance. These tests will be conducted at loads similar to those encountered in the performance of common army tasks.

4. Dynamic endurance capacity test will consist of trapezius lifts. This test will be conducted utilizing free-weight dynamometer with loads encountered in repeated performance of common army tasks.

5. The body composition determination will involve Hydrostatic Weighing. A rectangular tank six feet in height, four feet in width and 10 feet in length will be

used for this purpose. Before entering the tank, I will be weighed, in a swim short, on a balance scale to the nearest tenth of a kg. Residual volume then will be estimated from the vital capacity measured in the hydrostatic tank. Then hydrostatic weight will be determined. The procedures for hydrostatic weighing are as follow:

A. I will dislodge air bubbles from my swim suit, hair, and the body.
B. Then I will maximally inhale and close the nasal passages. At this point I shall remain motionless.
C. I will be slowly submerged in the water. Once a steady motionless state is observed by the tester, a six second underwater weighing reading will be recorded. The chair then will be pulled up, by the tester, to raise my head and neck from the water.
D. The computer will calculate the percent of body fat (based on the formula of Brozek et al. (1963)), and fat free body weight.

This procedure will be repeated until two similar readings are recorded on the computer.

For safety purposes, during performance of these laboratory tests if I experience intolerable discomfort, pain in the chest, shortness of breath, nausea, or dizziness then I will terminate the test without any explanation. The instructions in regard to conduction of each test will be given prior to the start of each test.

Every effort will be made to conduct the tests in such a way as to minimize discomfort and risk. However, I understand that just as with other types of fitness and body composition tests there are potential risks. These include episodes of transient lightheadedness, fainting, chest discomfort, leg cramps, nausea , and extremely rarely heart attacks.

I acknowledge that the testing procedures have been fully explained to me and that I can withdraw my participation from the study at any time without any explanation. I hereby consent to participate on my own volition.

DATE:_______________ SUBJECT:____________________
(SIGNATURE)

WITNESS:____________________
(SIGNATURE)

A4-ii. THE INFORMED CONSENT FORM FOR THE FIELD TESTS

I,______________ ________________authorize Dr. M. Singh and P. Chahal, the University of Alberta, to administer and conduct testing of filed tasks. These measures consist of casualty evacuation, ammunition box lift, maximal effort jerry can carry, maximum effort digging, and weight load marching tasks. These tests are designed to monitor and record my physical abilities to perform army job related tasks. They will be conducted very much similarly to the ones in realistic army situations.

For safety purposes, during performance of these tasks if I experience intolerable discomfort, pain in the chest, shortness of breath, nausea, or dizziness then I will terminate the task without any explanation. The instructions in regard to conduction of each test will be given prior to the start each task.

For casualty evacuation task, I will be required to evacuate an other soldier of similar height and weight.

For ammunition box lift, I will be required to lift 48 boxes (one box at a time) from the floor and replace them at a height of 1.3 m (height of a truck bed). Each box weighs 20.9 kg.

For maximal effort jerry can task, I will be required to carry three full jerry cans, in three shuttles runs for a distance of 35 m and then empty them into a gas-tank simulator table at 1.3 m height. I will only be required to carry one can at a time. Total time to complete the task will be recorded.

For maximal effort digging task, I will be required to dig gravel from a box-hole. The quantity of the gravel will be 0.5 cubic meter. This represents the approximate volume of a one fox hole which is 1.8 m x 0.6 m x 0.45 m in dimensions.

For weight load marching, I will be required to march 16 km at 120 paces per minute with full gear (24.5 kg). Each pace is 30 inches in distance. This pace is equivalent to marching speed of 5.33 km/h.

Every effort will be made to conduct all of these tests in such a way as to minimize discomfort and risk. However, I understand that just as with other types of physical testing there are potential risks. These include episodes of transient lightheadedness, fainting, chest discomfort, leg cramps, nausea, and extremely rarely heart attacks.

I acknowledge that the testing procedures have been fully explained to me and that I can withdraw my participation from the study at any time without any explanation. I hereby consent to participate on my own volition.

DATE:________________ SUBJECT:__________________

(SIGNATURE)

WITNESS:__________________

(SIGNATURE)

APPENDIX B. LABORATORY TEST INSTRUCTIONS TO SUBJECTS AND CALCULATION PROCEDURES FOR DETERMINATION OF BODY COMPOSITION

1. Subject Instructions for Muscular Strength Tests.
2. Subject Instructions for Muscular Endurance Tests.
3. Subject Instructions for Hydrostatic Weighing.
4. Calculation Procedures for Determination of Body Composition.

B1. INSTRUCTIONS TO SUBJECTS FOR MUSCULAR STRENGTH TESTS

The tester read the following instructions to each subject prior to testing (all the laboratory test instructions were also posted on the walls in their respective testing areas):

1. You will be required to do two type of strength tests: isometric strength tests, and dynamic strength tests. Before you perform each test, it will be explained in more details. During any of these tests you shall not generate force in any bouncy movement. The jerking movement during the contraction can result in an artificial increase of peak force and thus could confound the results of the study.

2. For **isometric strength tests** before attempting the maximal contractions you will perform a warm-up contraction at a intensity of 50 to 60% of your maximal voluntary effort. Then you will do two maximal voluntary contractions. Each contraction will be five seconds in duration. The maximal force generated will be recorded. A rest period of three minutes will follow between each set of contraction.

   A. **Isometric Handgrip Strength Test:** This test will be conducted with a handgrip dynamometer. Initially, you will hold the handgrip dynamometer in shoulder flexion position (straight arm above the head). Then on the command "Start" you will slowly flex your shoulder, at the same time exerting maximal handgrip force. Once the shoulder is fully extended (straight arm hanging downward) you will maintain the maximal contraction for three seconds. This procedure will then repeat on the other hand. Two maximal contraction will be performed with each hand. A maximal score from each hand will be recorded

   B. **Isometric Arm Flexion Strength Test:** This test will be conducted at an elbow angle of 105 degrees. This represents the angle at which soldiers carry ammunition boxes while maintaining the isometric contraction.

   C. **Isometric Trunk Flexion Strength Test:** You will be required to perform a maximal abdominal strength test at a hip angle of 160 degree while standing. The hip angle will be measured with a goniometer during a warm up contraction. Feet positioning during testing will be shoulder width apart. The heels of each foot shall touch the front edge of the white tape placed on the standing surface.

   D. **Isometric Trunk Extension Strength Test:** You will execute a maximal isometric trunk extension at a hip angle of 160 degree. The hip angle will be measured with a goniometer before testing during a submaximal warm-up contraction. While performing the test you will be required to keep your back straight. For safety reasons, this is standardized for all of you to eliminate any excessive curving of the upper back while contracting. Excessive curving of the back tends to put most of the brunt of the load on the paravertebral ligaments and thus increases the chance of back related injury. The position of feet is standardized with the out side edges being shoulder width apart. Shoulder width for you will be measured with an "Anthropometric Measuring Stick". A white paper tape is put on the standing surface with markings on it to facilitate the placement of feet in the appropriate position. A over and under handgrip shall be used to perform this test. The dominant hand will under grip and the other shall over grip. During the test do not hold your breath, breath normally.

3. For **isokinetic-concentric strength tests** knee flexion and extension will be conducted at an angular velocity of 180 degrees per second. Leg extension, arm flexion, trapezius lift, and bench press tests will be conducted at a cable velocity of 13 cm/s. This speed translates to an angular velocity of 30 degrees per second. Trunk extension and flexion tests will be conducted at a cable velocity of 6.5 cm/s. For each of these tests you will conduct a warm-up set consisting of six repetitions at about 50 to 60% of maximal voluntary effort. Then you will perform two sets of two maximal voluntary contractions. A three minutes rest will be given between each set of exercise. The maximal force generated will be recorded.

   A. Isokinetic-Concentric Knee Flexion and Extension Torque Tests: These tests will be performed with each leg, in a sitting position, knee angle range of 90 to 180 degrees. The 180 degree represents full extension of the knee. After a warm-up set, upon the command "Start" you extend your knee by exerting maximal voluntary force. Once reaching full extension you shall flex the knee at a maximal effort. Once the knee reaches 90 degree flexion you repeat these procedures.

   B. Isokinetic-Concentric Arm Flexion Strength Test: For this test, you will perform the contractions through full range of motion. On the command "Start" you shall flex maximally by pulling the bar upward. Once full flexion is reached then you slowly extend your arms to the starting position for another repetition. Relax your arms while bringing them down to the starting position. You only need to generate maximal force when pulling upward.

   C. Isokinetic-Concentric Trunk Flexion Strength Test: The trunk flexion test will be conducted through a hip angle range of 170 to 150 degrees. The body positioning is similar as for the isometric trunk flexion strength test. From the starting position you shall pull forward and downward while the cable is released from the back. Once reaching 150 degree of flexion you should relax while the dynamometer returns you to the starting position for another maximal contraction.

   D. Isokinetic-Concentric Trunk Extension Strength Test: This test will be conducted through a hip angle range of 150 to 170 degrees. The body positioning and handgrip is similar as for the isometric trunk extension strength test. While maintaining legs and back straight, you will pull-up on the bar while the cable is released upward. Once reaching a hip angle of 170 degree then you shall passively brings your self to the starting position.

E. **Isokinetic-Concentric Leg Extension Strength Test:** At start of the test, a dynamometer belt will be put and secured around your waist. Then the cable will be adjusted to suit your waist height. During the test you shall hold the bar with your hands for a greater stability. At onset of the test you shall pull up on the cable as it is released. Once reaching the standing height then return to the starting position of 90 degree knee flexion for another maximal effort contraction.

F. **Isokinetic-Concentric Trapezius Lift Strength Test:** This test will be conducted in a standing position, feet shoulder width apart. Special handles on the weight bar have been designed to simulate the handles of an ammunition box. The distance between the handles is 38.5 cm. At start of the test, from full arm extension, you shall lift the bar upward until the top part of the grip handles reaches a height parallel to the clavicle height (sternal end). Once reaching this point you relax, maintaining the grips as the bar returns automatically to the starting position. Then you will execute an other maximal contraction.

G. **Isokinetic-Concentric Bench Press Strength Test:** This test will be conducted on the Isokinetic Electric Dynamometer. It will be performed lying on a bench. The bar height will be preset two inches above the chest, at a mid sternum level. At start of the test you will push up until reaching full extension at the elbow joints. Then you passively return the arms to the starting position.

4. You will be provided a general warm-up phase at the start of the tests. It will consist of three minutes of general cardiovascular and stretching activities of your choice.

5. Verbal encouragement will be given to help motivate you.

6. Once the test has ended, you will walk about the test area in order to actively cool-down. Continue to walk until you feel fully recovered (two to three minutes or until your heart rate has decreased to less than 120 beats per minute). Do not leave until the tester is confident that you are fully recovered.

7. If you feel any of the test is too demanding, you may stop at any time without any explanation.

8. Are there any questions?

B2. INSTRUCTIONS TO SUBJECTS
MUSCULAR ENDURANCE CAPACITY TESTS

The tester read the following instructions to each subject prior to muscular endurance testing:

1. Isometric muscular endurance capacity test battery consist of handgrip, and arm flexion tests. These tests will be conducted at loads similar to that encountered in the performance of the common army tasks.

   A. **Isometric Handgrip Endurance Capacity Test:** This test is designed to simulate the handgrip endurance requirements while transporting jerry cans. It will be conducted on each hand using the handgrip dynamometer. During the test you will be required to maintain the force output dial at 21 kg force for long as possible. The tester will provide you feedback when the force starts to deviate. When you are unable to maintain this required force the test will be terminated.

   B. **Isometric Arm Flexion Endurance Capacity Test:** This test will be conducted at an elbow angle of 105 degree with a 20 kg Olympic bar. This represents arm position when a soldier carries an ammunition box while maintaining an isometric contraction. A goniometer will be used to monitor your elbow angle. The hand width and body positioning will be the same as for the arm flexion strength tests. Feedback will be given to you by the tester if the angle starts to deviate. You shall hold this position for long as possible. When you are no longer able to maintain this position the test will be terminated. The total time for which the contraction is sustained will be recorded.

2. The **Isotonic Trapezius Lift Endurance Capacity Test** will be conducted with a 21 kg load representing weight of an ammunition box. It will be performed utilizing the free-weight dynamometer. The test will be conducted while you are standing with a slight knee flexion. At the onset of the test you will start from arm extension position. Then you shall lift the bar so that top of both thumbs reaches parallel height to your shoulders. While lifting you must lead upward with your elbows. The downward (eccentric) phase of the test will be performed passively. You will perform 10 contractions per minute. Each contraction will require about three seconds followed by a three second rest interval. The pace will be set with this metronome. It will beep every six seconds. In this time frame you should complete one repetition. You will maintain this pace for long as possible or until 100 repetitions are achieved. The total number of successfully completed repetitions will be recorded.

3. You will be provided a general warm-up phase at the start of tests. This will consist of three minutes of general cardiovascular and stretching activities of your choice.

4. Verbal encouragement will be given to help motivate you.

5. Once the test has ended, you will walk about the test area in order to actively cool-down. Continue to walk until you feel fully recovered (two to three minutes or until your heart rate has decreased to less than 120 beats per minute). You must stay in the test area until your heart rate has dropped below 100 beats per minute. Do not leave until the tester is confident that you are fully recovered.

6. If you feel any of the test is too demanding, you may stop at any time without any explanation.

7. Are there any questions?

B3. INSTRUCTIONS TO SUBJECTS FOR HYDROSTATIC WEIGHING

The tester read the following instructions to each subject prior to hydrostatic weighing:

1. This test will be conducted to determine your percentage of body fat and fat-free weight.

2. Before entering the tank for hydrostatic weighing, you will be weighed, in a swim short, on a balance scale to the nearest tenth of a kg. Then you shall take a shower before entering the tank.

3. Once in the tank you shall sit in the steel chair. A 9.45 kg diver's weight belt then will be placed across your thighs close to the waist.

4. Residual volume will be estimated in this position from a measure of vital capacity.

5. Following the residual volume determination the hydrostatic weight will be determined. The procedures for hydrostatic weighing are as follow:

   A. You shall dislodge all air bubbles from the swim suit, hair and the body using your hands.

   B. On tester's indication you will close the nasal passages and maximally inhale. At this point you shall remain motion less.

   C. Then you will be slowly submerged in the water. Once a steady motion less state is observed by the tester, a six second underwater weighing reading will be recorded. The chair then will be pulled up so your head and neck raises from the water.

   D. The computer will calculate the percent of body fat (based on the formula of Brozek et al. (1963)), and fat free body weight.

   This procedure repeats until two similar chart readings are obtained.

7. Once the test has ended, you shall once again take a shower. Soap, shampoo, and a towel will be provided to you.

8. If you feel this test is too demanding or discomforting, you may stop at any time without any explanation.

9. Are there any questions?

B4. CALCULATION PROCEDURES UTILIZED BY THE COMPUTER FOR DETERMINATION OF BODY COMPOSITION (Mottola, 1980)

(1.) Water Density at Temperature Observed ________

(2.) Dry Body Weight ________

(3.) Vital Capacity ________

(4.) Residual Volume (0.24 x Vital Capacity) ________

(5.) Volume Gastro-Intestinal Tract* ________

(6.) Submerged Weight $= \frac{(8.22 \text{ X chart reading})}{(75)} - 8.22$ ________

(7.) Total Gas Volume (at 37 °C) = (3.) + (4.) + 0.1 ________

(8.) Weight Equivalent of Gas Volume (Total Gas Volume (7.) X Dw (1.)) ________

(9.) Corrected Submerged Weight (6.) + (8.) ________

(10.) Difference in Air to Water Weight (2.) - (9.) ________

(11.) Body Volume (10.)/(1.) ________

(12.) Body Density (2.)/(11.) ________

(13.) Fat Fraction $\frac{4.570}{Db(12)} - 4.142$ ________

(14.) Percentage of Body Fat (13.) X 100 ________

(15.) Fat Weight (13.) X (2.) ________

(16.) Fat Free Weight (2) - (15) ________

* Volume of Gas in Gatro-Intestinal tract assumed to be 0.1 l

l = litre, kg = kilogram

APPENDIX C. INSTRUCTIONS TO SUBJECTS FOR FIELD TASKS

1. Subject Instructions for Casualty Evacuation.
2. Subject Instructions for Ammunition Box Lift.
3. Subject Instructions for Maximal Effort Jerry Can Task.
4. Subject Instructions for Maximal Effort Shellscrape Dig.
5. Subject Instructions for Weight Load March.

C1. INSTRUCTIONS TO SUBJECTS FOR CASUALTY EVACUATION

The tester read the following instructions to each subject prior to testing (all the field test instructions were also posted on the walls of their respective test areas):

1. This task is a simulation of a wounded soldier casualty evacuation at a maximal effort.

2. On the command "Start" you will be required to evacuate an other soldier of equivalent height and weight for a distance of 100 m, using the fireman's carry, at a maximum voluntary effort. Once any part of your foot touches or passes the finish line the task will be complete.

3. You will be provided a general warm-up phase at the start of the test. It will consist of three minutes of general cardiovascular and stretching activities of your choice.

4. Verbal encouragement will be given to help motivate you.

5. When lifting an other soldier avoid excessive forward bending, use your legs for lifting in order to reduce stress on the lower back.

6. Once the test has ended, you will walk about the test area in order to actively cool-down. Continue to walk until you feel fully recovered (two to three minutes or until your heart rate has decreased to less than 120 beats per minute). You must stay in the test area until your heart rate has dropped below 100 beats per minute. Do not leave until the tester is confident that you are fully recovered.

7. If you feel this test is too demanding, you may stop at any time without any explanation.

8. Are there any questions?

C2. INSTRUCTIONS TO SUBJECTS FOR AMMUNITION BOX LIFT

The tester read the following instructions to each subject prior to testing:

1. This test is a simulation of one person material handling task.

2. It will involve lifting ammunition boxes, each weighing 20.9 kg. On the command "Start", you will start lifting the boxes, one at a time, from the floor and placing them on a counter at a 1.3 m height. Do not start this task at a maximal effort. This may potentially be harmful for the lower back. Start it at a moderate pace until you reach 70% of your maximal aerobic power. This will be determined using a heart rate monitor. You will continue working at this pace until 48 boxes have been moved.

3. During the test you will wear a Sport Tester to monitor the intensity of your work every five seconds. Accordingly, the tester will give you feedback on when to slow down or fasten your pace.

4. You will be provided a general warm-up phase at the start of the test. This will consist of three minutes of general cardiovascular and stretching activities of your choice.

5. Verbal encouragement will be given to help motivate you.

6. Avoid excessive forward bending, use your legs for lifting in order to reduce stress on the lower back.

7. Once the test has ended, you will walk about the test area in order to actively cool-down. Continue to walk until you feel fully recovered (two to three minutes or until your heart rate has decreased to less than 120 beats per minute). You must stay in the test area until your heart rate has dropped below 100 beats per minute. Do not leave until the tester is confident that you are fully recovered.

8. If you feel this test is too demanding, you may stop at any time without any explanation.

9. Are there any questions?

C3. INSTRUCTIONS TO SUBJECTS FOR MAXIMAL EFFORT JERRY CAN TASK

The tester read the following instructions to each subject prior to testing:

1. This is a one person maximal effort jerry can task.

2. On the command "Start", you will carry one full jerry can for a distance of 35 m, quickly as possible, and empty it into a gas-tank simulator table at a 1.3 m height. Then you run back and pick up another can and repeat the procedures. After three shuttle runs, emptying three cans, you run back to the finish line. The total time to complete the task will be recorded.

3. You will be provided a general warm-up phase at the start of the test. This will consist of three minutes of general cardiovascular and stretching exercises of your choice.

4. You will not be instructed on technique. You may use any technique that feels natural to you.

5. Verbal encouragement will be given to help motivate you.

6. Avoid excessive forward bending, use your legs for lifting, in order to reduce stress on the lower back.

8. Once the test has ended, you will walk about the test area in order to actively cool-down. Continue to walk until you feel fully recovered (two to three minutes or until your heart rate has decreased to less than 120 beats per minute). You must stay in the test area until your heart rate has dropped below 100 beats per minute. Do not leave until the tester is confident that you are fully recovered.

9. If you feel this test is too demanding, you may stop at any time without any explanation.

10. Are there any questions?

C4. INSTRUCTIONS TO SUBJECTS FOR MAXIMAL EFFORT SLIT TRENCH DIG

The tester read the following instructions to each subject prior to testing:

1. This task is a simulation of a one person slit trench dig at a maximal voluntary effort.

2. On the command "Start", you must dig as quickly as possible pitching the crushed rock into the other box. You may move freely from one side of the box to the other while digging. The task will be complete when the laboratory personnel overseeing the test says "Stop". This will require to scoop out the final bit of soil by hand until you can no longer pick up a handful of soil, particularly from tight corners where it may be difficult to reach with the shovel.

3. You will be provided a general warm-up phase at the start of the test. It will consist of three minutes of general cardiovascular and stretching activities of your choice.

4. You will not be instructed on technique. You may use any digging technique that feels natural to you.

5. Verbal encouragement will be given to help motivate you.

6. Avoid excessive forward bending in order to reduce stress on the lower back.

7. Once the test has ended, you shall walk about the test area in order to actively cool-down. Continue to walk about the test area until you feel fully recovered (two to three minutes or until your heart rate has decreased to less than 120 beats per minute). You must stay in the test area until your heart rate has dropped below 100 beats per minute. Do not leave until the tester is confident that you are fully recovered.

8. If you feel this test is too demanding, you may stop at any time without any explanation.

9. Are there any questions?

C5. INSTRUCTIONS TO SUBJECTS FOR WEIGHT LOAD MARCH

The tester read the following instructions to each subject prior to testing:

1. This task is a weight load march in full fighting order. It will be conducted at a set speed of 120 paces for a maximal distance of 16 km (10 miles) or until you can no longer continue. Each pace is 30 inches in distance. This pace is equivalent to marching speed of 5.33 km/h.

2. Should you not be able to maintain the pace, move to the inside of the track and your test will be stopped once you have fallen back 100 m from the required pace.

3. You will be provided a general warm-up phase at the start of the test. This will consist of three minutes of general cardiovascular and stretching exercises of your choice.

4. Verbal encouragement will not be given to help motivate you.

5. Once the test has ended, you shall walk about the test area in order to actively cool-down. Continue to walk about the test area until you feel fully recovered (two to three minutes or until your heart rate has decreased to less than 120 beats per minute). You must stay in the test area until your heart rate has dropped below 100 beats per minute. Do not leave until the tester is confident that you are fully recovered.

7. If you feel this test is too demanding, you may stop at any time without any explanation.

8. Are there any questions?

APPENDIX D. SELECTION OF SUBJECTS

In the total population of approximately 650 potential subjects, only nine were rated as borderline or fail, 33 were rated as superior.

All of the borderline and fail personnel who were selected as subjects completed all of the testing.

A random table of numbers was used for selection of the subjects from the remaining population.

Seven of the ten superior personnel did not complete the weight load march and as a result were disqualified from the data set.

APPENDIX E. PANEL OF EXPERT JUDGES

It consisted of a group leader and four members.

They individually judged each candidate on each task as pass or fail. The Judges were allowed to keep notes on each subject but could not compare with other Judges. Only the group leader timed the subject in each task and recorded the time to complete the task. At the end of the day, the Judges would meet and discuss each individuals performance. They rated the subjects as pass or fail. Then by a committee process a consolidated time was selected for each task.

APPENDIX F. PREDICTIVE REGRESSION EQUATIONS OF SELECTIVE LABORATORY VARIABLES AS BASED ON FIELD TASK PERFORMANCES

Table 1. Field Task Variable in the Stepwise Regression Equation for the Body Weight.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.303	0.092	0.078	10.81	6.66	0.012	68

Variable	B	SE B	Beta	T	Sig T
Maximal Effort Dig	-0.071447	0.027679	-0.302815	-2.58	0.012
Constant	97.832623	7.338977		13.33	0.000

Table 2. Field Task Variable in the Stepwise Regression Equation for the Percentage of Body Fat.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.355	0.126	0.113	5.76	9.54	0.003	68

Variable	B	SE B	Beta	T	Sig T
Ammunition Box Lift	0.039081	0.012655	0.355321	3.09	0.003
Constant	11.647253	2.230537		5.22	0.000

Table 3. Field Task Variable in the Stepwise Regression Equation for the Fat Free Body Weight.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.494	0.244	0.233	7.27	21.30	0.000	68

Variable	B	SE B	Beta	T	Sig T
Maximal Effort Dig	-0.085877	0.018609	-0.493919	-4.62	0.000
Constant	86.911096	4.934114		17.61	0.000

Table 4. Field Task Variable in the Stepwise Regression Equation for the Static Right Handgrip Strength.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.320	0.103	0.089	8.47	7.66	0.007	69

Variable	B	SE B	Beta	T	Sig T
Maximal Effort Jerry Can Task	-0.090971	0.032863	-0.320365	-2.77	0.007
Constant	762.210347	78.349060		9.73	0.000

Table 5. Field Task Variable in the Stepwise Regression Equation for the Static Arm Flexion Strength.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.305	0.093	0.079	15.37	6.47	0.013	65

Variable	B	SE B	Beta	T	Sig T
Maximal Effort Dig	-0.104491	0.041076	-0.305202	-2.54	0.013
Constant	740.765948	106.518131		6.95	0.000

Table 6. Field Task Variables in the Stepwise Regression Equation for the Static Trunk Flexion Strength.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.498	0.248	0.225	9.81	10.88	0.000	69

Variable	B	SE B	Beta	T	Sig T
Casualty Evacuation	-0.389093	0.144268	-0.314786	-2.70	0.009
Maximal Effort Dig	-0.065671	0.027470	-0.279025	-2.39	0.020
Constant	1031.91848	76.033829		13.57	0.000

Table 7. Field Task Variable in the Stepwise Regression Equation for the Static Trunk Extension Strength.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.547	0.299	0.288	23.39	27.34	0.000	66

Variable	B	SE B	Beta	T	Sig T
Maximal Effort Dig	-0.313860	0.60022	-0.547128	-5.23	0.000
Constant	2527.87218	156.234873		16.18	0.000

Table 8. Field Task Variable in the Stepwise Regression Equation for the Dynamic Right Knee Flexion Torque.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.324	0.105	0.091	18.36	7.52	0.008	66

Variable	B	SE B	Beta	T	Sig T
Maximal Effort Dig	-0.131463	0.047928	-0.324329	-2.74	0.008
Constant	151.613167	12.754729		11.89	0.000

Table 9. Field Task Variable in the Stepwise Regression Equation for the Dynamic Right Knee Extension Torque.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.346	0.120	0.106	24.96	8.72	0.004	66

Variable	B	SE B	Beta	T	Sig T
Maximal Effort Dig	-0.192448	0.065162	-0.346324	-2.95	0.004
Constant	209.949217	17.341008		12.11	0.000

Table 10. Field Task Variables in the Stepwise Regression Equation for the Dynamic Trunk Flexion Strength.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.528	0.279	0.246	9.53	8.38	0.000	69

Variable	B	SE B	Beta	T	Sig T
Casualty Evacuation	-0.295608	0.143448	-0.242870	-2.06	0.043
Maximal Effort Dig	-0.061135	0.036770	-0.263786	-2.28	0.026
Maximal Effort Jerry Can Task	-0.078328	0.038449	-0.222986	-2.04	0.046
Constant	1200.65493	102.728078		11.69	0.000

Table 11. Field Task Variable in the Stepwise Regression Equation for the Dynamic Leg Extension Strength.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.442	0.195	0.183	59.95	16.27	0.000	69

Variable	B	SE B	Beta	T	Sig T
Maximal Effort Dig	-0.619046	0.153472	-0.442027	-4.03	0.000
Constant	4173.98774	398.871966		10.46	0.000

Table 12. Field Task Variable in the Stepwise Regression Equation for the Dynamic Bench Press Strength.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.285	0.081	0.067	26.11	5.49	0.022	64

Variable	B	SE B	Beta	T	Sig T
Maximal Effort Dig	-0.165626	0.070676	-0.285252	-2.34	0.022
Constant	1598.17374	183.882035		8.69	0.000

Table 13. Field Task Variable in the Stepwise Regression Equation for the Dynamic Trapezius Lift Strength.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.278	0.077	0.0623	15.82	5.27	0.025	65

Variable	B	SE B	Beta	T	Sig T
Maximal Effort Dig	-0.097006	0.042262	-0.277804	-2.30	0.025
Constant	879.912904	109.593057		8.03	0.000

Table 14. Field Task Variable in the Stepwise Regression Equation for the Static Right Handgrip Endurance.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.321	0.103	0.090	52.91	7.61	0.008	68

Variable	B	SE B	Beta	T	Sig T
Maximal Effort Dig	-0.374898	0.135940	-0.321447	-2.76	0.008
Constant	218.828196	35.990985		6.08	0.000

Table 15. Field Task Variable in the Stepwise Regression Equation for the Static Arm Flexion Endurance.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.449	0.202	0.189	42.84	16.65	0.000	68

Variable	B	SE B	Beta	T	Sig T
Maximal Effort Dig	-0.447710	0.109705	-0.448887	-4.08	0.008
Constant	227.528360	29.086186		7.82	0.000

Table 16. Field Task Variable in the Stepwise Regression Equation for the Trapezius Lift Endurance.

Multiple R	R Square	Adjusted R Square	Standard Error	F	Sig F	n
0.377	0.142	0.129	19.59	10.92	0.002	68

Variable	B	SE B	Beta	T	Sig T
Maximal Effort Dig	-0.170288	0.051530	-0.376793	-3.31	0.002
Constant	135.119249	13.591095		9.94	0.000