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THE UNIVERSITY OF ALBERTA

Task Related Aerobic And Anaerobic Physical Fitness Standards For The Canadian Army

BY

© Major S. Wayne Lee

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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DEDICATION

This doctoral manuscript is dedicated to:

Claire, my wife, who for 23 years has provided unending support throughout all my academic upgrading and to my daughter Yvette and son Robin who have provided me with love and inspiration.

My sincerest appreciation is extended to:

My friend Jose Gonsalves who twenty years ago provided me with academic help and support that culminates in this academic achievement.

Lieutenant Colonel Bob Swan who made it possible for me to participate in this program and provided me the opportunity to fulfill a lifelong dream - the completion of this Ph.D.

The Canadian Forces and the Officers and Members of the Physical Education and Recreation Branch who have had confidence in my abilities to pursue this program of studies and provided moral support in its most difficult hours.

MENS SANA IN CORPORE SANO

ABSTRACT

This study is part of a larger investigation designed to develop task related physical performance standards for combat soldiers in the Canadian Army. One hundred and sixteen male infantry soldiers took part in the study and 99 completed all tests. The purpose was to develop standards based on physical requirements of the job and physiological capacity of the soldiers. To achieve this a field and a laboratory test battery were administered to all soldiers. The field test battery consisted of:

1. casualty evacuation,
2. ammunition box lift,
3. maximal effort digging, and
4. weight load march.

These tasks represented the most difficult and representative common field tasks a soldier was expected to perform. The laboratory test battery consisted of:

(i) weight load treadmill march test,

(ii) Wingate leg anaerobic power test, and

(iii) Wingate arm anaerobic power test.

The reliability coefficients of all tests included in the two test batteries ranged between 0.83 to 0.96. An expert panel of judges was also utilized in the establishment of final standards. Statistical analysis of the data included Pearson Product Moment Correlations, Multiple Stepwise Correlations, Regression equations and Canonical Correlation. These were computed to determine overall

relationship between the laboratory and field task variables. The final performance standards were based on:

(a) pass - fail performance levels suggested by subject matter experts,

(b) discriminant analysis of possible cut off performances in selected field tasks, and

(c) soldiers physiological capabilities to meet job requirements.

The recommended physical performance standards were:

1. Casualty evacuation in 60 seconds,
2. Ammunition box lift in 300 seconds,
3. Maximal effort digging in 360 seconds, and
4. Weight load march of 13 km in two hours and 26 minutes.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

History shows the intimate relationship between physical education and the military. In the ancient world, for example, the Spartan youth's entire life was centered around physical education, the sole purpose of which was to prepare him for military service. The Spartan physical education program included ball games, wrestling, archery, stone throwing, javelin throwing and hunting (Hackensmith, 1966). In Athens, all young men were also subject to a form of military conscription during which time physical and military education were emphasized. The Panhellenic games, the forerunner of the modern Olympic games, brought together the best athletes of the ancient world competing in running, jumping, javelin throwing, boxing, pentathlon, and chariot racing – all skills required by the military. All of the previously mentioned activities required continuous practice in order to be proficient. In effect, the training program involved actual participation in the related task activity thereby developing skill in the activity while at the same time maintaining or improving general physical fitness. In this way the principle of task specificity was fulfilled while an improvement in physical fitness occurred concomitant to progressive skill development.

This duality may have been the perfect match of improving skills required in an activity and maintaining or improving the fitness components specific to that activity at the same time. In the future, due to increased reliance on mechanization and the subsequent dissociation of physical fitness development from the skill requirements of highly specialized military tasks, this relationship may not be as clear. The need for specific physical fitness activities in order to ensure the development of skill in a specific work task and physical fitness development will become evident.

In a modern army, many demanding physical tasks that previously required muscle power are now being handled by machines (Marston et al., 1981). 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 or helicopter. Nonetheless, there are still many military tasks that demand a high level of physical fitness, in terms of both strength and endurance. Today's soldier, like those in the past, must be prepared to be deployed anywhere in the world in all types of terrain and weather conditions. 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 addition to carrying weapons, the soldier must also carry many new pieces of personal gear which did not exist 20 years ago. Such gear includes special electronic equipment for communication and for detection of the enemy (Marston et al., 1981). Trucks, armoured personnel carriers, tanks, and other heavy equipment used on the battle field may break down and require repairs that may involve the lifting and fitting of heavy parts. Modern devices such as night vision goggles have made the 24 hour battle day a reality. As a consequence, today's soldier must have the stamina to fight for longer periods of time without rest and sleep. Due to all of these factors, the need for a physically fit soldier is at least as great as or even greater today than ever before (Jette et al., 1986).

It may be argued that in today's highly mechanized military, fitness may not be as important because of reliance on sophisticated mechanical aids. However, the Falkland experience supports the concept that soldiers cannot fully depend on the availability or worthiness of their transport equipment in operational theatres. 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 arrive fit to fight on the same day. British commanders have described physical fitness and esprit de corps as their "secret weapon" in this conflict (Time magazine, 14 June 1982).

The Canadian Forces (CF) defines physical 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 Operation Manual, 1981). As Daniels et al., (1979) state, "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 emphasize that physical fitness, for Army purposes, could be defined as those factors which determine the soldier's ability to perform heavy physical work and contribute toward maintaining good health and appearance.

Other countries such as the United States, Britain, Norway and France have also conducted studies of their military forces physical fitness levels. Overall, findings are similar to Canadian investigators. Personnel working in physically demanding jobs and participating in compulsory fitness training programs were fit while the remainder demonstrated a level of fitness similar to the civilian population. Allen et al., (1981) observed on the dilemma of the Canadian Forces: "For the majority of CF personnel, poor fitness does not immediately appear to interfere with job performance and a certain degree of obesity has often been tolerated".

Other than demonstrating a soldiers' ability to adequately perform occupational tasks, optimal levels of physical fitness will provide many additional benefits for the soldier. These benefits may include improved job efficiency, decreased rate of accidents, injuries and sick leave, increased productivity and alertness, as well as more positive work attitudes (Mayo, 1984).

For the past three decades, the concept of physical fitness for the Canadian Army was based on prediction of physical performance by factors such as low body fat, ability to run fast for extended periods of time (presuming a high relative maximal oxygen uptake), and ability to do a large number of push-ups, sit-ups, and/or chin-ups (presuming high levels of muscular strength and endurance). It was thought that the individuals who were successful in these measures would be the ideal soldiers. It was assumed that these soldiers would possess the highest fitness level and that this high fitness level would generalize to an ability to better perform their duties. However, the Falklands situation proved this concept to be faulty. There, the soldiers who had a fitness level similar to typical marathon runners were found to be least successful in carrying out their duties even though they had high oxygen uptake values. Being successful, in the above mentioned physical performance factors (such as distance running, push-ups and sit-ups etc.), did not necessarily mean that one was fit to perform the specific occupational requirements of the related army tasks. Many of the army tasks may or may not have similar physical demands as would field or laboratory tests. In post-operation reports, Commanders noted that the individuals who were most successful in the Falklands situation were those who had mesomorphic (large muscle mass) type of bodies and superior upper and lower body strength.

As an example of an operationally related task, every soldier in the army must carry 20 to 30 kg of personal equipment. To successfully carry this load for extended periods of time demands adequate strength and muscular endurance capacities. Currently, the consensus of opinion of army personnel appears to be that high levels of muscular strength and endurance are as important as high levels of oxygen consumption capacity. Marching with external loads places extra muscular strength and endurance demands on the body in comparison to marching or running with minimal or no equipment.

Mayo (1984) states that the necessity for a high level of physical fitness for Canadian Forces (CF) personnel has never been questioned. The evaluation of performance of an individual in his/her specific job situation is complicated not only by the diversity of work situations but is also greatly influenced by factors such as fatigue, environmental conditions and psychological and health status. In the past, the maintenance of appropriate levels of physical fitness of CF personnel has largely been an individual responsibility. However, the CF requires its members to be alert, responsive, and both physically and mentally prepared for the unexpected. New soldiers are recruited from a population which is, for the most part, relatively physically inactive. The sedentary pre-military life-style tends to carry over into the military population (Mayo, 1984). Murphy et al., (1984) state that a soldier in a combat situation is required to perform a wide spectrum of physical activities ranging from long to short duration high intensity activities. A military person may be called upon to change jobs and environments quite often during his/her career. Traditionally, military personnel have had highly active jobs to fulfil in emergency situations. For example, soldiers may be called upon to respond and to provide aid to the civil administration; to charge a prison yard full of rioting prisoners; to assist in fighting forest fires; or to build sand bag dikes for flood control (Mayo, 1984).

During these emergency situations, individuals are expected to perform highly physically demanding tasks. They are required to be alert, responsive and to demonstrate strength and stamina. However, presently there are no task specific physical fitness standards in the Canadian Army to determine if a soldier can satisfactorily meet these requirements.

Some of the persons who tend to complain about any testing programs reason that fitness was not a requirement when they first entered the military and therefore, poor fitness should not be a cause for reprimand or dismissal. However, if task specific standards are used and the individual fails to demonstrate physical capability to carry out the duties of their bona fide occupational requirements then dismissal may be justifiable regardless of past selection inadequacies. The current minimal physical fitness standards of the CF are set in the CF EXPRES Program. These standards do not appear to relate well to the demands placed on soldiers in combative roles. Physical demands of the army, for the most part, exceed those in other trade specialties of the CF. Therefore, there is a need to set task specific minimal performance standards for the Canadian Army and combat forces.

<u>Selection Criteria for the Common Tasks for the Army</u>

From the potentially hundreds of physical tasks which could have been chosen for further study in the present investigation, a series of representative common tasks were selected by a committee of army experts, at headquarters and in the field, and approved by the senior authority – Command Council – as representative of the physical requirements of the Canadian soldier. The selection of common tasks was based on:

1. a comprehensive review of the scientific and national and 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, special meetings and briefs at Forces Mobile Command (FMC) Headquarters in Montreal, Quebec.

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 common tasks were approved by the Commander of Forces Mobile Command (FMC) and the FMC Command Council Staff. In addition, each of the generals were provided consultation from their senior staff officers based on previously held meetings under the chairmanship of the researcher, held at CFBs' Calgary, Wainwright and FMC Headquarters Montreal. Thus, the number of common tasks were verified and approved by Command Council as representative of the physical demands of all Combat Arms personnel.

As a result of the field observations and interviews, it was agreed that instead of selecting representative tasks from the Armour, Artillery, Infantry and Combat Support groups and developing individual common tasks, one thing that all groups had in common was the fact that they could be called upon to carry out the duties of the Infantryman at some point in the battle scenario. It was also agreed that the Infantryman's physical tasks were probably the most demanding physical tasks in the Combat Arms groups. This concept was discussed during field visits and with senior staff officers and was ratified by the Command Council members.

Field Tasks

The following common tasks were selected for further study:

1. **Execute Survival Duties:**

(i) <u>Digging Slit Trenches</u>

Scoop, lift, throw (a given amount) of standardized earth out of a shell scrape or slit trench (in a given time) using an issue shovel.

(ii) <u>Weightload March</u>

March (a given distance in a given time at a given pace) cross country in full fighting order in all weather and light conditions.

2. **Casualty Evacuation:**

(i) <u>Casualty Evacuation</u>

A soldier must lift another soldier (of approximately the same weight using the Fireman's Carry and evacuate that soldier (a given distance in a given time).

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

(i) <u>Transport Jerry Cans</u>

Carry a full jerry can (a given weight a given distance). Lift and empty jerry can into a container. Continue with the task (for a given time).

(II) <u>Handle Material Manually</u>

Lift a box equivalent in size/weight to a box of 5.56mm ammunition unassisted to a level of a truck bed (a given height).

COMMON TASK #1

EXECUTE SURVIVAL DUTIES

(I) <u>Digging Slit trenches</u>

Scoop, lift, throw (a given amount) of standardized gravel out of a slit trench (in a given time) using an issue shovel.

This task is intended to simulate digging and building defensive positions which provide personnel protection against incoming enemy fire. This task is considered by subject matter experts as a task common to all soldiers.

Chakraborty et al., (1974) determined that oxygen consumption was sustained at 29.1 ml/(kg . min), the equivalent of 69% of their subjects' maximal aerobic capacity. Heart rates were sustained well over 130 bpm during prolonged digging. The workers naturally appeared to select an optimal energy expenditure of approximately 400 kcal/h. This work rate permitted a high peak efficiency while digging over a prolonged period of time without experiencing undue fatigue. This corresponded to an oxygen consumption value of approximately 1.5 l.min. In MPFS, Phase III (Stevenson et al., 1988) the subjects' heart rate responses to digging reflected a similar elevated rate of 155–160 bpm. Stevenson et al.,

(1988) found that during digging tasks, energy was expended at a constant, submaximal rate approaching 70 percent of their maximal aerobic capacity, and equivalent to 400 kcal/h for males. The subjects for the study were instructed to dig at a maximal rate possible. However, these subjects were restricted to work between 66-90 percent of their maximal heart rate capacity depending on age. Seventy percent of aerobic capacity was estimated from the direct relationship between heart rate and VO_2 obtained from the step-test of the Canadian Standardized Test of Fitness (CSTF). The fastest digging times for male and female were 2-4 minutes, and the very slowest in well under 20 minutes. In MPFS, Phase II (1987), at maximal and submaximal efforts the majority of personnel were able to complete the task in less than 10 minutes. The average time, for individuals under 35 years of age, was 4:14 minutes and for over 35 years it was 5:36. The older individual were limited to work in a heart rate range of 200 bpm minus their age. The maximal heart rate in these individuals was an indirect estimate of 200 bpm.

<u>Digging Slit Trenches Task</u>: This task is appropriate in a battle situation where the soldier is required to provide immediate personal protection and is limited by the time available. The soldier is required to dig at maximal intensity.

Task Standardization: In order to ensure standardization, dig simulators were constructed. The purpose of the simulators was to ensures equal volume of work completed by each subject. The dimensions of the slit trenches were determined by the Army Working Group. The gravel contents of the simulators were standardized. This gravel can be obtained at any military location. The volume of gravel for the maximum dig was calculated to be 0.5 m^3 for the maximum dig and 1.0 m^3 for the submaximum dig.

(ii) **Weightload March**

Subjects marched (a given distance in a given time at a given pace) cross country in full fighting order in all weather and light conditions.

A distance of between 10 - 16 km was agreed by the subject matter experts as the most appropriate distance for marching. Factors involved in the choice of this distance included: test adequacy, ease of administration, safety, and amount of time to administer the evaluation. The selection of an appropriate distance was based on statistical and physiological analysis of group performance.

Task Standardization: The load utilized by the subjects was selected as the summer load with weapon. The total weight of all equipment and backpack was 24.5 kg. This represents the minimum load any soldier will carry at any time. The pace was determined by discussion with the Working Group and a review of the literature on sustained effort. The choice of test site represented the most ideal circumstance, i.e., indoors with minimal impact of weather and/or terrain.

COMMON TASK #2

EXECUTE RESCUE DUTIES

Casualty Evacuation: In a simulated battle field situation, perform Fireman's lift of an individual of approximately the same weight person and evacuate a given distance (in a given time).

In a battle situation, an individual may need to evacuate a wounded soldier in the shortest possible time. Depending on the circumstances in realistic situations, the time it takes one to evacuate another soldier may mean life or death for either or both soldiers. For this reason, this task will be performed at maximal voluntary effort.

Task Standardization: Subjects will evacuate others of their approximate size and weight, the prescribed distance of 100 meters. This distance has been selected as representative of the requirement in a battle scenario by the Army Working Group.

COMMON TASK #3

LIVE AND WORK IN ARMY ENVIRONMENT:

(I) Transport Jerry Cans

Carry a full jerry can of water (a given distance). Lift and empty jerry can into a container. Continue with task (for a given time).

Task Standardization: This task was completed using issue equipment and a gas tank simulator constructed to simulate the gas tank of a multi purpose vehicle (height of 1.0 meter). The number of refills was recommended by the Army Working Group as the minimum requirement and the distance was determined in consultation with subject matter experts.

(ii) Manual Material Handling

This task involved lifting ammunition boxes, each weighing 20 kg. The task was completed at a submaximal effort of 70% maximal aerobic power as determined from the laboratory treadmill task. A maximal test for this task was not conducted for safety purposes, since individuals may have attempted to move the boxes so quickly as to presuppose injury due to sacrificing biomechanical correctness for speed.

Task Standardization: A multi purpose vehicle truckbed simulator was constructed to simulate the appropriate height required to move the boxes. The number of boxes moved was determined by the Army Working Group as the minimum requirement.

Statement of the Problem

The primary purpose of this investigation was to develop task related physical performance standards for the Canadian Army. In the process, the researcher quantified, measured and assessed aerobic and anaerobic physical fitness components of the Canadian soldier in both the laboratory and field setting. The criteria for selecting common tasks and the basis for the recommended physical fitness standard that represented the Army's needs were reviewed. The outcome of this research was to develop physical fitness standards based on the physical requirements of the soldier as observed in both the laboratory and during selected field tests and to recommend appropriate physical fitness standards based on valid and reliable field tasks.

Significance of the Study

The Canadian Human Rights Commission Bona Fide Occupational Guidelines (1978) suggests 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 the achievement on fitness test scores of certain upper percentile of the normal army population. In this study, the researcher investigated an approach in establishing standards based on valid and reliable field tasks that correlate with laboratory measures. This study was designed to investigate and report on a task-related physical fitness standard approach for the Canadian Army that are valid and reliable measures of aerobic and anaerobic physical capability.

This study was part of a larger project which also considered the contribution of muscular strength and endurance associated with the completion of the common tasks.

Hypotheses:

The following hypotheses were tested:

1. The weightload march laboratory test aerobic parameters including , Expired volume V_E, VO_2max absolute and relative, 70% VO_2max absolute and relative, 50% VO_2max absolute and relative, and ventilatory threshold VO_2max relative will demonstrate a significant ($p=.05$) simple correlation with field tasks including Casualty Evacuation, Ammunition Box Lift, Maximum Jerry Can, Maximum Dig, and

Weightload March parameters of 50% VO_2max Heart Rate and Distance, 70% VO_2max Heart Rate and Distance and Total Distance completed.

2. The laboratory Wingate anaerobic leg ergometer power test parameters of peak power output, maximal power output, power decline and total work will demonstrate a significant ($p = .05$) simple correlation with the field tasks including Casualty Evacuation, Ammunition Box Lift, Maximum Jerry Can, and Maximum Dig.

3. The laboratory Wingate anaerobic power arm ergometer test parameters of peak power output, maximal power output, power decline and total work will demonstrate a significant ($p = .05$) simple correlation with the field tasks including Casualty Evacuation, Ammunition Box Lift, Maximum Jerry Can, Maximum Dig.

4. Blood lactate taken after the laboratory anaerobic leg and arm ergometer test will demonstrate a significant ($p =.05$) simple correlation with the field tests including Casualty Evacuation, Ammunition Box Lift, Maximum Jerry Can, Maximum Dig and Weightload March parameters of 50% VO_2max Heart Rate and Distance, 70% VO_2max Heart Rate and Distance and Total Distance completed.

5. Blood lactate taken post march and post dig will demonstrate a significant ($p = .05$) simple correlation with the field tests including Casualty Evacuation, Ammunition Box Lift, Maximum Jerry Can, Maximum Dig, and Weightload March parameters of 50% VO_2max Heart Rate and Distance, 70% VO_2max Heart Rate and Distance and Total Distance completed.

6. Aerobic and anaerobic laboratory tests will demonstrate a significant canonical correlation with the time measures of the field tasks including Casualty Evacuation, Ammunition Box Lift, Maximum Jerry Can and Maximum Dig task.

Limitations

1. The statistical methods used to analyze the data.

Delimitations

1. The study was restricted to 116 healthy male subjects, 17-44 years of age.

2. All subjects were male infantry personnel selected from the Army population at Canadian Forces Base Calgary, Alberta.

3. Subject familiarization with test protocols was limited to a walk around during the test introduction (walk on treadmill for selected period without grade increase) and the warm-up prior to the test.

4. Subjects' motivation during laboratory and field testing was limited to investigator encouragement and individual motivational levels.

5. The laboratory measures were delimited to aerobic and anaerobic power tests which consisted of the Wingate upper and lower body arm and cycle 30 second ergometer tests.

6. The field tests consisted of the following common military tasks:

a. Casualty Evacuation,

b. Lifting Carrying Ammunition Boxes at a set rate,

c. Maximum Digging of slit trenches,

e. Maximum effort movement of Jerry, and

f. Weightload Marching.

Definition of terms

1. **Maximal Oxygen Uptake(VO_2max)**: refers to the maximal volume of oxygen which is consumed per minute (litre/min (absolute) or ml/(kg . min) (relative)) during a progressive treadmill exercise test while carrying a load of 24.5 kg (which represents the absolute minimum load a soldier will carry). During continuous treadmill ergometer test, it will be a point when a plateau (as indicated by a change $< 100\ ml.min^{-1}$) or a slight drop in the VO^2max occurs as work is increased beyond the work intensity that first results in a maximal value or when the subject will no longer be able perform due to fatigue (From Physiological Testing of the Elite Athlete)

2. **Aerobic Power**: used synonymously with maximal oxygen uptake and refers to an individual's capability to diffuse oxygen across alveolar tissue, transport it in the blood and utilize oxygen to the working tissues in order to perform maximal work.

3. **Maximal Heart Rate** : The maximal heart rate attained by a subject when he has reached maximal oxygen uptake.

4. **Anaerobic Power**: anaerobic energy is the energy utilized from sources other than the oxidative process and is highly dependent upon the intensity and duration of the activity.

5. **Wingate Upper Body Power Test**: A 30 second supra-maximal arm ergometer test for determining upper body and arm power.

6. **Wingate Lower Body Power Test**: A 30 second supra-maximal leg ergometer test for determining lower body leg power.

7. **Wingate Force Setting**: A relative setting in kiloponds determined by multiplying individual's body weight by 0.075 kg for the lower body power test and 0.050 kg for the upper body power test.

8. **Wingate Peak Power Output (PPO)**: Measurement of power output for each 5 second interval of the 30 second test to determine the interval in which peak or highest power output occurred. This event usually occurs in the first 5 second of maximal exercise.

9. **Wingate Maximal Power Output (MPO)**: The combination of maximal pedal frequency and resistance for an individual that will elicit the highest possible cumulative measure of mechanical work over a 30 second time frame. The power output for each 5 second interval of the 30 second test will be totalled and a mean value calculated.

10. **Wingate PPO(R) and MPO(R)**: The resistance needed to elicit peak power output and maximal power output (e.g.. PPO (5) indicates a resistance of 5 kp was needed to elicit peak power output)

11. **Wingate Peak Power Decline (PD)**: Index of fatigue, percentage of peak power calculated by (peak power - lowest power / peak power x 100).

12. **Peak Lactic Acid**: Blood sampled by finger puncture 5 minutes post-exercise and analyzed for lactic acid.

13. **Wingate Absolute Power Output**: Raw scores without compensation for weight.

14. **Wingate Relative Power Output**: Scores transformed to compensate for body weight.

15. **Revolutions Per Minute (RPM)**: The number of pedal revolutions in each 5 second period extrapolated for 1 minute. (i.e., 10 revolution in 5 second period equals 120 RPM)

16. **Ventilatory Threshold (VT)**: During the maximal treadmill test, a point where there is a nonlinear increase in V_E, VCO_2 and a sudden increase in RQ with a decline in expired CO_2 tension ($FECO_2$) and elevation of O_2. This point is known as the ventilatory threshold

17. **Standards**: Indicate the minimum level of physical fitness that Army personnel should attain and maintain. These levels are considered necessary for satisfactory performance of the job.

18. **Laboratory Tests**: Tests of aerobic and anaerobic power completed under controlled circumstances, using state of the art measurement devices.

19. **Field Tasks**: Physical tasks completed as a requirement of a job or occupation - Infantry tasks.

20. **Combat Arms**: Armour, Artillery, Infantry and Combat Support; that portion of the Army involved in the most physically demanding tasks in their day to day function.

21. **Full Fighting Order**: This dress order includes combat clothes, helmet, weapon and rucksack (backpack) with summer order (Combined total weight of 24.5 kg)

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

23. **Command Council**: Committee chaired by Commander FMC with General officer representatives from all elements of Combat Forces.

CHAPTER II

REVIEW OF THE LITERATURE

A. PERFORMANCE TESTS IN THE CANADIAN MILITARY

A common physical fitness test for the Canadian Forces (CF) was in existence until 1972. This test battery included muscular strength and endurance, cardiovascular endurance, and agility components of physical fitness. This test was discontinued after one and a half years since: practically all stress was placed on passing the test with little or no emphasis on development and maintenance of physical fitness; test items could not be related by commanders directly to military tasks; and, lack of adequate preparatory programs and poor screening resulted in purported casualties during or as a result of testing (Mayo, 1984).

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 the work of Kenneth Cooper (1977) and the use of the Astrand nomogram (Astrand, 1954). Many personnel who attempted to complete this test did not have adequate training. Administrators introduced a compulsory conditioning program to train those individuals who failed to pass the test. This program was poorly run and often ignored at some units. As a result of perceived difficulties stemming directly from participation in this test, the Surgeon General concluded that this method of fitness assessment carried an unacceptable risk of potential injury for participants aged 30 years and over. All fitness testing was subsequently stopped for those above 30 years of age in September, 1980.

The CF EXPRES Program was subsequently introduced in 1983 to safely assess the basic fitness level of CF personnel. In the Surgeon General's view the 1.5 mile run was an inappropriate test of general physical fitness 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. Mayo (1984) suggested that it failed to give indication of an individuals capability to meet occupational requirements, for example the soldiers' ability or inability to meet their occupational needs .

The CF EXPRES Program

The CF EXPRES (EXercise PREScription) program was derived from the Fitness Canada Canadian Standardized Test of Fitness (1981).

The CF EXPRES program consists of four components:

1. A pretest screening which ensures the absence of health risk factors prior to testing. This screen includes a health appraisal and analysis of resting blood pressure and heart rate.
2. A physical fitness evaluation which consists of an aerobic, muscular strength, upper and lower body muscular endurance, and body composition measurements.
3. An exercise prescription which consists of a individualized physical fitness training program promoting activities of sufficient frequency, duration, and intensity to ensure improvement or maintenance of physical fitness (ParticipAction, 1986). Additionally, unit training programs

could be used as part of the exercise prescription.

4. <u>Training</u> which is the major emphasis of the program.

The primary goal is to promote habitual participation in effective exercise training programs.

For testing 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. Maximal oxygen uptake (VO_2max) is predicted from measurements of heart rate during a submaximal step-test, the Canadian Aerobic Fitness Test (1981).

The CF EXPRES evaluation which is based on the Canadian Standardized Test of Fitness is reported to be a reasonable measure of general physical ability (Stevenson et al., 1988). It is considered to be appropriate for gross fitness evaluation for large populations. Bell and Jacobs (1986) and Jacobs et al., (1987) indicate that it may not be sensitive enough to detect minor but significant improvements in fitness that may occur as a result of a training program. In the study (Jacobs et al., 1987), subjects completed 12 weeks of hydraulic resistance training, laboratory tests demonstrated significant improvements in the measured fitness variables. However, the EXPRES evaluation was not sensitive enough to detect these changes.

The CF EXPRES program is designed to meet most general physical fitness needs from a health consideration viewpoint, however, it may fail to meet the needs of special groups within the military. From a job performance viewpoint, there are times when individuals or groups will require other means of assessment to measure and demonstrate operational capability of an individual for effective performance. Such is the case for an Army Physical Fitness Standard. Combat forces clearly require a higher level of fitness than can be demonstrated by the CF EXPRES Program. Additionally, individualized testing and programming associated with the CF EXPRES Plan may not fulfil the needs of a large group such as the Army where individuals are expected to perform tasks demanding low to very high fitness levels and work as an individual within the context of a larger cohesive group. Until a special program is developed for the Army, recognizing their unique needs, the only acknowledged assessment currently available is the Battle Efficiency Test.

Battle Efficiency Test (BET)

The BET consists of two 16 km route marches (run and walk), in light fighting order, conducted on consecutive days. The first march must be completed in less than two hours and 45 minutes and includes the scaling of a six foot (1.33m) wall, jumping an eight foot (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 conducted in groups of 10 or more soldiers (Jette et al., 1986). Myles et al. (1985) indicated that although the BET provides a measure of one infantry function, the ability to perform a forced march in light battle gear (weapon, helmet and equipment weighing approximately 5 kg), the test is not a measure of aerobic power or endurance capacity. It is also hampered by terrain and weather conditions. It lacks standardization and the norms are somewhat arbitrary, based on undocumented rationale. Furthermore, during the testing, individuals can carry each others equipment if necessary and it is highly dependent on motivation and group encouragement (Jette et al., 1986). Although these factors may be important to unit esprit de corps, it may be that certain individuals lack the basic physical capability to do the task.

Myles (1985) stated the need for an index of a Canadian soldier's ability, other than the only one that is currently available – the Battle Efficiency Test, to demonstrate a soldier's ability to meet the physical demands of the job. His recommendation was that performance tests should emphasize those components of fitness that have been shown by research to be involved in the performance of identifiable military tasks. The test should also be recognized and accepted by military commanders. He suggested that:

> The test should result in a simple easily measured score... requiring nothing more than the ability to operate a stopwatch. Any test which stresses the appropriate fitness components, predicts some aspect of military performance and is simple to administer would be of great value to the field commander. It would allow him a quick and easy way to identify those of his men who are fit to fight" (Myles et al., 1985).

A recent response to this question was the development of a 19 item Indoor Standardized Obstacle Course (ISOC) consisting of running, crawling, scaling, pulling, lifting, carrying and pushing events arranged in a sequential order (Jette and Kimick, 1986). The purpose of the course was to assess the fitness of soldiers by execution of tasks similar to those which are encountered in combat type 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 a minimal level of skills. Forty-three healthy male subjects between the ages of 21 to 31 years underwent a series of laboratory tests similiar to those suggested for the current study. The subjects ran through the obstacle course on three occasions. The results indicate that ISOC performance was related to valid fitness components which are considered important in the performance of military tasks. These components, measured through laboratory testing, are aerobic and anaerobic power, muscular strength and endurance and body composition. Based on the results, Jette and Kimick (1986), stressed the importance of aerobic conditioning for military performance but recommended that greater effort be directed to the development of upper body strength.

The ISOC is administered indoors and is not subject to varying climatic conditions. The ISOC seems to provide a practical and challenging procedure to assess the fitness readiness of infantry and other field units in the Canadian Forces. At present, the ISOC requires further validation and acceptance by the Canadian Army.

B. INTERNATIONAL OVERVIEW

Traditionally in militaries around the world, physical fitness standards have been established by a process of "normative referencing" i.e., based on the achievement on a fitness test of an arbitrarily selected percentile of the normal Army population. The normative references have been established separately for each gender, age group, and type of unit assignment (combat or support) as these factors are thought to influence physical fitness requirements for performance. The question often asked in regards to these standards is what does running a certain distance, completing push-ups and sit-ups have to do with successful completion of a specific military task?

A positive solution to this problem might be to establish standards based on the one need that can be objectively determined, i.e, the fitness requirement of the job itself. If an activity requires a certain level of performance capability as well as physical fitness, that requirement must remain the same irrespective of the age of the soldier filling that position.

In order to get a better appreciation of the methods employed by other countries to determine the level of Army physical fitness, the following overview of Army physical fitness training programs and activities of selected nations has been provided.

Performance Tests of United States Army

The United States Army evaluates its personnel by using the Army Physical Readiness Test (APRT) which consists of maximum number of push-ups and sit-ups in two minutes each along with time taken to complete /o-mile run (Jette et al., 1986). Specific units, within the Army, such as the Rangers and Special Forces, have their own performance testing procedures. Their test battery consists of six items performed dressed in combat pants, T-shirt and combat boots. The battery consists of the following items:

(a) 40 yard inverted crawl in 25 seconds,

(b) 37 bent leg sit-ups in one minute,

(c) 33 push-ups in one minute,

(d) run, dodge and jump through a 26 yard course which is comprised of four wooden obstacles and a shallow ditch in 24 seconds,

(e) a two-mile run in 16.5 min,

(f) a 15 meter swim dressed in combat uniform, boots, including a rifle and equipment.

The test also includes a 50 meter swim with fatigues, shirt, pants and combat boots for special forces.

Performance Test of Australian Army

The Physical Training Test (PTT) is the basic test of fitness for the Australian Army (Rudski, 1983; Rudski, 1987). It is composed of three parts:

1. A 5 km run -This test is designed to, access the level of aerobic fitness;
2. A series of chin-ups - testing strength; and
3. sit-ups - (possibly testing muscular endurance and anaerobic fitness).

As a result, most physical training is directed towards achieving a pass in the test. Consequently, most unit programs utilize running as their major form of exercise. Dissatisfaction has been voiced with this mode of training. Rudski (1983) reported that:

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

Performance Tests of British Army

In Great Britain, the Regular Army has three types of physical fitness tests. These tests are known as Army Personal Fitness Assessment Test, Basic Fitness Test, and a Combat Fitness test. The Army Personal Fitness Assessment is considered to be a diagnostic test which provides the basis for planning of fitness training. "It is utilized primarily by selection and basic training units whose personnel are under 40 years of age" (Jette et al., 1986). It requires individuals to do pull-ups, trunk curls, dips on parallel bars, and a step-test, which are all dependent on one's age and sex. The Basic Fitness Test is also age and sex related. It is conducted twice a year. Men under 40 years are required to walk and run 2.4 km in combat clothes as a group in 15 minutes followed immediately by a best effort run of the same distance but alone, in times of under 11.5 – 12.5 minutes, dependent on one's age. Men 40 and over have a choice of either doing the same tests as those mentioned previously (except that the standards for the second 2.4 km are under 14 or 15 minutes, dependent on age), or walking/running 4.8 km in under 29 or 30 minutes, dependent on age.

The Combat Fitness Tests are optional. Various branches of the Army can design and utilize these tests over and above the Basic Fitness Test. The concept of this test is similar to the Canadian Battle Efficiency Test.

Performance Tests of Israeli Army

The Israeli Defence Force (IDF) has abandoned the traditional western methods of fitness training, i.e., running and calisthenics. Instead they choose weight-load walking (Rudski, 1987; Bar-Khama, 1980) as their primary method of conditioning troops. In addition to other work in the area (Beckett et al., 1987; Borghols et al., 1989; Dziados et al., 1987; Goldman et al., 1962; Pollack et al., 1971), the Israelis conducted extensive research (Shoenfeld et al., 1977; Shoenfeld et al., 1978; Shoenfeld et al., 1980; Weinraub,1986) to develop a training program which would fulfil the aims of: achieving high levels of fitness without the significant attrition attendant with traditional regimes (Bar-Khama, 1980); and finding a method whereby this higher level of achieved fitness could be maintained when troops returned to their reserve status. They discovered some interesting facts. First, they showed that weight-load walking was as effective (and potentially more efficient) in improving objective measures of fitness; second, it caused fewer injuries and third, they demonstrated that by encouraging a convivial approach to endurance marching, the troops developed a positive attitude to their training (Bar-Khama, 1980). Accordingly, the basic requirement for all Army personnel is a 5 km march in full battle order (with each soldier carrying approximately 30 kg) in one hour . The elite requirement for special personnel is to march 25 km in full battle order in 5 hours or less. Although there are other fitness requirements, weight-load marching is the basis of the IDF fitness program (Bar-Khama, 1980).

Tests in Swedish Army

In Sweden, when soldiers' enlist, they spend two days undergoing various screening tests (Jette et al., 1986). The physical fitness of soldiers is assessed by a "Physical Working Capacity" test. This testing involves testing on a cycle ergometer and a "muscular power" assessment. The muscular power test is comprised of the weighted sum of three isometric strength tests. These tests consists of the hand grip, knee extensors and elbow flexor strength measures.

<u>Performance Tests of Soviet Army</u>

The Soviet system is called "GTO" program which, when translated, means "Ready for Labour and Defence". At the age of 10, children are tested in seven events such as sprinting and swimming. Records are maintained throughout their youth and are available to the military at the time of their induction. From the ages of 19 to 28 years, civilians are expected to perform 10 events and achieve prescribed set standards. A number of events have alternatives to accommodate for climatic or geographic conditions. Some of the male events are: 100 and 1000 m runs, long jump, a 700 gm grenade throw, five kilometre ski, 100 m swim, pull-ups, rifle firing, 25 to 30 km marching, and obtaining a level II sports ranking. Russian soldiers are believed to be regularly tested regardless of age, on a 100 m standardized obstacle course found on all Soviet military posts. The course consists of a series of seven obstacles: ditch, dummy demolished bridge, brick wall, etc., and typical obstacles that were encountered on the European battle fields during World War II. The purpose of the course is believed to be to help the soldier to develop skills in negotiating various natural obstacles and barriers, conditions closely resembling real battle, as well as to become strong, resilient and ready for immediate response (Jette et al., 1986).

As mentioned by Hertling (1987), more pressure is placed on the Soviet soldiers to participate in off-duty athletic events. Winners of these competitions are promoted to "Non Commissioned Officer" and Officer ranks. They are also believed to receive rewards of money and material goods (Hertling, 1987).

Although the international overview is limited to a cross sectional view of selected countries, it is considered to be representative of the various methods currently employed by armies of the world. There is a great variation associated with the prediction of physical performance and physical fitness criteria ranging from the normative referencing approach of the US, Great Britain and Australia, to the laboratory method of Sweden and to the military skill related approach of the Soviet Union. A recurrent theme in articles reviewed (Bar-Khama, 1980; Patton, 1987; Burkett,1983; Myles et al.; Haslam, 1984; Rasch et al., 1964) in regards to combat fitness testing and training is that tests must be physically and militarily challenging as well as being realistic. The Soviet experience supports this approach.

Although the dilemma would appear, for the most part, to be universal, it is well described by Murphy et al. (1984) who comments on the experience of the U.S Army:

> Physical training requirements and physical fitness standards have traditionally been based on experience and subjective judgement rather than objectively determined requirements for successful performance. For example, passing scores (standards) for the Army Physical Readiness Test (APRT) are currently based on age and gender without consideration of military occupational needs of the unit. Commanders often train their unit to exceed these standards based on a perceived need for a higher level of fitness for morale, readiness, appearance and unit performance. There is a paucity of information indicating actual requirements for physical fitness (exercise capacity) for operational units in the Army which deal in situations such as sustained combat. This information is needed not only to establish actual combat needs, but also to develop more appropriate and efficient physical training programs.

C. NATO OVERVIEW

In an effort to respond to the need for information on the subject of military physical fitness requirements and methods, a Research Study Group 4 on Physical Fitness was established by the North Atlantic Treaty Organization in September 1975. It aimed to promote collaborative and complimentary research among nine participating nations: Belgium, Canada, Denmark, France, Germany, the Netherlands, Norway, The United Kingdom, and the United States, by means of exchanging reports, holding meetings and conducting joint experiments. Six meetings were held and reports were completed between 1978-1984 culminating in a Final Report in 1986. This overview associated with articles from scientific journals, texts, reports and observations provides the basis for this review.

While senior military authorities mutually agree as to the need for high levels of physical fitness within the Army and administratively support the concept, only recently has there been an attempt to quantify physical fitness using scientific methods. Generally speaking physical fitness requirements have been determined experientially by senior tradesmen or by Commanders' expectations. An example of this type of approach may be observed in the US Army's former method for setting standards. The solution for this problem appeared to be in establishing standards based on the one need that can be objectively determined, i.e., the fitness cost of the job itself. If an activity requires a certain level of fitness, that requirement remains the same irrespective of the gender or age of the soldier filling that position. This approach has been accepted by the U.S. Department of Defence, the

Military and the Army Research Establishment. In the future, every military activity will be placed into one of the five groups or clusters according to a rating of its physical fitness demands (Table 1, 2, 3) (Haslam, 1984).

An analysis of modern military job requirements carried out in NATO countries reveals a consistent demand for a high level of physical capability. Generally these demands will be similar in all countries,

Table 1 – U.S. Department of Labour (DOL) Categories for Lifting as Modified by the U.S. Army

Light	Medium Heavy	Moderate Heavy	Heavy	Very Heavy
Lifting 20 lbs (9.0 kg) max with frequent lift of 10 lbs (4.5 kg)	Lifting 50 lbs (22.8 kg) max with frequent lift of 25 lbs (11.4 kg)	Lifting 80 lbs (36.0 kg) with frequent lifts of 40 lbs (18.0 kg)	Lifting 100 lbs (45.6 kg max with frequent lift of 50 lbs (22.8 kg)	Lifting in excess of 100 lbs (45.6 kg) with frequent lifts of 50 lbs (22.8 kg)

In Table 1, an attempt is made to describe the lifting requirement for military trades using an available five category system developed by the US Department of Labour and modified by the US Army. It revealed that over 70% of trades requiring a lifting capability described as moderately heavy (Table 2).

Table 2 – Distribution of Trades (Percent in Parentheses) Using Department of Labour Lifting Categories to Describe Lifting Requirements **

	Light	Medium Heavy	Moderately Heavy	Heavy	Very Heavy
U.S. Army	42 (8.3)	65 (7.3)	64 (7.6)	48 (12.4)	132 (64)
Canadian Forces	13 (13.5)	11 (11.3)	57 (58.7)	13 (13.5)	3 (3)

**The difference in moderately heavy and very heavy categorizations between the two groups, results from differing approaches. The CF categorization considers representative tasks for each trade and the U.S approach considers the most demanding task for each trade.

Examples of such trade classifications are shown at Table 3.

Table 3 – Examples of Trade Tasks and Weights Lifted to Determine Department of Labour Category

Trade / Task	Weights Handled kg (lbs)	DOL Category
Artilleryman		
Handle Breech Block	34 (75)	Mod Heavy
Load 155mm ammunition	48 (105)	Very Heavy
Infantryman		
Lift and Carry Sandbags	29.6 (65)	Mod Heavy
Lift Ammo Boxes onto 2.5 Ton Truck	30.8 (68)	Mod Heavy

differing only as equipment specifications may change; for example, size of artillery shells or height of truck beds may vary from country to country (although efforts have been made to standardize NATO equipment). Additionally, another aspect of military job demands must be borne in mind; with few exceptions the characteristics of a job cannot be changed to suit differences in human capability whether they are related to anthropometry, sex or age. All personnel likely to be required to perform a specific task must be able to perform that task satisfactorily (Defence Research Group, 1986).

Consistent with the analysis and quantification of the job requirement, a variety of test methods for assessing human physical capability have been developed. Test methods developed and refined in the laboratory have been adapted for field use so that reliable on-the-job information is available. These techniques are particularly useful for monitoring the effect of training on specific abilities (eg., lifting) and general conditioning (aerobic power) (Defence Research Group, 1986).

A factor that must be considered in a cross-sectional analysis of the physical fitness capabilities of NATO Countries is the difference in length of service. While some countries (Netherlands, Germany, France) rely on compulsory military service with high turnover rates, others (Canada, United States, United Kingdom) are voluntary with members remaining for careers of twenty or more years. These differences create a need to consider age and long term health implications when physical fitness capability is considered.

When military commanders' attitudes towards the need for physical fitness were surveyed in Canada (Defence Research Group, 1986), all agreed on the requirements. Four reasons were identified to: a. improve job efficiency,

b. enhance ability to cope with emergencies,

c. promote esprit de corps, and

d. maintain physical health and mental well-being.

Although these needs may be difficult to fulfil in regards to assessment, quantification and measurement, they may represent the measuring stick by which the results of work pertaining to military physical fitness capability will be considered.

D. THE REQUIREMENT FOR PHYSICAL FITNESS

Medical and Health Considerations:

Prior to enrolment, candidates for military service undergo a medical examination to determine general suitability for military service. In addition to clinical medical considerations, an assessment of capabilities to serve in areas of climatic or geographic extremes may be completed. These assessments are preliminary and not specific to concepts such as "acceptable level of endurance in combat environment" and "able to perform heavy work". There is no reference to specific work requirements or location (Defence Research Group, 1986).

With regard to post-enrolment health, there is evidence that higher levels of fitness are associated with lower risk of cardiovascular disease. Several countries have carried out assessments of cardiovascular risk factors in their military population (Jung, 1978; Allen, 1978) and Canada and the United States have reported a positive correlation between higher levels of aerobic power and reduced incidence of hypertension and hyperlipidemia in male personnel over 35 years of age (Allen, 1987; Allen, 1980). Lower levels of smoking and obesity seem to be related to higher activity levels, thus reducing the probability of morbidity and enhancing long term personnel efficiency (Allen, 1980; Bardsley 1978).

Occupational Requirements:

In the final analysis, the only true occupational consideration is the ability to complete the task quickly and efficiently, to do whatever has to be done in a general military or a specific trade related task. In physiological and biomechanical terms, these requirements may be considered under a variety of classifications (aerobic, anaerobic, whole body or body segment, single effort or repetitive task). Any physically demanding task will have a requirement for anaerobic, aerobic and strength capabilities in some ratio defined by the characteristics of the job (Rudski, 1983).

In regards to the early work of the NATO Research Study Group, much effort was devoted to the assessment of the aerobic component of fitness. Several member countries have reported the results of surveys and training programs for both male and female personnel. These data are normally expressed as time taken to run a fixed distance (typically 1.5 miles) or maximum oxygen consumption, absolute or relative to body weight. Table 4 (Defence Research Group, 1986) provides an overview. A typical military requirement such as covering 10 miles on foot in fighting order in 2 hours or less requires an energy expenditure equivalent to an oxygen consumption of about 2 litres/minute. Tasks such as loading shells for a 155 mm howitzer at a rate of 1 shell per minute requires an energy expenditure of about 1.5 litres/minute. These rates of work will require a VO_2max of at least 3.0 to 3.5 litres/minute if acute fatigue is to be avoided. For the 70 kg soldier this becomes 43-50 ml/(kg . min) respectively. These rates of energy expenditure can be increased by up to 50% if uneven surfaces or hilly terrain are encountered (Defence Research Group, 1986). Similarly, heavier loads or extra protective clothing will increase the energy requirement. As can be seen from Table 36, these rates of energy expenditure will exceed the capabilities of most recruits.

It has been recognized for some time that aerobic capacity alone may not sufficiently discriminate when considering physical fitness capability for many jobs. Several NATO militaries have worked on a more eclectic approach in an attempt to match physical capability to job requirement. Three approaches have been used. The Netherlands Army uses a system of broad categories of job requirements. The U.S

Table 4 – Aerobic Power Survey – Military Forces – Pre-Training males

Nation	Age (yrs)	VO2max ml/(kg.min)	Timed Run	Reference
Canada	21	4[illegible].4	11.5 min-1.5 mi	Myles et al., 1978
United States	21	50.8		Vogel et al., 1978
United Kingdom	24	44.2		Amor, 1978
Germany	20	38.3		Barlet, 1978
France	20	46.3		Eclache et al., 1978
Netherland	recruits	----	1.56 mi/12 min	Bertina, 1978
Norway	20	45.0		Hermansen, 1978

Army, Navy and Air Force and the Canadian Forces have begun work on a detailed examination of physical requirements on a trade-by-trade basis. The U.K Army uses a process of limited investigation of specific problems. The detailed trade investigations have revealed that manual material handling , basically lifting and carrying (Table 2) is the commonality in many trades.

These classifications are arbitrary and cannot be applied directly to lifting tasks. Several factors, such as height of lift, position of load relative to the lifter, will all influence the relative difficulty of a particular lifting task (Defence Research Group, 1986). In an analysis of Canadian Forces task requirements, it was determined that 80 percent of lifting tasks required lifts from the floor (Nottrodt et al., 1984). Twenty-five percent of the lifting tasks required lifting above shoulder height (145 cm for males). For females with a shoulder height of 137 cm, the comparable figure is 40 percent.

Physical Performance

Basically, the amount of physical work that one can do is a function of the rate of doing work. The more intensely an individual works, the faster one will fatigue. Astrand (1960) reported that aerobic work can be continued for one work day (7 hours of work consisting of 50 mins work, 10 mins rest, with one hour off for lunch) if the work rate is maintained at approximately 50% of the maximal rate of oxygen consumption. Continuing work beyond one day would require that the work rate be maintained below 50 % of VO_2max. Other studies (Soule et al., 1973; Myles et al., 1982) have shown that undue fatigue is not encountered if the work rate is maintained near 40% of VO_2max. When allowed to select their own work rate, soldiers seem to work at a rate less than the 40% of VO_2max. Myles (1982) found that soldiers selected a marching pace which required 31.6% of VO_2max. Myles has shown that the average soldier has a VO_2max of approximately 53 ml/(kg . min). Using the 70 kg. man as a model and 40% VO_2max as the energy expenditure rate over several days, the average American soldier could perform continuously (with some rest pauses) at an average expenditure rate of 21.2 ml/(kg . min). Carrying a 25 kg. pack, this average soldier could maintain a pace of 5.8 km/hr along a blacktop road, 5.3 km/hr through light bush, or 4.8 km/hr through heavy brush (51).

It has been suggested that continuous material handling tasks, such as lifting, is limited by maximal aerobic power. Research (Williams et al., 1982; Legg et al., 1985) suggests that fatigue does not occur in one hour if the work rate is maintained at less than 40% of VO_2max. The data, however, suggests an interaction between weight lifted and lifting rate on the development of fatigue at a given oxygen uptake, i.e., lifting a 22.73 kg box at a rate sufficient to require 30-40% VO_2max caused no increase in arterial lactate concentration, while lifting a 36.36 kg box at a rate requiring 25% VO_2max resulted in elevated lactate levels over one hour. Both studies demonstrated a decrease in isometric forearm contraction at all VO2 levels, after one hour of hard work.

An interaction between weight lifted and rate of lifting has also been shown (Monod, 1985) in a study of maximal repetitive lifting capacities of British soldiers. Plots of time to exhaustion versus percentage of VO_2max required for lifts of 25, 50, and 75% of maximal lifting capacity at three different energy expenditure levels fails to give a single curve. There are three different curves, one for each relative weight lifted. Thus limitations to lifting performance do not appear to be determined simply or solely by aerobic power. Other factors such as anaerobic capability must play a part.

Monod (1985) suggested that limitations to material handling may be imposed by strength limitations and maintenance of adequate blood flow to the working muscles. He found that limitations to repeated lifting to be directly related to an individual's maximal voluntary contraction force. Additionally, contraction of muscles decreases the blood flow to that muscle limiting the blood supply and allowing waste metabolites to accumulate. Thus, the weight that can be lifted repeatedly depends upon the amount of time the muscle is contracted (blood supply interrupted). Monod states that a critical fraction (between 15 and 20%) of maximal voluntary contraction (MVC) force can be maintained virtually indefinitely without local fatigue developing. Forces above this level can only be maintained on an intermittent basis. If the ratio of contraction time to relaxation time is 0.8, only 22% of the MVC force can be maintained without development of local fatigue. If the work : rest ratio is 1 : 3, static forces of 58% of MVC can be exerted without local exhaustion.

Rowell (1974) suggested that for work involving more than 50% of the muscle mass that the cardiovascular system limited oxygen delivery to the working muscles. In these cases, measured VO_2max was a good indicator of work capacity. For work that involves less of the musculature, the rate of oxygen uptake by the muscles, in part, limits performance. He suggested that factors such as maximal strength, submaximal endurance time or lactate production at submaximal loads become better indicators of performance potential.

Physical Fitness

The rate at which one can perform work in a continuous fashion is a function of one's maximal capability. Current research does not indicate whether an individual can be expected to work continuously at 30 or 40% of VO_2max or 25 to 40% of maximal lifting capacity, it is obvious that higher levels of fitness (either in terms of aerobic power or muscular strength and endurance) will enable higher rates of work to be sustained.

E. PERFORMANCE/TASK ANALYSIS

A recurrent theme in articles reviewed (Murphy et al., 1984; CSTF, 1981; Stevenson et al., 1988; Bar-Khama, 1980; Beckett et al., 1987; Myles et al., 1986; Rasch et al., 1964) in regards to combat fitness testing and training was that the test must be physically and militarily challenging as well as being realistic. The Soviet experience definitely supports this approach. Although the US Military fitness test is not as task oriented, some dissatisfaction with this approach has been voiced. As a veteran of two tours in Vietnam commented when the new U.S Marine Fitness tests were introduced (pull-ups, sit-ups, and a three mile run), rarely if ever did Marines do anything that resembled a pull-up or sit-up in combat experiences (Patton, 1987). However, he did recall doing every one of the exercises in the old physical readiness test (a series of tasks done in full combat equipment, including carrying a pack and weapon) (Hertling, 1987).

Although this point is well taken and should be strived for in the development of realistic and meaningful physical fitness tests, it may be possible as demonstrated in the development of CF Minimum Physical Fitness Standards to develop common tasks that are indicative of the requirement and correlate these to more easily administered test items, such as common field tests (i.e., sit-ups, push-ups, a simple aerobic test). These tests will not consume as much training time but will appropriately predict one's ability to perform the common task. Ultimately, the development of the skill to do the task is the responsibility of the trainers of the soldier. Although this skill involves a great deal of physical competence, the physical trainer should not be the scapegoat of the commander whose troops are not combat ready.

THE CANADIAN ARMY APPROACH

Based on the evolution of physical fitness testing in the Army over the last ten years (i.e., the termination of the 1.5 mile run test, the development of an individualized fitness testing and prescription program - the CF EXPRES Program (CF EXPRES Operations Manual, 1981, Stevenson et al., 1988) and doubts as to the efficacy of the BET (Myles, 1985) have led to uncertainty as to the CF's emphasis on fitness. A need to develop objective Army physical fitness standards has been identified which are realistic, challenging and standardized. To this end, it is suggested that a similar approach be used in the development of Canadian Forces Minimum Physical Fitness Standards (MPFS). This approach involves the use of the "task-related" method as detailed in the Canadian Human Rights Commission Bona Fide Occupational Guidelines (1978). It consists of four steps:

a. Identify tasks, based on operational requirements;

b. Identify the physical capability required to complete the tasks;

c. Developing the appropriate tests which predict the capability to complete the tasks; and

d. Setting minimum standards based on the tests.

Dwyer et al., (1987) reviewed the problems associated with making physical fitness standards job-related:

> A job analysis involves systematically collecting information about a job in order to prepare a job description. Performing a job analysis requires a fairly standard series of steps, but it is a highly technical procedure and should be performed only by a

> qualified expert. The process involves determining what tasks are included in the target job (e.g., infantryman) and what job skills or other worker characteristics (in this instance, physical strength and proficiency) are required. Current subject matter experts can provide information on whether or not the tasks and skills are part of or required for the job, and their frequency or occurrence or use on the job. From this comes an accurate, detailed job description upon which fitness standards can be based.

The Dwyer group (1987) appropriately points out that if job standards are established based on either a complete job analysis leading to content validity, or, as an alternate strategy, on an acceptable criterion-related validity approach, potential legal action can be avoided. Recently, a review of 60 court cases involving the use of physical standards and physical tests for employee selection was conducted by Hogan and Quigley (Dwyer et al., 1987). The authors concluded that litigation in the United States involving physical fitness standards and physical tests centre around three main issues: job analysis, content validity and empirical(or criterion related) validity.

With the passing of the Canadian Human Rights Act in 1978, great interest was shown and efforts made to obtain objective information on the 100 trades in the Canadian Forces (CF). Tasks which imposed high physical demands were identified so that the Defence Civil Institute of Environmental Medicine (DCIEM) could develop tests which would predict performance and assist in the selection/screening of CF applicants, regardless of their gender or age (Allen et al. 1984). Data were obtained through questionnaires, subject matter expert interviews and on-site evaluations. As an example of this process, the physical requirements of the Infantry will be overviewed. The Infantry tasks shown in Table 1 were identified as being physically demanding (Directorate of Military

Occupational Structures, 1983). Four tasks were selected as being relatively quantifiable and considered possible items to test Infantry personnel (Table 5).

Table 5 – Representative tasks for Infantry requiring a high degree of muscular strength / endurance. (Allen et al., 1984)

Serial	Task	Weight
1.	Lift modular tentage onto 2.5 ton truck (133 cm)	20.9 kg
2.	Lift jerry cans onto 2.5 ton truck (133 cm plus 50 cm height of hands on handles)	20.4 kg
3.	Lift and carry sandbags 4.6 m	29.6 kg
4.	Lift 7.62 mm ammunition boxes(no handles - only ridges 17 cm from bottom) onto 2.5 ton truck	30.8 kg

As outlined previously, the U.S response to the problem of physical fitness standards was the process of "normative referencing." This system worked well from a practical standpoint until the expansion of women into jobs traditionally held only by men – many of which are physically demanding. This response has resulted in situations where assignments are made irrespective of physical capability.

The solution to this problem appeared to be in establishing standards based on the one need that can be objectively determined, i.e., the energy/strength cost of the job itself. If an activity requires a certain level of fitness, that requirement remains the same irrespective of the gender or age of the soldier filling that position. This approach has been accepted by the U.S. Department of Defence, the Military and the Army Research Establishment. Preliminary work began and it was suggested (Table 6) that every military activity would eventually be placed into one of the five groups or clusters according to a rating of it fitness demand (Myles et al., 1985).

Table 6 – US Army trade clusters (Daniels et al., 1979)

Level of demand		
Strength	Aerobic	Cluster designations
high	high	alpha
high	medium	bravo
high	low	charlie
medium	low	delta
low	low	echo

The trade clustering criteria were determined through a selective task analysis and actual measurements and are presented in Table 7.

Table 7 – US Army Trade clustering criteria (Daniels et al., 1979)

Intensity rating	Strength demands (kg weight lifted to waist height)	Aerobic demands (Energy cost in Kcal/min)
Low	<30	<7.5
Medium	30-40	7.5 - 11.25
High	>40	>11.25

The placement of activities into clusters was based on an examination of the physical task list of each activity. This process was subsequently verified by actual measurements of aerobic cost (caloric energy expenditure) and strength (force or torque) required to perform the tasks. Thus, the initially estimated ratings of low-medium-high were replaced with actual measured costs for the most demanding tasks within each cluster. These energy and strength requirements were then translated into equivalent physical fitness test event scores and training exercise intensities. Thus five fitness standards in the U.S. Army, one for the five job groupings, irrespective of gender or age, were recommended. It was suggested that the Echo standard be met, at a minimum, by every soldier by the end of basic training. It must be noted that these are minimum standards required for each military activity based strictly on what is required to physically complete the task. The Infantry trade was classified in the alpha cluster (only 3% - 10% of 349 trades) of Military Occupational Specialities were so designated) reinforcing the fact that the Infantry is a most physically demanding occupation in the Army requiring a high degree of aerobic power and muscular strength.

Although recommendations were made and preliminary work started, the project was never completed. The U.S military decided to continue to use the "normative reference" approach. This response, in part, was due to the fact that there is no Human Rights legislation that requires the military to demonstrate a relationship between occupational and physical fitness requirements in the U.S. The Directorate of Military Occupation Structures (DMOS) analyses each trade in the CF on a periodic basis. The most recent examination of the Infantry trade was completed in 1983 (and 571 tasks were identified as a result of its study /questionnaire/ interview/and validation techniques. The following list illustrates the vast sample of tasks which could be available for inclusion as physically demanding tasks:

PHYSICALLY DEMANDING TASKS
- performing individual movements (leopard crawl etc.)
- digging trenches
- constructing bunkers/fortifications

PARTICIPATION IN:

- route marches
- obstacle course training
- combat swimming
- unarmed combat
- mountain climbing /repealing
- mountain warfare training
- approach and assault operations
- village clearing operations
- woods clearing operations
- range ammunition party
- construction of obstacles
- clearing/breaching obstacles
- laying mines
- nuclear, biological and chemical warfare drills
- changing tires
- fighting floods
- fighting forest fires

In addition, soldiers (Infantrymen) must be able to work outdoors in all types of weather and in a wide range of geographical locations, and this for prolonged periods, without rest, food or shelter. They must perform efficiently when suffering from extreme mental and physical fatigue. Considerable physical exertion is required as well as a high degree of mental dexterity and coordination. They may be required for special operations of the air mobile or amphibious types and may serve in arctic, mountainous or desert environments (CF Manual of Other Ranks' Trade Structure).

F. AEROBIC POWER

Perhaps the most studied component of fitness is aerobic power. Aerobic power may be simply defined as the body's capability to take up, transport and utilize oxygen to do continuous work. It is readily associated with many tasks and it is also important for health maintenance and body weight control. It is relatively easy to measure with test batteries that range from those which require little or no equipment to sophisticated laboratory measures. Aerobic power as an important physical fitness component has been emphasized within the military units of the world for a long time and is still very important today.

The capacity to generate energy through the aerobic (citric acid, tricarboxylic, Krebs cycle) metabolic pathway is a function of the various components of the oxygen transport system. It begins with pulmonary ventilation and ends with oxidation of substrates in the mitochondria (Wasserman, 1966; Wasserman, 1978; Wasserman 1979). The rate limiting component along this chain may vary depending upon the existing conditions but usually is thought to be the heart's pumping capacity or cardiac output (Kaijser, 1970; Wasserman, 1978). This topic may be discussed from the point of view of central and peripheral factors.

<u>Central Factors</u>

Oxygen is carried to the lungs (alveoli) and diffused across the alveolar membrane and bound to haemoglobin. Neither of these steps appears to be limiting factors in healthy individuals. There is no evidence that minute ventilation reaches a plateau. It continues to increase exponentially with increasing exercise intensity. Near complete oxygen saturation of the arterial blood, even at maximum exercise suggests that this step is also limiting to aerobic capacity in healthy individuals (Wasserman, 1978).

The next step in the aerobic transport process is the pumping action of the heart to deliver blood to the exercising muscles. This action– cardiac output (total blood flow per minute) is a product of the heart rate and the stroke volume of each contraction. It has been shown that cardiac output does reach a limit that coincides with maximal exertion and maximal oxygen delivery. Heart rate and cardiac output show a tendency to level off as maximal transport is achieved. Rates of ventilation and circulation are functionally coupled to metabolic activity of the cell. Exercise increases cellular O_2 requirement and CO_2 production, breathing must keep pace to allow venous blood to be oxygenated to maintain arterial CO_2 and H^+ ion homeostasis (Wasserman, 1978).

Peripheral Factors

Local blood flow to the exercising muscles is a function of cardiac output, vasomotor control of peripheral resistance and the anatomical size of the vascular bed. Evidence suggests that muscles are capable of greater flow rates than they normally receive, suggesting that cardiac output is the primary determinant of oxygen transport and aerobic capacity (Wasserman, 1978). An exception may be when a limited muscle mass is involved in which case oxygen extraction is limiting rather than cardiac output. An alternative to cardiac output being the primary determinant is the oxidative capacity of the muscle cells to utilize the delivered oxygen for substrate oxidation to replenish phosphagens. Thus the number and size of mitochondria and their concentration of the enzymes of the respiratory chain could be the rate limiting factor of aerobic capacity.

If local circulation is adequate for the work rate being performed, all of the energy requirements may be supplied by ATP generated by the aerobic mechanism. However, if the aerobic requirement exceeds delivery and exhausts oxygen stores, oxygen levels will drop to critical levels in each muscle unit and prevent adequate level of generation of ATP in the mitochondria. This will result in increased anaerobic glycolysis in order to sustain ATP availability and increased rate of lactic acid production and imminent termination of activity (Wasserman, 1973).

Aerobic Requirements

Aerobic fitness is a function of four primary factors: genetic potential, environment, and health. Generally, the current belief is that approximately 80% of one's aerobic potential is genetically determined and the remaining 20% can be modified by training (Sharp et al., 1988; Bouchard et al., 1988).

Maximal oxygen intake is best expressed in millilitres per kilogram of body weight per minute (aerobic power) for weight-bearing activities such as running (Sharkey, 1988). For non-weightbearing like activities the results are best expressed in litres per minutes (aerobic capacity).

The intensity and duration of a task can be used to determine its metabolic cost. The percentage of maximum work capacity that is available to complete physical work will depend upon work duration and intensity of the task. If it continues beyond an indicated time (without recovery) then the amount of energy output will decline as a result of fatigue.

Astrand et al. (1986) observed that:

> Great individual differences do exist in physical work capacity, and practical experience has indicated that a work load taxing 30 - 40 percent of the individuals maximum oxygen uptake is a reasonable average upper limit for physical work performed regularly over an 8 hour working day.

Rodger,1988 suggests that:

If the effort (intensity) exceeds 60% of an individual's maximum capability, the time to recover from the task will exceed the time of doing it.

Glesser and Vogel (1980) demonstrated that an individual (on average) could work at 50% of his VO_2max for up to eight hours. This would appear to be the upper limit for the "average" fit individual (Vogel, 1980). Therefore it would be inappropriate to actually expect anyone to work at 50% of their VO_2max for eight hours on a routine basis. Vogel (1980) suggests that the average energy expenditure rates for an eight hour work day should not exceed 35 to 50% of one's aerobic capacity in order to prevent excessive fatigue, from which one could not recover overnight. If the rate of performance is to be sustained for a relatively long period of time (e.g., 2 h) then it would not be unreasonable to expect individuals to be performing the task at no more than 60% of their maximal oxygen consumption (Vogel, 1980). If the length of task is 30 minutes, then it would be reasonable to expect individuals to work as high as 75% of their VO_2max.

In applying these principles in consideration of the duration and intensity of the tasks, Burkett et al. (1983) demonstrated that to successfully perform duties through five days of continuous close combat operations, a VO_2max of 45 ml/(kg . min) would be the minimum necessary.

Sharp et al. (1988) suggest that when developing performance standards, any minimum fitness requirement above 50% should be considered unacceptable as a desirable fitness level. This is particularly true of oxygen consumption, where genetic makeup has a large bearing on aerobic capacity and training can improve it only marginally. This could create a demand for fitness level that may be unattainable by some individuals, regardless of how hard they train to improve their aerobic capacity.

Measurement of Aerobic Power and Performance

The development and validation of methods for direct and predicted methods of measuring aerobic capacity have been extensive. In regards to the study of the components of physical fitness, The topic of aerobic fitness has received the most interest by researchers and fitness practitioners throughout the world. Aerobic power may be operationally defined in many way. As an example, the NATO Research Study Group defines aerobic power as: the point in a progressive exercise test in which oxygen uptake no longer increases despite increases in exercise intensity. A common criterion of not more than 1.5 - 2.0 ml kg.min per incremental increase in exercise intensity (such as a 2% treadmill grade increase is used). The use of treadmill or cycle is one of choice and equipment availability. The treadmill produces higher maximal oxygen uptake values (Hermansen, 1969), and minimizes the possibility of limiting local muscle fatigue than cycle ergometer protocols. Perhaps most importantly it is a mode of exercise more common to the military than is cycling. The cycle offer the advantage of being safe and providing precise information concerning the load being applied but that information is not essential in the determination of maximal oxygen uptake. Another variation in procedure is the use of progressive loads which are applied separately with intervening rest periods or applied in a continuous step or ramp scheme (Stamford, 1976). The separate or interrupted procedure is of value as it yields slightly higher values, is more comfortable for the subject, easier to gain subject cooperation, and minimizes complications from other factors, such as local muscular fatigue.

Estimating Aerobic Power

The majority of current methods used to estimate or predict maximal oxygen uptake are based on heart rate response to submaximal exercise (Shephard et al., 1976). It is well established that heart rate increases in a relatively linear fashion with increasing exercise intensity until the individual's maximum rate is reached. Since maximum rate is closely related to age and oxygen uptake, the exercise intensity relationship is quite consistent, then the determination of submaximal heart rate can be used to estimate, by extrapolation, the oxygen uptake that would occur at maximal heart rate. A common alternative is the determination of PWC 170 or the exercise load that is achieved at a heart rate of 170 beats per minute (Withers, 1977; Ulmer, 1983). There are many variations of these two common procedures (Albrecht, 1978, Astrand, 1954, Smith et al., 1984; Fox et al., 1973; Duggan et al., 1983). Tests may be carried out on treadmill, cycles or using graded step tests. The NATO RSG recommends a cycle test due to a greater ability to establish and control the exercise intensity. elsewhere. In Britain a step test was developed in which the heart rate measured during submaximal exercise is used in regression equations incorporating lean body mass and has been shown to produce a good correlation with measured maximum oxygen uptake (Duggan, 1982; Duggan et al., 1983).

NATO Tests

This procedure involves a cycle ergometer which is pedalled at 75 RPM with the intensity increased 37.5 watts each minute until one is unable to maintain the pedalling frequency. This test is referred to as the Wmax test. Since its inception by Ulmer (1983), the Wmax test has been investigated by several NATO participants (Patton et al., 1982; Myles et al., Hodgdon et al., 1983; Pederson et al., 1983) and compared to measured maximal oxygen uptake with good results. The Wmax can be presented in absolute terms as highest wattage or exercise time achieved, or these scores can be converted into VO_2max values derived from regression equations (Patton et al., 1982; Myles et al., Hodgdon et al., 1983;Dubois, 1983).

Since maximal tests are not always possible, a submaximal test was developed and called NATO II. This procedure uses the same exercise conditions as the Wmax test but uses as the end point the exercise intensity achieved at a heart rate of 190 BPM minus age. Evaluations of this test have been reported (Hodgdon et al., 1983; Pederson et al., 1983).

Field Tests

While sophisticated laboratory measurements involving gas analysis are more precise and appropriate, rarely will this equipment be available in a field testing situation. Occasionally laboratory measures are used by some NATO Countries for entrance testing but rarely are they used to evaluate periodic troop fitness. In the past, tests for this purpose have included a one and one-half mile or two mile run or a 12 or 15 minute distance run. The correlations between these tests and tests of maximal oxygen uptake can vary from fair to good depending on the conditions and the motivation of the subjects. A constant critique, however, is the applicability of the test and what it means in regards to the individual's ability to do the job.

Aerobic Power Values in Military Populations

Table 8 provides a compilation of data on maximal oxygen uptake in military populations. Several observations can be made from the data:

Table 9 provides an overview of predictive values of maximal oxygen uptake of military populations.

Table 8 – Actual Maximum Oxygen Uptake of Military Populations

Ref	Procedure	Subject	Subject Description	Maximal O2 uptake l.min	ml kg.min
1	Interrupted Treadmill Running	US Army Recruits n=200	Male-start trg -end trg		50.8 55.1
2	Interrupted Treadmill Running	US Army Cadets n=55	Male Age:17-21 Female	4.27 2.86	60.6 49.7
3	Interrupted Treadmill Running	US Infantry n=60	Age:19-34		47.1
4	Continuous Treadmill Walking	US Infantry n=260	Age:40-53	3.16	38.1
5	Interrupted Treadmill Running	US Infantry n=34	Age:18-29	3.92	53.6
6	Continuous Cycle	French Soldiers n=70	Age:18-22	3.15	46.3

References:
1 - Daniels et al., 1979
2 - Patton et al., 1983
3 - Gollnick et al., 1973
4 - Daniel et al., 1979
5 - Byrd et al., 1973
6 - Froelicher et al., 1974

Table 9 - Predictive Values of Maximal O2 Uptake of Military Population

Ref.	Procedure	Subjects	Subject Description	Max. O_2 l/min	Uptake ml/kg/min
1	Astrand Rhyming Cycle	British Army Recruits n=438	age 17-19 19-21 21-23 23-25 25-30		43.4 40.9 38.5 39.9 37.2
2	Astrand Rhyming Cycle	Canadian Forces Personnel	pre-recruit post-recruit age 17-24 25-29 30-39 40-55		46.7 53.2 45.1 38.8 36.3 32.4
3	Astrand Rhyming cycle	British Army Personnel n=3,070	Total Infantry Paratroopers Gurkha		44.2 46.1 47.8 58.5
4	Astrand Rhyming Cycle	Norwegian Conscripts n=801	Pre-training	2.90	45.0

References:
1 - Pollack, 1973
2 - Vogel et al., 1979
3 - Vogel et al., 1979
4 - Hermansen, 1978

Summary

The optimal measurement of aerobic power is by direct measurement of gas exchange during interrupted load uphill treadmill running (Allen, 1980). Other tests could be continuous load treadmill, interrupted load cycle ergometer and continuous load cycle ergometer. If a maximal test cannot be used, then alternative predictive submaximal tests must be used with their attendant predictive error.

G. – Aerobic Performance – Anaerobic Threshold

It is well known that the performance of aerobic type tasks, such as long term marches is not solely a function of aerobic power but also include other physiological factors that relate to the utilization of energy substrates (Dubois, 1983). This is thought to be related to the ability of the exercising muscles to aerobically utilize lipids and carbohydrates and conversely the ability to buffer the products of the anaerobic metabolic pathways of glycogen utilization which results in blood lactate accumulation and H^+ ion dissociation. Thus, the higher the capacity of the body to use aerobic pathways, the higher will be the capacity to perform aerobic tasks before they are limited or terminated by excess muscle tissue acidity or depletion of carbohydrate reserves. The latter can be conserved if the body has a greater capacity to aerobically metabolize lipids and carbohydrates.

The results of research in this area have led to the search for a measure referred to as "ventilatory threshold" (Karlsson et al., 1982). Anaerobic threshold is defined as the point of exercise intensity where blood lactate begins to accumulate significantly above resting levels. Thus, the higher the aerobic capacity of an individual, the higher intensity the individual can exercise without lactate accumulation and therefore the higher the ventilatory threshold value. Individuals who have a high capacity for aerobic work not only have high maximal oxygen uptake but they also can exercise at higher intensities (utilizing a greater percentage of lipid substrates) before accumulating blood lactate and muscle acidosis.

A number of procedures are available to identify threshold. A subject performs a series of progressively increasing submaximal exercise loads with blood lactate being measured at each step. The work rate at which blood lactate deviate from the resting values can be used as the threshold value. Many procedures are available (Wasserman, 1973; Kinderman, 1979; McLennan, 1981; Skinner et al.,1980; Weltman et al.,1978).

H. – ANAEROBIC FACTORS

In comparison to the amount of attention that has been focused on the measurement and interpretation of maximal aerobic power, much less consideration has been given to the measurement and meaning of anaerobic functioning in the military and academic literature. This lack of interest is surprising, since more sporting and individual athletic endeavours seem to involve greater than aerobic factors (Katch et al., 1977). Different investigators have chosen to use different criterion scores including initial or post exercise glycogen levels, initial levels of muscle phosphagen (ATP PC), and peak exercise muscle or blood lactic acid and/or pyruvate concentrations, one or several enzyme concentrations or even the quantity of post exercise oxygen debt (Katch et al., 1977; Evans, 1981).

Despite the lack of agreement of biochemical or physiological criterion measures of anaerobic functioning, the characteristics of a performance test to elicit a response seem apparent. Fitness tests reflect individual human ability to do maximal or supra-maximal work in a brief period of time (Evans, 1981). The test must be of a maximal intensity (for a given subject) and the rate of work must allow for the greatest percentage of energy production from anaerobic sources. The history of research on power tests begins with the Sargent Jump (1921) to the present. Sargent incorporated factors of body height, weight and vertical jump height into a physical efficiency index. Thus body dimension, "mechanical advantage", performance, "strength, speed and energy", have long been accepted concepts in power testing (Evans, 1981).

Tests of power may be categorized as:

1. physiological tests which include the measurement of oxygen debt and lactic acid levels in the blood and muscle;
2. performance oriented tests which include standing broad jump, vertical jump, and stair run of Margaria, most of which last less than one second; and
3. mechanical tests of power in the laboratory setting usually involving supra maximal bicycle trials with a fixed resistance or force setting on an "all out" cadence in which the subject pedals at maximum frequency for the duration of the test (Evans, 1981).

Anaerobic Metabolism

Anaerobic metabolism refers to the synthesis of ATP through chemical reactions that do not require the presence of oxygen. The ATP-PC (Phosphagen) and glycolysis (lactic acid system) are anaerobic. Phosphocreatine, like ATP, is stored in muscle cells. PC is similar to ATP in that when its phosphate group is removed, a large amount of energy is liberated (Fox et al., 1981). At the beginning of work and during heavy work, there is a discrepancy between energy demand and the energy available through aerobic processes. The anaerobic energy yield must therefore contribute to the breakdown of glycogen to pyruvic acid and lactic acid is quantitatively the most important step in the anaerobic process (Astrand, 1977). The phosphagens are the most rapidly available source of ATP available for use by the muscle. This is the system used for ATP production for high intensity, short duration events such as the performance oriented tests previously described, or athletic events such as, sprinting 100 meters. glycolysis releases energy for ATP synthesis through the partial breakdown of carbohydrates (glycogen and glucose) to lactic acid. Lactic acid contributes to muscular fatigue when it accumulates in blood and muscles. Anaerobic glycolysis is also a major supplier of ATP during high intensity, short duration events such as, the mechanical tests of power in the laboratory setting or athletic events such as sprinting 400 or 800 meters.

In review, the phosphagen system represents the most rapidly available source of ATP available for use by the muscle. Some of the reasons for this are that:

1. it does not depend on a long series of chemical reactions;
2. it does not depend on transporting oxygen to the working muscles; and
3. the speed of the system is enhanced since both ATP and PC are stored directly within the contractile mechanism of the muscles;

The anaerobic glycolysis system:

1. results in the formation of lactic acid, which contributes to muscular fatigue;
2. does not require the presence of oxygen;

3. uses only carbohydrates as its fuel: and

4. releases enough energy for the resynthesis of a few moles of ATP (Fox et al., 1981).

The time course of phosphagen and glycolytic energy contributions to supra maximal work has been investigated. Margaria et al. (1966) studied the contraction of maximal alactacid and lactacid oxygen debt. They calculated the maximal increase of lactate in the blood during strenuous exercise to be phosphagen splitting alone in exercise. They stated that stores may last only 4 to 5 seconds. Slightly higher phosphagen pools found in trained subjects and the start of glycolysis before ATP-PC depletion were possible factors in modifying the time course of phosphagen breakdown. Lactate was formed even in 5 to 10 second work periods. The energy required for high power arises from fuel supplies.

<u>Anaerobic Training Adaptations</u>

Changes which occur in skeletal muscle from chronic anaerobic training programs include increases in the activities of the ATP turnover enzymes - ATPase, myokinase and creatine phosphokinase. Other increases occur within the muscular stores of ATP and PC in glycolytic capacity (Fox et al., 1981). Anaerobic changes in skeletal muscle resulting from training include increased capacities of the phosphagen (ATP-PC) system and glycolysis i.e., the lactic acid system. Training alters several important enzymes of the ATP-PC system. The breakdown of ATP is facilitated by the enzyme ATPase, whereas its resynthesis is facilitated by the enzymes myokinase and creatine phosphokinase. Studies have shown increased activities of these enzymes following 8 weeks of sprint training: ATPase increased by 30%, MK by 20% and CPK by 36%. Thus not only storage is increased, but also their rates of turnover are enhanced (Fox et al., 1981)

Glycolytic enzymes are reported to increase following training. The significance of increased glycolytic activity is in speeding up the rate and quantity of glycogen breakdown to lactic acid. Therefore, ATP energy derived from the lactic acid system is increased also and thus contributes to improved performance of activities that depend heavily on the system. Evidence for increased glycolytic capacity following training is also demonstrated by the ability to accumulate significantly greater quantities of blood lactic acid following maximal exercise (Fox et al., 1981). Other chronic changes which may occur as a result of anaerobic training include:

1. increased blood lactate tolerance,
2. Increased blood volume and improved capilllarization, and
3. increased oxidative enzyme levels.

The end product of glycolysis can be lactate and hydrogen ions. Hydrogen ions lower blood Ph and attenuate the activity of phosphofructokinase which is critical as the rate limiting enzyme in glycolysis thereby decreasing ATP production. Increased lactate production and decreased Ph affect permeability of muscle cells to Na and K and reduces action potentials resulting in inhibition of muscular contraction. For this reason the hydrogen ion must be buffered. Associated with lactate production and heavy exercise is increased production of Carbon dioxide.

This assists in the buffer system as a result of the follow... interaction:

$$CO_2 + H_2O <---> H_2CO_3 <---> H^+ + HCO_3$$

thereby reducing the effect of increased H^+ ion production.

Anaerobic Processes

During light work, the required energy may be produced almost exclusively by aerobic processes, but, during more severe work, anaerobic processes are brought into play. As the severity of the work load increases, anaerobic energy yielding processes play an increasingly greater e (Astrand et al., 1977). Astrand and Rodahl (1977) suggest that an increase of lactic acid concentration in the blood as the main indication of involvement of anaerobic processes, since lactic acid concentration is relatively easy to analyze. They further suggest that the energy yield from the breakdown of ATP and phosphocreatine is indispensable, but that, quantitatively, the available stores of these high energy phosphates alone can cover only the energy requirement for less than one minute during maximal exercise. The dilemma of determination of optimal time to elicit maximal contribution of anaerobic processes is demonstrated by additional review of the literature (Evans et al., 1981). Margaria et al. (1966) indicate that 4-5 seconds of maximal power may be indicative of the phosphagen-splitting mechanism of work production alone. Their test of less than one second duration (Sargent, 1921) was called a test of maximal anaerobic power. Gollnick and Hermansen (1973) stated that 10 seconds was too short a time to permit anaerobic processes to be taxed to a maximal extent. They calculated relative contributions of the anaerobic processes to a maximal extent. For all out effort for 10 seconds, the contribution was 83%; for 1 minute, 60%; for 2 minutes, 40%; and for 5 minutes, 20%, decreasing thereafter. Margaria et al. (1964) studied the speed and capacity of energy production processes in exercise. They stated that all the alactacid oxygen debt contraction is completed in less than 40 seconds when lactate production is at its maximum rate. They also indicated that aerobic contributions were increased after 40 seconds. Hughson (1978) found the expression of VO_2 response time was important to conceptualizing the onset of aerobic energy contribution to supramaximal work. The half time peak VO_2 was 36.6 plus or minus 1.8 seconds and for required VO_2 was 53.4 plus or minus 4.2 seconds for 3 minutes of work at a power output to elicit 110-120% of VO_2max. McGilvrey (1973) estimated a 1000-fold increase in the amplification of the Embden-Meyerhof energy contribution in going from rest to maximum work over a period of 20 seconds, the time for the ADP level to rise to the concentration he assumed necessary for maximum glycolysis. Keul (1973) considered the relationship between aerobic and energy delivery as a function of time and intensity of work. Evans and Quinney (1981) selected the 30 second protocol to elicit mechanically maximum power output and predominantly anaerobic efforts and the exhausting nature of brief maximal tests.

The wide variety of tests available and the differences in test duration make the choice of the most appropriate test challenging. The tester must understand the differences in protocol and the subjects' requirements in order to make the best choice of the many protocols available.

Measures of Anaerobic Power

The ability to jump, sprint, put the shot, throw the javelin, or perform fast starts, are examples of anaerobic power activities. Power is performance of work expressed per unit of time(s). Mathews (1973) defines power as the rate of doing work. For example W= F x D in which W= work, F= force and D= distance through which the force moves. Provided the work was performed in a specific time frame i.e., one minute, power output would be calculated as: P = W / T in which P= power, W= work, and T= time in minutes. Apart from physiochemical methods, performance oriented or mechanical tests have been used to measure anaerobic work, power and duration of effort. The Sargent Jump has been used, although it may not be a measure of power (Costill et al., 1968). Costill et al. (1968) investigated the relationship among various impulse power tests along with anthropometric measures in 76 male football players. Margaria's stair test was correlated with the squat lift with an r of 0.752, weight correlated r= 0.783 and 0.848 with the squat lift and the Margaria test respectively. Other impulse tests and anthropometric parameters demonstrated significant but less meaningful correlations. Body weight appeared to account for the relationship between squat lift and anaerobic power. The treadmill has been used for a variety of anaerobic test protocols. Cunningham and Faulkner (1969) used a short exhaustive at 11-13 km/hr or 20% grade with run times varying from 36-66 seconds. Watt et al. (1975) employed a 12.8 km/hr run at 10 to 20% grade which produced exhaustion in subjects in 60 seconds. Cerretelli et. al. (1975) employed a 20-30 second exhausting run at 18 km/hr and a grade from 10-15%. Roberts (1978) utilized 25-40 seconds exhausting run at 14.5 - 16.1 km/hr at 20% grade to demonstrate high reproducibility of alactic oxygen debt. The cycle ergometer has also been used as a test mode for anaerobic power (Evans, 1981). Most tests utilizing ergometry have fixed resistance settings that are the same for all subjects or are relative to body weight, as an anthropometric parameter or to VO_2max, as a physiological function of the individual subject. Cadences are maximal "all-out" or fixed submaximal cadences. Durations range for peak 4 second values to 120 second total time, indicative of the time course for maximal exercise. Evans (1978) provided a classification for tests of anaerobic power reproduced as Figure 1. The myriad of tests available to consider anaerobic power is evident, the problem is to choose the most appropriate test in consideration of the test requirement.

Figure 1 – A Classification of Tests of Anaerobic Power

Duration	Type (Max. Isometric strength)	Energy Source	Tests
0-1 Sec.	Strength (Impulse)	ATP	-Margaria Stair Run -Vertical Jump -Angled Rack Press -Standing Broad Jump -Cybex
1-10 Sec.	High Power Phosphagen splitting	ATP-CP	-50 yd dash
10-30 Sec.	Power- Glycolysis	ATP-CP Lactic Acid	-Wingate Bike Test
30 Sec.- 2 Mins.	Power-Endurance -/Aerobic Glycolysis	Lactic Acid Oxygen	-Lactate -Oxygen Debt (Glycogen Depletion) -Szogy & Cherebetier -Other
2-5 Mins.	Endurance -Aerobic/ Glycolysis	Lactic Acid Oxygen	-VO2 Tests -H.R Tests -(submax or max.)
5 Mins.	High Endurance Metabolic Capacity	Lactic Acid Oxygen	-Astrand 6 Min Bike Test -Cooper 12 Min Run -Exhaustive Exercise Tests

Anaerobic Factors in the Military

In review, anaerobic power is characterized by brief (5 - 60 seconds) of high intensity work which derives its energy primarily from anaerobic glycolysis. In regards to military personnel, minimal work has been done in this area. The ability to sustain a high intensity constant (isometric) or repetitive (dynamic) muscular task for periods of 5 – 60 seconds will depend to a great degree on the mass and the type of muscle involved; the capacity of anaerobic pathways for glycolysis within these muscle fibres. A high ratio of type II fast twitch fibres will favour a high power. This relationship has been reported by Bar-Or et al. (1977) and Bosco et al. (1983) Metabolically, anaerobic power is related to the ability to convert glycogen to lactic and pyruvic acid and to tolerate decreased blood Ph due to their accumulation. Thus as anaerobic power improves as a result of training, the following changes take place: 1. Increase in glycolytic enzyme content of the muscle. (LDH, HK, PFK);

2. increase in levels of substrates, glycogen and phosphagens; and,

3. enhanced tolerance for lactic acid levels, and greater ability to convert lactic acid (Gollnick et al., 1973).

Measurement of Anaerobic Power

The ability to quantify anaerobic power in military testing has provided some difficulty (Defence Research Group, 1986). This is due to the fact that it is more difficult to measure this component in comparison to muscular strength and aerobic capability. Thus in many instances, performance measures - measures of the maximum power output that can be generated in a specific period and activity that coincides predominantly with energy derived from glycolysis are all that is left to measure. A criterion for such a test would be very high intensity for periods lasting 10-60 seconds.

Field Measurement

Field tests could include any of the following:

1. Standing broad jump,

2. Vertical jump (Sargent),

3. Margaria–Kalamen stair run,

4. Ball throw for distance

5. Shotput,

6. Sprint run, 40–60 seconds,

7. Shuttle runs, man carries,

8. Push–ups, sit–ups, chin–ups.

Laboratory Measures

Greater precision, validity and reliability can be achieved in the laboratory setting. Tests could include:

1. Bicycle ergometer tests – with fixed resistance and duration of the test and "all out cadence"(Evans, 1981);

2. Isokinetic fatigue tests – i.e., Thorstensson (1976). This test requires 50 repeated maximal isokinetic contractions performed in 60 seconds, at an angular velocity of 180 degrees per second. The average torque and rate of torque decline are utilized as measures;

3. Wingate tests – using a cycle or arm ergometer (Bar-Or et al., 1980). This technique can be used for leg pedalling as well as arm cranking. The resistance is applied quickly to the ergometer and is pedalled or cranked at maximal revolutions for thirty seconds. Power output is calculated for the mean of 30 seconds as well as the rate of decrease. The Wingate test is an anaerobic power test, that is the mean power output over 30 seconds, also includes the phosphagen alactic component, therefore it is not a pure glycolytic or lactic component test.

4. Isometric endurance time – records the time that an individual can

maintain some percentage of maximal isometric force, usually between 50 and 75% (Mathews, 1973.; Costill, 1968). Whether this is a true reflection of anaerobic power potential of the involved muscles or whether it is complicated by the restricted blood flow to the muscles that occurs with static contraction can be questioned.

Blood Lactate Concentration

The blood lactate concentration is relatively simple to determine. It is an index of anaerobic metabolism but not a measure of anaerobic power. At rest, blood lactate concentration is about 1.0 Mm. Blood lactate levels start to increase when the exercise rate becomes more severe (Astrand et al., 1986). Blood lactate levels of 4.0 mM have been referred to as the lactate threshold or the onset of blood lactate accumulation - OBLA (Karlsson et al., 1982). Increased lactate level in muscle and blood indicates an anaerobic supplement to the aerobic production of ATP (Astrand et al., 1986). Trained individuals can exercise at higher oxygen uptake levels than untrained individuals without an increase in blood lactate accumulation. In untrained individuals, blood lactate accumulation begins to increase at 50 to 60 percent of maximum oxygen uptake, whereas in conditioned subjects, blood lactate begins to accumulate at 80 - 85 percent of maximal oxygen uptake (Hurley et al., 1984).

Anaerobic Power Values in a Military Population.

Murphy et al. (1984) and Patton et al. (1985) have reported on military studies using the Wingate upper and lower body tests for the arms and legs. These results are provided in Table 10

Table 10– Values of Anaerobic Power in Military Personnel

Ref.		Mean	SD	Range	Mean	SD	Range
	WINGATE TEST	UPPER BODY			LOWER BODY		
1	Mean Power (watts)	424	73	301-567	440	101	238-683
2	Mean Power (watts)	383	42	312-481	611	57	520-699

References:
1 - Murphy et al., 1984
2 - Patton et al., 1985

Anaerobic Training in the Military.

Limited information is available on anaerobic training in the military. Typically, this mode of training would involve repeated bouts of high intensity exercise alternated with periods of recovery. Periods of activity are of very high intensity so that the metabolic pathways are engaged. The relief period allows one to load the system without achieving complete exhaustion thereby promoting a tolerance to accumulated lactic acid.

J. – SUMMARY

In a military context, the three main aspects of physical fitness comprise of muscular strength, anaerobic and aerobic fitness. Laboratory and field measures are available to assess these areas. Relevant measures of muscular strength include maximal lifting capacity, maximal alactic power, the isometric and dynamic strengths of various muscle groups and field tests such as the standing vertical jump. fitness can be measured dynamically, or isometrically. Dynamic methods include the Wingate 30 second bicycle ergometer test, and the Thorstensson 50 second repeated contraction fatigue test. Isometrically, it can be measured as holding time at a percentage (50%)

of maximal isometric force. For tasks of more than one minute in duration which require predominantly aerobic fitness, the NATO Research Study Group (RSG) suggests that the most reliable index is obtained by the direct measurement of VO_2max. Physical performance for prolonged periods (up to 2 hours) is a function of the ability to engage the aerobic metabolic pathway while minimizing the involvement of the pathway which will result in the imminent termination of physical activity. Aerobic fitness (endurance) can best be assessed by measuring maximum aerobic power. In addition, the RSG suggests that the onset of lactate accumulation (OBLA) may serve as a useful marker of exercise intensity and the start of processes indicating the eminent termination of exercise. The RSG suggests that the OBLA signifies the exercise intensity at which blood lactate increases above resting and may be the single best measure of capacity for prolonged aerobic exercise.

In the military situation, there are many practical difficulties in the actual measurement of VO_2max, particularly for large numbers of military personnel. As a result alternative methods may be required, which could include:

1. Maximal tests. For example the RSG4 (NATO1 or Wmax test) or a running test such as the 1.5 mile run.

2. Submaximal tests. Generally these are less accurate and performed on bicycle and treadmill ergometers. Other tests such as the step test are available which establish a relationship between heart rate and workload and predict an individual's maximum performance. Ideally, these tests must show a high correlation with

directly measured VO_2max tests.

The RSG recommended that the following areas deserve special attention:

1. Despite mechanization, strength training is important. The RSG suggests that weight resistance training is more effective than calisthenic exercises for developing strength.

2. Upper body strength and fitness are required for tasks such as load bearing and ammunition handling. Physical training limited only to running is not sufficient for such tasks.

3. Typically military training programs can produce improvements in VO_2max of 5-15%. These higher levels of aerobic fitness can be achieved by a minimum training frequency of three times per week at an intensity of 70% of maximal aerobic power.

The level of physical fitness determines the work rate that can be maint[illegible] ring periods of sustained military operations, in consequence high levels of all aspects of fitness are required in order to undertake the prolonged physical activit which may be encountered. High levels of physical fitness have not been directly linked to changes in the rate of degradation of cognitive performance under conditions of sleep deprivation.

CHAPTER III

METHODOLOGY

Experimental Design

The following steps were followed in regard to the design of this project:

1. Identification of the most physically demanding common tasks.
2. Identification of physical capabilities required to successfully complete the selected work tasks, and development and\or selection of appropriate laboratory tests which relate to the capability to complete these tasks.

3a. Measurement of physical capacity required for completion of laboratory tests and field task performances.

3b. Statistical analysis of data to determine population performance characteristics on different tests and predictive relationships amonglaboratory and field task variables.

4. Determination of acceptable level for the performance standards.

Step 1: This phase dealt with identification of tasks and their subcomponents for the organization or occupational group. 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) consists of four main job classifications: armour, infantry, artillery, and support staff. A job may involve several tasks. For example, the tasks involved in the duties of an infantry soldier consist of digging, casualty evacuation of another soldier of equivalent height and weight, weightload marching, jerry can lifting and carrying, and ammunition box lifting. Each task then can be subdivided into subtasks which further consist of basic physical fitness elements. For example, the casualty evacuation task can be broken down into subtasks: lifting another soldier and then running

100m while carrying the injured soldier in a fireman's carry position. 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 working conditions (Ayoub et al., 1987; Marston, 1984).

Step 2: This stage involved identification of various physical fitness components required to perform the selected tasks. Once appropriate components were identified, laboratory tests were developed and/or selected to quantify them.

Step 3a: In this phase representative workers, selected to develop the standards, performed these tests under simulated working conditions. The time to complete the task along with intensity of effort were the most important variables in determining ability to work.

Step 3b: Relevant statistical procedures included the use of:

a. Pearson Product Moment Correlation (PPMC),
b. Selected best set of predictor variables,
c. Multiple and stepwise multiple correlation,
d. Canonical correlation,
e. Identification of standards, and
f. Discriminate function.

Step 4: To determine cutoff points for an acceptable performance standard a combination of two approaches were used. First, when collecting the data a panel of Expert Judges was established. This panel observed performance of each field task very carefully and determined based on the occupational requirements, which performances were pass or fail. Once this process was completed, then the panel of judges decided collectively if they

III. INFORMED CONSENT FORM FOR LABORATORY TESTS

I, _________________________ authorize Dr M. Singh of the University of Alberta, and Major Wayne Lee of the Canadian Forces to administer and conduct an exercise fitness test battery designed to determine my cardio-respiratory capacity and anaerobic power.

I understand that the test for assessing cardio-respiratory capacity will involve performing on a treadmill ergometer at progressively increasing work loads until exhaustion. Throughout this period my heart rate will be monitored using an Sports Tester heart rate monitoring device. During the test, I will be required to breathe into and out of a mouth piece and wear a noseclip. All the air that I breathe in and out will be measured by the Beckman metabolic measurement cart. During continuous treadmill ergometer test, it will be a point when a plateau (as indicated by a change < 100 $ml.min^{-1}$) or a slight drop in the VO_2max occurs as work is increased beyond the work intensity that first results in a maximum value or when I will no longer be able perform due to fatigue. VO_2max refers to the maximal volume of oxygen which is consumed per minute (litre.min (absolute) or ml/(kg . min) (relative)) during a progressive treadmill exercise test while carrying a load of 24.5 kg.

I also understand that I will be tested for anaerobic power. These tests will include pedalling/cranking leg and arm ergometers at maximal effort for 30 second periods in order to determine lower and upper body anaerobic muscle power. Sports tester heart rate monitor will be worn in order to assist in appropriate warm-up and assess recovery after the anaerobic tests. Finger prick blood lactate analysis will be completed before my test, four minutes after the leg ergometer and four minutes after the arm ergometer tests in order to measure lactate development during the post exercise period.

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 completion 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 tests there are potential risks. These include episodes of transient lightheadedness, fainting, chest discomfort, leg cramps and 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.

You are reminded that during the test procedures that you are on military duty and are entitled to all rights and considerations pertaining thereto.

DATE: ______________

SUBJECT: ____________________
(SIGNATURE)

WITNESS: ____________________
(SIGNATURE)

IV. HEALTH APPRAISAL QUESTIONNAIRE /
(CF EXPRES, 1989)

This questionnaire is a screening device to identify those members for whom physical activity might be inappropriate at the present time.
To the best of your knowledge:

1. Do you have a restricted medical category which may prevent you from being evaluated or participating in a progressive training program?
   Yes No

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?
   Yes No

3. Do you suffer from such things as:
   High blood pressure, heart disease, asthma, bronchitis, emphysema, diabetes, epilepsy, arthritis or cancer or from previous injuries that might limit your ability to do a exercise test?
   Yes No

4. In addition to the above is there anything which you feel should be discussed with a medical officer prior to assessment?
   Yes No

5. Are you taking medication (prescribed or otherwise) which may affect your ability to undertake a physical evaluation?
   Yes No

6. How are you feeling today? (circle one)
   Excellent Good Physically tired Mentally tired

   Don't feel good at all

   Other (please specify)

   ____

   ____

Date______________ Name ______________

V. TREADMILL WEIGHTLOAD MARCH PROTOCOL

H.R(bpm)	Time(mins)	Speed(mph)	Elevation(%)	A.T	Time	Grade
	1 2	2.5 2.5	0 0			
	3 4 5	3.3 3.3 3.3	0 0 0			
	6 7 8	3.3 3.3 3.3	2 2 2			
	9 10 11	3.3 3.3 3.3	4 4 4			
	12 13 14	3.3 3.3 3.3	6 6 6			
	15 16 17	3.3 3.3 3.3	8 8 8			
	18 19 20	3.3 3.3 3.3	10 10 10			
	21 22 23	3.3 3.3 3.3	12 12 12			
	24 25 26	3.3 3.3 3.3	14 14 14			
	27 28 29	3.3 3.3 3.3	16 16 16			
THE TEST WILL CONTINUE UNTIL EACH SUBJECT REACHES VO2 MAX CRITERION						

NOTES: 1. This test will be completed in full fighting order (rucksack, helmet, webbing, gas mask, rifle-including basic ammunition load totalling approximately (24.5 kg).

2. VO_2max refers to the maximal volume of oxygen which is consumed per minute (litre.min (absolute) or ml/(kg . min) (relative)) during a progressive treadmill exercise test while carrying a load of 24.5 kg. During continuous treadmill ergometer test, it will be a point when a plateau (as indicated by a change < 100 ml.min) or a slight drop in the VO_2max occurs as work is increased beyond the work intensity that first results in a maximum value or when the subject will no longer be able perform due to fatigue.

3. Once subject has reached Ventilatory threshold (AT) – a point where there is a nonlinear increase in V_E, V_{CO2} and a sudden increase in RQ with a decline in expired CO_2 tension (FE_{CO2}) and an elevation of O_2 tension (FE_{O2}). The grade of the treadmill was raised 2% every minute until the subject reached maximal oxygen uptake or until exhaustion.

VI. RATERS ADVISORY

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY SINCE IT IS VERY IMPORTANT IN THE SELECTION PROCEDURES FOR SUBJECTS IN THE ARMY PHYSICAL FITNESS STANDARDS STUDY.

Introduction:

Army Physical Fitness Standards will be based on a series of selected common tasks that have previously been defined by army subject matter experts. The following selected tasks have been deemed to important components of the soldiers' tasks:

a. Digging a slit trench
b. Evacuating a casualty
c. Lifting ammunition boxes
d. Weightload marching.

You will be required to rate the personnel in your companies according to their physical ability to carry out the aforementioned tasks in an operational environment.

Physical ability refers to the individual soldiers ability to work in an operational environment under conditions in which these tasks will be performed repeatedly. Physical ability in this case does not refer to a soldiers ability to run a fast mile or to do push-ups or sit-ups or lift free weights. Consider the work and performance ability of the soldier in the field operation scenario and not in the gymnasium.

Raters:

Soldiers will be rated by senior leaders within the companies (total of three raters per group). Any conflict arising with regard to classification must be resolved in a majority decision basis. At least two out of the three raters must agree in order for a person to be classified. Please rate the soldiers according to the following criteria:

1) FAIL – From a physical performance viewpoint not ready to go into an operational environment.
2) BORDERLINE – Rater is unsure if the soldier is ready to go into an operational environment.
3) PASS – The soldier is ready for an operational environment.
4) SUPERIOR – These soldiers are the top physical performers in your unit.
5) NOT AVAILABLE – For medical or administrative reasons these soldiers are not available for testing. However they should be rated.

APPENDIX B

LABORATORY TESTS
INSTRUCTIONS TO SUBJECTS

I. AEROBIC TEST

II. ANAEROBIC TEST

INSTRUCTIONS TO SUBJECTS

AEROBIC TEST

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

1. The treadmill march test is a test of your maximal ability to take up, transport and utilize oxygen to do continuous work.

2. Throughout this test all gasses that you breathe in and out will be monitored every 30 seconds by a special apparatus. You will wear a Sports Tester heart rate monitor and your heart rate will be monitored every 30 seconds. Throughout this test you will wear your full fighting order (rucksack, helmet, webbing, gas mask, rifle-including basic ammunition load weighing 24.5 kg). You will be provided a warm-up phase at the start of the test. The warm-up phase will consist of 2 minutes at 0% grade at a speed slightly slower than the speed of the test and then for 3 minutes at the same speed as the test. At the end of five minutes of warm up, the test will begin. You will march at a pre-selected speed (88.9 meters/min) for the entire test. Every three minutes the treadmill incline will be increased until you reach your ventilatory threshold and then it will be raised 2% every minute. You must continue at the predetermined pace until you are stopped by the tester or until you can no longer continue due to fatigue.

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

4. Once the test has ended the incline will be quickly reduced to the minimum. You will continue to walk at a self selected speed. You will be allowed to march until you feel fully recovered (2-3 minutes or until heart rate has decreased to less than 120 bpm). You must stay in the test area until your heart rate has dropped below 100 bpm. Do not leave until the tester is confident that you are fully recovered.

5. If you feel this test is too demanding, you may stop at any time.

6. Are there any questions?

INSTRUCTIONS TO SUBJECTS
ANAEROBIC TEST

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

1. The Wingate lower and upper body power tests are mechanical tests of power using a pre-determined resistance relative to body weight and completed in a 30 second "supra-maximal" cadence.

2. Throughout this test you will wear a Sports Tester heart rate monitor.

3. The seat will be adjusted to a comfortable height on the cycle ergometer (knee in extended position approximately 15 degrees with toe clips utilized). A seat belt will be secured around the hips and shoulders for arm ergometer testing.

4. You must cycle / crank as fast as possible for the entire 30 second test and not preserve strength or pace yourself. As well you must remain seated throughout the test.

5. You will be provided a warm-up phase prior to the maximum test. The warm-up phase for the ergometer tests will consist of 3-5 minutes at 30 percent of your predicted load (kp) setting. The rate of pedalling or cranking will be determined by the subject. At three minutes if you have reached a heart rate of 150 bpm or if you have not reached a heart rate of 150 bpm, at the end of five minutes, the test will begin.

6. On the command "START" , you will begin cycling at maximum speed.

7. Verbal encouragement will be given to help motivate you. The last 5 seconds of the test will be counted down to help you put out maximum effort.

8. Once the test has ended the resistance will be quickly reduced to the minimum. You will continue to cycle / crank at a self selected speed, or in the case of the arm ergometer - cease cranking altogether. After either test, you will remain seated. You will be allowed to cycle /crank until you feel fully recovered (2-3 minutes or until heart rate has decreased to less than 120 bpm). Stay in the test area until your heart rate has dropped below 100 bpm. 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.

10. Are there any questions?

APPENDIX C

FIELD TESTS
INSTRUCTIONS TO SUBJECTS

I. WEIGHTLOAD MARCH

II. MAXIMUM EFFORT SLIT TRENCH DIGGING

III. MAXIMUM EFFORT SLIT TRENCH DIGGING TASK.

IV. CASUALTY EVACUATION

V. AMMUNITION BOX LIFT/CARRY

INSTRUCTIONS TO SUBJECTS FOR

I. WEIGHTLOAD MARCH

The tester will 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 88.9 meters/min for a maximal distance of 16 km (10 miles) or until you can no longer continue due to fatigue. This test is equivalent to a marching speed of 5.33 km/h (3.33 mph).

2. Throughout this test you will wear a Sport Tester heart rate monitor which will monitor and record your heart rate every 30 s. You must maintain the pace until you complete the distance or until you have reached exhaustion.

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.

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

5. Should you not be able to maintain the pace, move to the outside of the track. If at any time you are 100 m behind the rest of your group, your test will be stopped. After every five laps, you will be requested to call out your Rate of Perceived Exertion.

6. Once the test has ended, you will be asked to walk about the test area in order to actively cool-down. Continue to walk about 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.

8. Are there any questions?

INSTRUCTIONS TO SUBJECTS FOR

II. MAXIMUM EFFORT SLIT TRENCH DIGGING TASK

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

1. This task is a simulation of a one person slit trench dig.

2. You will wear a Sport Tester heart rate monitor which will record your heart rate every 15 s.

.. On the command "start", you will dig as quickly as possible pitching the crushed rock into the other box. You may move from one side of the box to the other while digging but you may not step outside the box. The task shall be complete when the researcher overseeing the test says "stop". The researcher will determine when there is less than a shovelful of gravel remaining in the simulator.

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

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 will be disconnected asked to 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.

9. Are there any questions?

INSTRUCTIONS TO SUBJECTS FOR

III. CASUALTY EVACUATION TASK

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

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 a soldier of the same height and weight for a distance of 100 m, using the fireman's carry, at a maximal effort. The task will be complete once any part of your foot touches or passes the finish line. You will carry a soldier of approximately the same weight as yourself. The wounded soldier will be dressed in light fighting order with weapon.

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

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

5. 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.

8. Are there any questions?

INSTRUCTIONS TO SUBJECTS FOR

IV. MAXIMUM EFFORT JERRY CAN TASK

The tester will 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 dist of 35 m as quickly as possible and then empty it into a funnel at a 1.0 m height (gas tank simulator). The empty can will be placed alongside the simulator. Then you will run back and pick up another can and repeat th procedure. After three shuttle runs, emptying the three cans into th funnel and leaving the empty can alongside the simulator, you will run to the starting line. As soon as your foot touches or crosses the lin the task will be completed. The total time to complete the task will be recorded.

3. During the test you will wear a Sport Tester heart rate monitor wh will record your heart rate every 5 s.

4. You will be provided a general warm-up phase at the start of the te This will consist of three minutes of general cardiovascular and stretching exercises.

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

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

7. Avoid excessive forward bending, use your legs for lifting, in orde reduce stress on the lower back.

8. Once the test has ended, you will walk about the test area in order actively cool-down. Continue to walk until you feel fully recovered (t three minutes or until your heart rate has decreased to less than 12C beats per minute). You must stay in the test area until your heart rat 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.

10. Are there any questions?

INSTRUCTIONS TO SUBJECTS FOR

v. AMMUNITION BOX LIFT – CARRY TASK

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

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

2. This task will involve lifting ammunition boxes, each weighing 20 kg. On the command "Start", you will lift the boxes from the floor and place them on a truck bed at a height of 1.3 m. Do not start this task at maximal effort. This may potentially be harmful for the lower back. Start it at a moderate pace until you reach your pre-determined heart rate (heart rate at 70% of your maximal aerobic power taken from the laboratory treadmill task). This will be determined using a heart rate monitor. The researcher will advise you on pacing. You will continue working at this pace until 48 boxes have been moved.

3. During the test you will wear a Sport Tester heart rate monitor which will record the intensity of your work. Heart rate will be recorded every 15 s. Accordingly, the tester will give you feedback on when to slow down or speed up your pace.

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

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.

9. Are there any questions?

APPENDIX D

ARM AND LEG ERGOMETER STREAMING COLLECTION PROGRAM AND GRAPHICAL EVALUATION PROGRAM

I. INTRODUCTION

II. INSTALLATION

III. PROGRAM OPERATION (STREAMER PROGRAM)

IV. PROGRAM OPERATION (EVALUATION PROGRAM)

Introduction

These programs were designed to facilitate gathering data on the Wingate arm and leg ergometer tests specifically for this project. A computer programmer was employed to develop the programs based on the requirements as stated by the researcher. Two programs were created. A streaming program that prompts for a workload and then digitizes the crank revolutions of the ergometer for a set period of time and a evaluation program designed to evaluate and graph output from the first program.

Data acquisition was completed using a form of the True Transistor Logic (TTL) shaft encoding. The streaming program used the MetraByte CTM-05 encoder. The CTM-05 timer board measured the time between rising edges of the TTL encoder. It was accurate up to 1 microsecond. Knowing the distance that the flywheel travels between TTL pulses makes it possible to compute instantaneous acceleration and speed, as well as: RPM, work done, power output etc.

The second program evaluated output generated from the streaming program. This program evaluated data and produced average power and RPM for a user definable number of intervals or user definable size. It also calculated peak power output, average power output, lowest power output, power decline, relative power output based on both peak power output and maximal power output divided by the body weight of the subject, total work done and relative work done. It also produced an on screen graph, could print the output (on demand) and save the data in a Lotus importable file.

Installation

Data acquisition is recommended on at least a 10MHz, 286 class computer. Data acquisition can be demanding on CPU resources.

There is no installation program to be run.

Once the progra is started it will display the subjects weight from previously entered data and request confirmation. Weight may be changed by entering the appropriate values or accepted the current value by pressing the <return> key.

Program Operation - Streamer Program

The program prompted for confirmation of the load constant. This was done in the same manner as the subject weight. Load constants were calculated by multiplying the individual's body weight by 0.075 kg for the leg test and 0.050 kg for the arm test. The computed load was then displayed. Next, an instruction screen was displayed. The warm up load (1/3 of the test load) as well as the test length in seconds.

An RPM gauge was seen on the screen. This gauge also served to indicate that the test equipment was operational.

Once the subject was ready to begin the test, the subject was instructed to begin pedalling maximally. Pressing any key resulted in a 3 second period of adjustment to permit the researcher to provide the appropriate resistance . Immediate sampling continued for the duration of the 30 second test. Once the testing was completed, the evaluation program commenced.

Program Operation – Evaluation Program

This program analyzed the specific file. The program drew a bar graph representing the power output for each user definable interval. Each bar in the graph was labelled with its power value in three formats: power output in watts, RPM, and kpm/min. It also displayed the following:

-body weight (kg),
-load constant (kp),
-actual test load (kp),
-wheel distance (m),
-peak power output (watts),
-interval in which it was displayed,
-maximal power output (watts),
-lowest power output (watts),
-power decline (%)
-relative power output based on maximal power output (MPO/body weight) (watts/kg),
-relative power output based on peak power output (PPO/body weight) (watts/kg),
-work done (joules),
-relative work done (work done/body weight) (joules/kg),
-the number of valid intervals (in case an individual did not finish the test)
-test end time. The time in seconds the evaluation ended. In the event an individual did not complete the test.

APPENDIX E

PILOT STUDY RESULTS

I. RELIABILITY COEFFICIENTS

II. SUBJECT DATA FORM

III. FIELD TESTS – RELIABILITY FORMS

IV. LABORATORY TEST – WEIGHTLOAD MARCH

V. LABORATORY TEST – WEIGHTLOAD MARCH TREADMILL VS ELITE RUNNING PROTOCOL RESULTS

VI. LABORATORY TEST – VENTILATORY THRESHOLD

VII. FIELD TEST – WEIGHTLOAD MARCH 1

VIII. FIELD TEST – WEIGHTLOAD MARCH 2

PILOT STUDY
RELIABILITY COEFFICIENTS

FIELD TASKS

VARIABLE	MEAN	r	r -square
TEST: Casualty Evacuation RETEST:	37.4 37.1	0.85	0.72
TEST: Maximum Jerry Can RETEST:	134 126	0.83	0.69
TEST: Maximum Slit Trench Dig RETEST:	308 271	0.86	0.74
TEST: Sub-Max Slit Trench Dig RETEST:	927 902	0.96	0.92
TEST: Ammunition Box Lift RETEST:	262 251	0.90	0.81

Laboratory Tests
Weightload March Treadmill Results

VARIABLE	MEAN	r	r-square
TEST: VE (ml.min - BTPS) RETEST:	127,595 128,199	0.89	0.79
TEST: VO2 (ml.min - STPD) RETEST:	3,675 3,724	0.90	0.81
TEST: VO2max (ml/(kg.min) - STPD) RETEST:	47.0 47.4	0.96	0.92
TEST: VCO2 (%age mixed average) RETEST:	4,253 4,255	0.84	0.71
TEST: Time (Secs) RETEST:	698 759	0.94	0.88

SUBJECT DATA FORM PILOT STUDY CFB EDMONTON – DEC 89

SUBJECT	AGE	WT(KG)	HT((CM)	GIRTHS			
NO.				CH	WST	GLUT	THI
1	31	69.5	170.5	92.0	78.0	96.0	56.0
2	26	74.6	169.0	99.0	80.0	59.0	57.0
3	20	76.0	179.0	95.5	79.0	91.0	56.0
4	25	64.0	173.0	93.0	75.0	88.0	50.0
5	21	61.2	173.0	93.5	79.0	61.0	53.5
6	19	78.0	185.0	96.0	82.0	96.0	57.0
7	21	82.0	172.0	100.5	83.5	97.5	60.5
8	29	92.5	176.0	113.0	96.0	106.0	61.0
9	26	73.0	174.0	98.0	78.0	96.0	57.0
10							
11	34	72.9	170.5	100.0	86.0	97.0	57.0
12	30	82.5	176.0	102.0	86.0	100.0	62.0
13	34	68.8	166.0	101.0	80.0	97.0	58.0
14	32	88.0	182.0	103.0	87.0	105.0	63.0
15	31	83.0					
16		80.0					
X	27.1	76.4	174.3	99.0	82.3	94.5	57.5

FIELD TESTS FOR PILOT STUDY
RELIABILITY FORM FOR CASUALTY EVACUATION, MAXIMUM EFFORT JERRY CAN, SUBMAXIMUM EFFORT JERRY CAN, MAXIMUM DIG, SUBMAXIMUM DIG, AND AMMUNITION BOX LIFT FIELD TASKS.

ID No	Casualty Evacuation		Maximum Jerry Can		Maximum Dig		Submaximum Dig		Ammunition Box	
	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
1	37.9	34.5	138	121	345	287	1088	1018	326	334
2	40.8	42.9	144	124	285	245	757	750	202	193
3	41.4	45.5	135	132	343	315	1242	1168	251	225
4	40.6	38.5	141	132	278	310	828	865	276	313
5	35.3	32.9	128	120	356	315			271	237
6	42.8	39.0	134	129	350	299			297	279
7	32.0	33.0	112	124	300	245	736	709	207	187
8	40.2	41.8	128	127	280	325	1083	1035	550	545
9	31.9	30.8	126	124	299	261	834	861	345	307
10										
11	37.8	38.1	162	146	251	250	883	821	269	241
12	32.8	39.1	126	112	226	212	747	821	173	194
13	30.9	32.3	106	112	345	271	996	947	300	284
14	37.2	35.5	140	128	288	284	1012	932	232	224
X	37.4	37.1	134	126	308	271	927	902	262	251
r	0.852(12)		0.828(12)		0.856(11)		0.96 (11)		0.90(13)	

1. Scores are given as a total time, in seconds, to complete the task.

2. The following information on calculation of reliability coeffficients is reported:
   a. In casualty evacuation subject 12 was dropped because he slipped at the start and would be re-tested in real life.
   b. In maximum jerry can subject 7 was dropped because he reported that he did not give his maximal effort on the second test.
   c. In maximum dig subject 4 was dropped because he reported he had a sore back, subject 8 was dropped because he had blisters during the second test (he refused to wear gloves during first test).
   d. In Ammo Box, subject 8 data was considered outlier and not included in the calculation of correlation coefficient. If included the R would be 0.974.

LABORATORY TEST FOR PILOT STUDY
WEIGHTLOAD MARCH TREADMILL RESULTS

ID	VE	WT	VO2	VO2MAX	VCO2	TIME(SEC)
1T1 1T2	107,300 107,670	72.0 71.0	3,592 3,491	49.9 49.2	3,967 4,090	12:36(756) 14:37(877)
2T1 2T2	144,308 144,687	75.0 75.0	3,701 3,753	49.3 50.0	4,477 4,604	12:35(755) 13:19(99)
4T1 4T2	145,684 165,850	64.6 66.0	3,486 3,740	54.0 56.7	3,888 3,993	11:35(695) 13:06(786)
5T1 5T2	119,444 119,556	72.5 72.3	3,675 3,665	50.7 50.7	4,221 4,087	11:31(691) 13:06(786)
6T1 6T2	106,106 111,777	80.0 80.0	3,744 3,851	46.8 48.1	4,406 4,339	12:05(725) 12:31(751)
7T1 7T2	119,087 113,119	82.8 84.0	4,099 4,104	49.5 48.9	4,601 4,435	12:05(725) 12:35(755)
8T1 8T2	119,218 95,882	95.1 95.1	3,424 2,894	36.0 29.7	4,117 3,352	10.00(604) 9:34(574)
9T1 9T2	138,319 133,688	73.6 74.0	3,548 3,556	48.2 48.1	4,142 3,930	10:34(634) 11:35(695)
11T1 11T2	130,403 130,790	74.5 75.1	3,387 3,497	45.5 46.6	3,980 3,925	10:34(634) 12:05(725)
12T1 12T2	147,672 152,937	84.0 84.0	4,108 4,512	48.9 53.7	5,219 5,480	14:00(840) 15:06(906)
13T1 13T2	121,805	70.0	2,989	42.7	3,696	8:36(514)
14T1 14T2	147,812 164,672	88.0 89.0	4,012 4,289	45.6 48.2	4.439 4,675	12:35(755) 14:06(846)
15T1 15T2	126,296 116,844	82.3 83.0	3,245 3,048	39.4 36.7	3,628 3,785	8:23(503) 8:03(483)
16T1 16T2	107,087 111,118	79.2 80.0	3,755 4,007	47.4 50.1	4,197 4,574	12:35(755) 14:48(888)
XT1 XT2	127,595 128,199	77.4 77.7	3,675 3,724	47.0 47.4	4,253 4,255	11:38(698 12:39(759
r	0.89	0.99	0.90	0.96	0.84	0.94

LABORATORY TEST FOR PILOT STUDY
WEIGHTLOAD MARCH TREADMILL VS ELITE RUNNING
PROTOCOL RESULTS

ID	[illegible]	WT	VO2	VO2MAX	MAX HR	VCO2	RQ	TIME(SEC)
1T1*	10[illegible]00	72.0	3,592	49.9	196	3,967	1.10	12:36(756)
1T2	107,670	71.0	3,491	49.2	199	4,090	1.17	12:40(760)
Run	98,283	70.0	3,683	52.6	195	4,329	1.18	11:05(665)
9T1*	138,319	73.6	3,548	48.2	193	4,142	1.17	10:34(634)
9T2	130,244	74.0	3,558	48.1	198	3,901	1.10	12:35(755)
Run	137,776	74.0	3,923	53.0	196	4,397	1.12	9:34(574)
12T1	147,672	84.0	4,108	48.9	194	5,219	1.27	14:00(840)
12T2*	152,937	84.0	4,512	53.7	194	5,480	1.21	15:06(906)
Run	148,415	84.0	4,688	55.8	187	5,672	1.21	10:34(634)
14T1	147,812	88.0	4,012	45.6	182	4,439	1.10	12:35(755)
14T2*	164,672	89.0	4,289	48.2	178	4,675	1.09	14:06(846)
Run	155,756	89.0	4,708	52.9	178	5,556	1.18	11:35(695)
XT1	135,276		3,815	48.2		4,442		(746)
XT2	138,881		3,936	49.8		4,537		(817)
r	0.93		0.99	0.40		0.96		0.81
XRUN	135,057		4,250	53.6		4,989		(642)
XWLM*	140,807		3,985	50.0		4,566		(786)
r	0.99		0.95	0.91		0.90		0.67

Correlation (r) between best weight load march (WLM) VO2MAX* score and run score

$$\text{PERCENTAGE CHANGE} = \frac{\text{RUN SCORE} - \text{BEST WEIGHLOAD MARCH SCORE}}{\text{BEST WEIGHTLOAD MARCH SCORE}} \times 100$$

SUBJECT	PERCENTAGE CHANGE
1	5.41 %
9	9.95 %
12	3.91 %
14	9.75 %
GROUP	7.25 % (3.88 ml/(kg . min)

LABORATORY TEST FOR PILOT STUDY
VENTILATORY THRESHOLD DURING WEIGHTLOAD MARCH TREADMILL

ID	VE	VCO2	RQ	FECO2	FEO2	TIME	WKLD	% of VO2 at VT	HR at VT
1T1 1T2	102,709 95,716	3,701 3,609	1.11 1.11	4.80 4.95	16.52 16.40	665 726	12% 12%	92.9 92.8	193 190
2T1 2T2	81,764 72,317	3,334 3,290	1.14 1.11	5.43 5.96	16.04 15.46	513 483	10% 10%	79.0 79.0	170 162
4T1 4T2	98,503 99,022	3,166 2,999	1.07 1.04	4.28 4.19	16.89 16.88	483 483	10% 10%	84.6 77.1	173 170
5T1 5T2	90,552 78,641	3,222 2,961	1.06 1.01	5.01 4.95	16.16 16.06	483 484	10% 10%	87.6 79.7	189 181
6T1 6T2	79,340 83,100	3,465 3,681	1.07 1.07	5.81 5.81	15.48 15.42	513 543	10% 12%	85.7 89.8	180 175
7T1 7T2	79,831 82,983	2,961 3,465	1.02 1.03	5.46 5.36	15.59 15.73	483 483	10% 10%	78.4 79.9	172 169
8T1 8T2	111,981 95,882	3,867 3,352	1.19 1.16	4.60 4.59	16.93 16.86	513 574	10% 12%	95.0 100.0	188 192
9T1 9T2	138,319 133,688	4,141 3,930	1.17 1.11	3.99 3.87	17.41 17.37	634 695	12% 12%	100.0 100.0	194 194
11T1 11T2	130,403 130,790	3,980 3,925	1.17 1.12	4.07 3.95	17.36 17.34	634 725	12% 12%	100.0 100.0	200 200
12T1 12T2	147,672 152,937	5,219 5,480	1.27 1.21	4.70 4.71	17.04 16.90	839 906	14% 16%	100.0 100.0	194 194
14T1 14T2	131,433 134,608	4,086 4,010	1.07 1.03	4.14 3.91	17.03 17.13	604 725	12% 14%	95.0 90.8	181 175
15T1 15T2	108,526 99,261	3,154 3,125	1.10 1.14	3.86 4.18	17.38 17.18	332 423	5% 10%	91.5 89.7	183 186
16T1 16T2	82,724 91,350	3,467 3,758	1.05 1.06	5.56 5.39	15.61 15.80	543 665	12% 12%	87.8 93.5	182 176
XT1 XT2	106,443 103,869	3,674 3,660	1.11 1.09	4.75 4.76	16.57 15.50	557 608			
r	0.95	0.91	0.90	0.96	0.97	0.94			

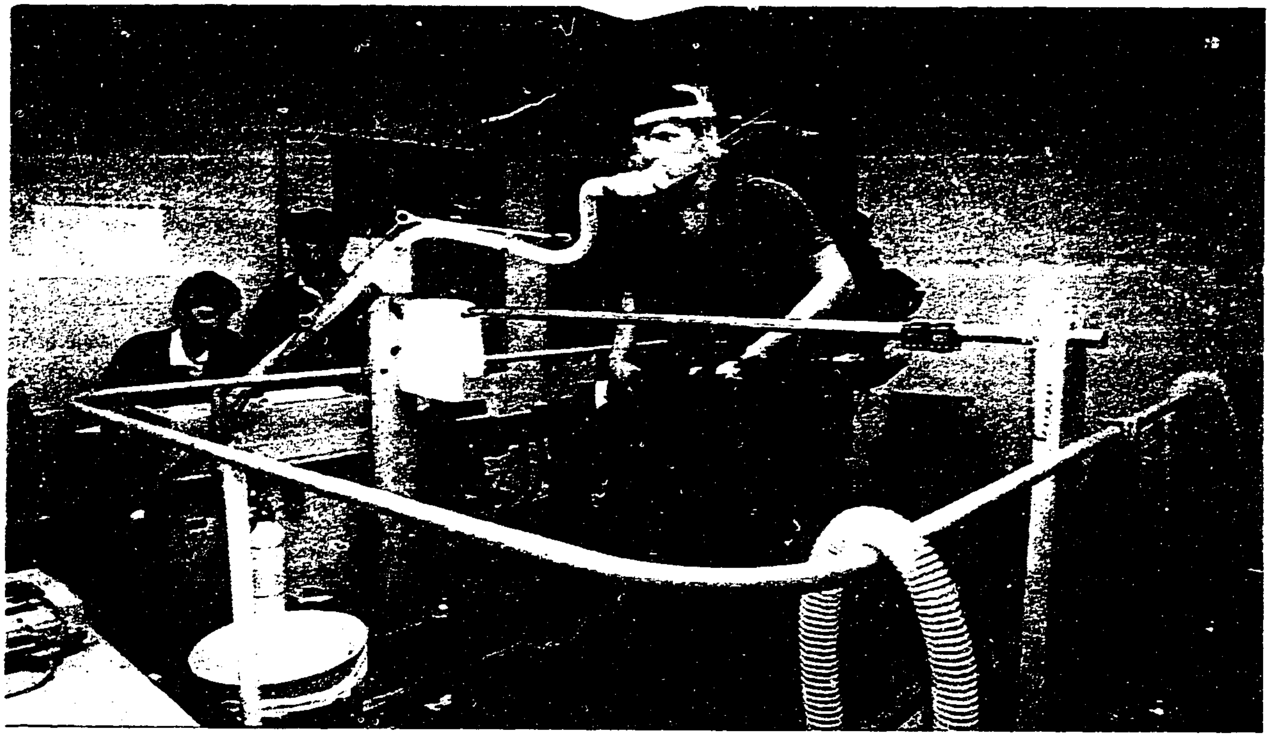
VENTILATORY THRESHOLD - A POINT WHERE THERE IS A NONLINEAR INCREASE IN VE, VCO_2 AND A SUDDEN INCREASE IN RQ WITH A DECLINE IN EXPIRED CO_2 TENSION ($FECO_2$) AND ELEVATION OF O_2 TENSION (FEO_2). PERCENTAGE VO_2 at VENTILATORY THRESHOLD - VO_2max at VT/VO_2max.

APPENDIX F

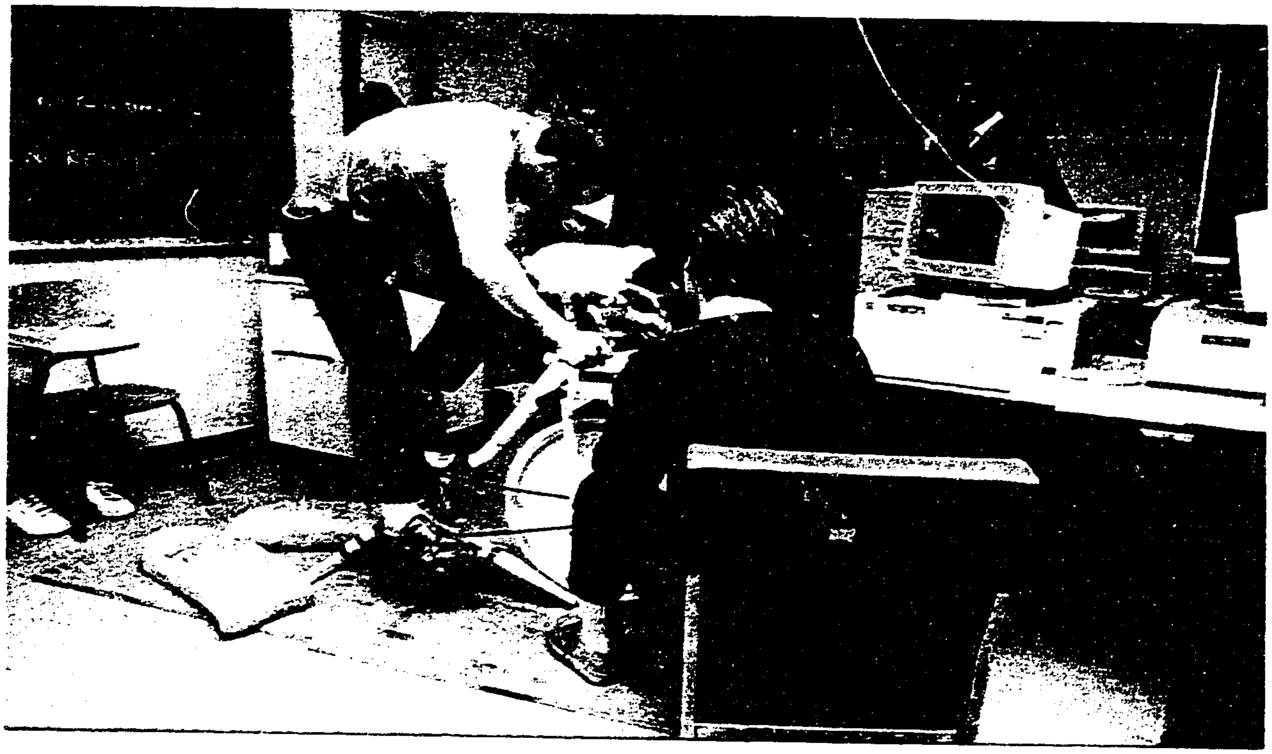
LABORATORY TEST

AND

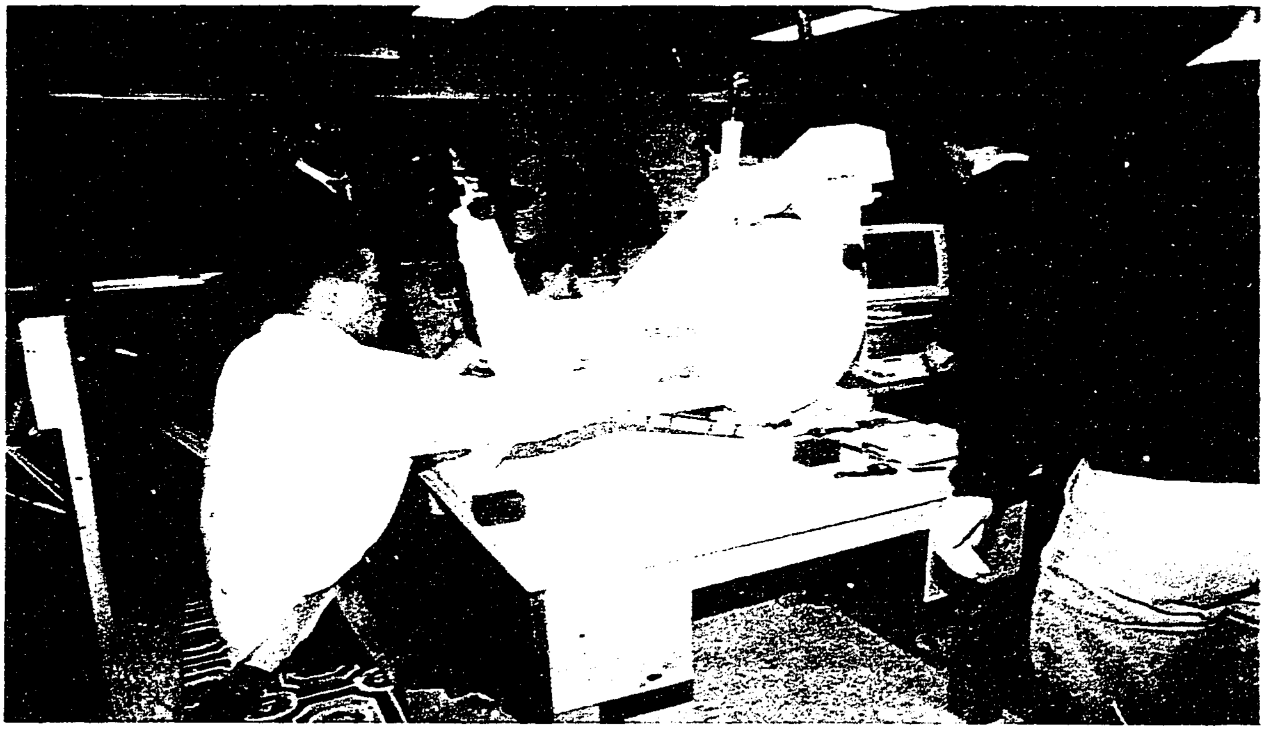
FIELD TASK PICTURES



The Aerobic Power Test



The Anaerobic Power Test (leg)



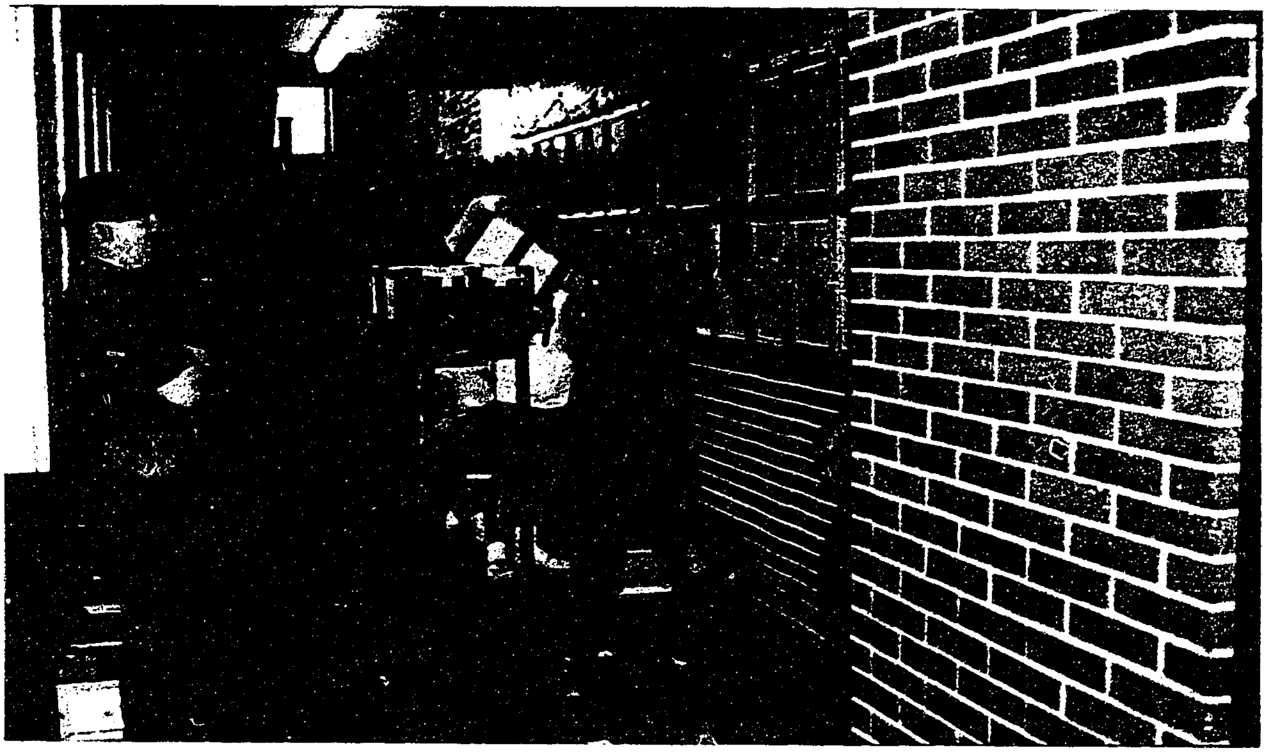
The Anaerobic Power Test (arm)

Blood Sampling

The Slit Trench Simulator for Digging Tasks

Casualty Evacuation

Gas Tank Simulator Table for Jerry Can Tasks



Ammunition Box Lift

APPENDIX G

EXPERT OPINION

DISCUSSION WITH SPECIALISTS IN THE FIELD OF PHYSICAL FITNESS AND PHYSICAL PERFORMANCE ON THE APPROACH BEING USED IN THE DEVELOPMENT OF PHYSICAL FITNESS AND PERFORMANCE STANDARDS FOR THE CANADIAN ARMY

DR SAFRIT - UNIVERSITY OF WISCONSIN - OCTOBER 25, 1989

Standards setting is moving in the direction of item response theory. However, programs to analyse the data under this model are still in the developmental stages as programs are presently not capable of dealing with polychotomous data. Dr Berk's approach is still being used as the approach to setting standards.

DR CURETON - UNIVERSITY OF GEORGIA - OCTOBER 30, 1989

He indicated that he is not involved in the statistical end of standard setting but that the approach we are proposing sounds more sophisticated than the current approaches he is aware of

DR SHARKY - UNIVERSITY OF MONTANA/US FOREST SERVICE - NOVEMBER 03, 89

In the courts of law the most acceptable criteria are not lab tests but field tests. He could not find fault with our approach including the sampling procedure. He recommended that if an individual does not complete the task, add on the extra time it would have taken them to complete the task. He indicated that he would like to become involved in the project.

DR IRA JACOBS - DEFENCE CIVIL INSTITUTE OF ENVIRONMENTAL MEDICINE NOVEMBER 30, 89

Generally, he was most impressed with the thought and organization that has gone into the proposal. He feels that the project will undoubtedly yield valuable results that will be immediately applicable by DPERA and the Army and the Canadian Forces .

DR JAMES VOGEL - DIRECTOR UNITED STATES ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE (USARIEM) - SEPTEMBER 14, 89

In spite of the fact that USARIEM has done a great deal of work in this area, he feels that our approach is much, much, much more elegant.

DR JOHN PATTON - RESEARCH SCIENTIST USARIEM - NOVEMBER 7, 1989

He knows of no other organization that is doing work in this area and feels our current approach is state of the art.

DR MAQUIRE AND DR RODGER - UNIVERSITY OF ALBERTA UNIVERSITY OF ALBERTA

Continuing discussions on the efficacy of our current sampling approach.