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Strength, Body Composition, Image and Performance Capacity of Women Soldiers

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled STRENGTH, BODY COMPOSITION, IMAGE AND PERFORMANCE CAPACITY OF WOMEN SOLDIERS submitted by MARGARET ANN MACKAY OSEEN in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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DEDICATION

This doctoral dissertation is dedicated to my daughter, Nicole Ritchie-Oseen and my husband, John Ritchie, who through their love, encouragement and steadfast support helped "stay my course" and enabled me to finish what seemed at times an onerous task.

Also, I dedicate this thesis to my two sisters, Collette and Lennea and my friend, Marcia Langenberg who through "thick and thin" have provided love, succour and the not to be denied strategy, women, working the "double shift", require.

Last, but not least, I dedicate this thesis with love, admiration and gratitude to my mother, Harley Katherine Gillmore Oseen, who as parent, teacher and mentor inspired me to appreciate the worthiness and richness of learning, discovery and wonderment.

ABSTRACT

The objectives of this study were to evaluate various physiological and psychological parameters of women in combat support and to investigate the relationship between these variables and work performance. Forty-five women, aged 19 to 36 years, volunteered to participate in the study. Muscular strength and endurance, body composition and body cathexes were evaluated. Questionnaires detailing physical activity, menstrual history, body weight and dieting practices were completed. The subjects performed 5 tasks: 16 km march, casualty evacuation, ammunition box lift, jerry can, and slit trench digging tasks.

Pearson Product Moment Correlations and Multiple Regressions were used to discern the relationship between the physiological and psychological parameters and the field task performance.

Statistical analysis demonstrated that the correlation between trunk flexion strength and the ammunition box lift was of sufficient magnitude to be predictive of performance. Other associated variables included age, chest and waist girths, waist/hip ratio, body weight, lean weight and femoral bone density. Psychological variables significantly affiliated with this task included posture, stamina and shoulders cathexes.

The relationship between the muscle strength and endurance measures and performance of the slit trench digging task was of insufficient strength to be predictive of performance. Bone density of the femoral neck, lean weight and amount of weight

lost and stamina, energy, muscle strength and body cathexes were significantly associated with this task.

Stepwise multiple regression demonstrated that static arm flexion endurance was predictive of performance of the jerry can task. The only demographic and psychological variable affiliated with this task was chest girth and hip cathexis, respectively.

The casualty evacuation task was significantly correlated with trunk extension. Multiple regression analysis showed that this relationship was of sufficient strength to be predictive of performance. Height, hip girth, percent body fat and fat weight were the demographic measures affiliated with this task. The psychological variables significantly associated with casualty evacuation were muscle and energy cathexes.

The relationship between the 16 km march and dynamic trunk flexion strength was of sufficient magnitude to be predictive of performance. The only demographic variable negatively associated with this task was weight lost over the past year.

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Also, I extend my appreciation to those individuals in the Canadian Armed Forces who deemed it important that women in combat support be included as participants in this study. Most importantly, however, I heartily acknowledge the contribution of those women volunteers who, having already braved the front of nontraditional work, have taken another sortie into hitherto a male domain.

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Chapter I

Statement of the Problem

A. Introduction

Over the past two decades women have been forming an increasing percentage of a physical labour workforce that has long been considered the purview of men. Recent human rights legislation has persuaded a number of organizations to redress previous imbalances in several job categories. Among these groups is the Canadian army which has recently adopted the mandate of the American and European Armed Forces. Their ideology suggests that an individual, if capable of performing a particular job, should not be discriminated against simply on the basis of gender.

As of February, 1989 the Human Rights Tribunal reclassified all trades and occupations and hence women theoretically were accorded the right to participate in all three categories of combat: infantry, armory and artillery. However, according to an official from the Princess Patricia Training School in Wainwright, Alberta, the passing rate for women recruits is dismal - only one out of 93 women who have participated in the combat training school has successfully met all the requirements. The particular characteristic typifying this successful candidate, in the estimation of this official, is that she apparently drove a logging truck for two years prior to entering the armed forces training school. He opines that women are unsuccessful in their bid to attain combat status because of insufficient motivation and lack of endurance and muscle strength - particularly upper body strength.

The Canadian Armed Forces have instituted a minimum standard physical training and testing regime for its members. However, what is being considered now is the relationship between certain physical fitness parameters and the ability to perform a certain task. For example, what are the minimal strength requirements to lift, carry and empty a jerry can repetitively, and similarly what strength is necessary to lift loaded boxes up onto a truck bed? Furthermore, are these strength requirements modified by practice and skill aquisition, even in these simple tasks?

Not only is muscular strength and endurance a consideration in the ability to perform this type of work, but concomitantly so is the structural integrity of the skeleton. Research shows that those individuals who engage in repetitive activities such as running or marching are subject to developing stress fractures (Jones et al. 1991; Reynolds et al. 1991; Matheson et al. 1987; Orava et al. 1978). Because there exists a relationship between muscle mass and bone mass, the individual who is characterized as predominantly mesomorphic is possibly at a lower risk of developing a stress fracture. However, Jones et al. (1991) in a study of the incidence of training injuries in a group of 124 male and 186 female recruits contended that those individuals, irrespective of gender, who are more aerobically fit are less likely to develop stress fractures.

The relationship between bone mass and muscle strength is not clear cut. In order to best accomplish tasks which require muscular strength, those individuals who have a preponderance of lean body mass possibly have an advantage over the person who is less well endowed. Similarly these muscular individuals may be less likely to compromise the structural integrity of their skeletons (Martin & McColloch, 1987). Furthermore, it is reported that a small frame and low body mass index is one of the risk factors for developing osteoporosis and its associated clinical manifestations in later years.

Notwithstanding the benefits accrued from a muscular body and a large frame, it is important to consider perception of body image. To subscribe to the prevalent cultural image of the small, diminutive woman, who is said to evoke male protectiveness, is antithetical to the actual body type of the individual who would most likely succeed in accomplishing tasks which require stamina and strength. Furthermore, it is unknown if women in the combat support group of the Canadian Armed Forces have a similar perception of body image as do women in other fields? Lastly, the current lack of success of women in the Canadian Armed Forces in achieving their goal of combat status has stimulated further study to dilineate the factors that may contribute to their success, as well as potentially isolating elements that would allow a greater percentage of women to successfully achieve their goal.

B. Purpose of the Study

The objectives of this study were to evaluate various physiological (including body composition and muscular strength and endurance measures) and psychological parameters (as detailed in the Body Cathexis Scale) of women in combat support and to investigate the relationship between these parameters and their work performance. This study was part of a larger project which was designed to develop physical performance standards for the Canadian Army.

C. Significance of the Study

Increasing numbers of women are entering occupations that were previously considered the purview of men. Some of these jobs, like many of those in the military, entail physical tasks which require strength of the musculoskeletal system. Women have been, and continue to be, prejudiced against because of the common perception that they do not have sufficient strength to accomplish the requisite job (Punnet,1988; Brunt & Hricko,1983). Hence, this is an investigation of some of the physiological parameters that may help to identify an individual, regardless of gender, who is capable of performing a variety of physically demanding jobs, which may be characteristic of army personnel.

D. Definition of Terms

Wolff's Law

Wolff's Law states that the internal architecture and external shape of bones are altered by the stresses applied to them.

Task

A task is defined as the work to be undertaken. In this study, for example, a task involved digging 0.5 cubic meters of gravel, or lifting a 20 kg box from the floor to a 1.3 meter high bench.

Weight Load March

A soldier, in full fighting order, carrying a pack weighing 24.5 kg, was to march a distance of 16 km at a rate of 5.33 km/h.

Casualty Evacuation

A soldier, using the "fireman's carry", was to evacuate an individual of her approximate body weight and height a distance of a 100 m. Each subject was instructed to exert maximal effort.

Maximal Effort Digging Task

A soldier was to dig 0.5 cubic meters of gravel from one slit trench simulator (1.8m x 0.6m x 0.45m) into another as quickly as possible.

Submaximal Effort Digging Task

Each soldier was to follow the previously described protocol at the moderated pace of 70% V02 max.

Maximal Effort Jerry Can Task

A soldier was to carry a jerry can, filled with water and weighing 35 kg, a distance of 35 m and to empty this jerry can into a funnel located at a height of 1.3 m. This process was to be repeated over three shuttle runs.

Ammunition Box Lift Task

A soldier was to lift a 20 kg ammunition box from the floor and place it on a 1.3 m high bench. In total, forty-eight ammunition boxes were lifted. Each subject was instructed to moderate effort so that they were working at approximately 70% V02 max.

E. Null Hypotheses

The following hypotheses were tested at the .05 level of significance.

* There will be no significant relationship between muscle strength and endurance and bone density,
* There will be no significant relationship between the questionnaires detailing childhood and adolescent physical activity and bone density,
* There will be no significant relationship between the menstrual history questionnaires and bone density,
* There will be no significant relationship between the laboratory measures and the field tasks.

F. Assumptions

The experimental population, which consisted of a group of 45 women from combat support who volunteered to participate in the study, likely represented a biased sample.

G. Limitations

* The women on the base comprised a group known as combat support, so unlike their male counterparts, they were unaccustomed to the field tasks as designated by the Canadian Armed Forces.
* Whereas 120 men were selected by the army, only forty-five women participated in the study. This effectively limits the power of this study and hence the external validity.
* The women participated alongside the men in both the field and laboratory tests. The subject's response was probably affected depending on how comfortable they felt in the testing environment.

H. Delimitations

Conclusions were delimited to women in the combat support group of the Canadian Armed Forces. The sample included women who reflected all levels of fitness. Furthermore, the women represented various occupations. The study group included women who not only worked as mechanics and in stores and thus could be classified as material handlers engaging in "medium to heavy work", but also those who were employed in the "light work" capacity of a secretary, pharmacist, or nurse.

Chapter II

Review of the Literature

A. Introduction

Physical Activity and its Effect on Bone

From the mid 1960's, when Issekutz et al. (1965) noted the effects of immobilization on bone as measured by urinary calcium excretion after prolonged bed rest, to the notable findings of Mack, La Chance and Vose who studied the bone demineralization of the foot and hand of Gemini-Titan IV, V, and VIII astronauts during orbital flights in 1967, the vital role of exercise in maintaining skeletal health has been confirmed (Bailey et al. 1988; Martin et al. 1987; Aloia,1981). However, universal agreement remains somewhat elusive about the exact mechanism of action and thus the most beneficial form of exercise. What is recognized, with incredulity, is that bone growth proceeds rapidly in the fetus which is suspended in a sea of amniotic fluid (Aloia,1981). Movement is essential for normal bone and joint growth and this occurs in the fetus from very early on. However calcium deposition and progression of bone density is more dramatic during postnatal life.

Most researchers (Bilanin et al. 1989; Shephard, 1989; Margulies et al.1988; Hedayati & Zuzga 1988; Martin & McColloch 1987; Riggs & Melton,1986), but not all (Swissa-Sivan et al. 1989), maintained that weightbearing is an essential ingredient for stimulating bone accretion. Others indicated that gravitational forces are only part of the equation. For instance, paraplegics or polio victims who have been placed in upright positions, still experience depletion of their bone mass, lending support to the concept that muscular action is also a necessary requirement in maintaining the integrity of the skeleton (Schoutens et al. 1989). Swissa-Sivan et al. (1989) did not agree that exercise, without a weightbearing component, will not enhance bone mass. They showed that when rats were trained to swim one hour daily, five times a week for a period of 4 months, bone mineral content was higher in these animals than a group of controls. He suggested that in other animal studies where running has been employed twice a day with a deleterious impact on bone, (Kiiskinen & Heikkinen, 1978) the training regime has been too vigorous. They reported that the forces on limbs during running at any given time can be anywhere from 6-12 times body weight. Their model allowed them to study the effect of muscular action on bone density independently. The buoyancy factor of the water mostly mitigates gravitational forces.

B. The Relationship between Bone Mass, Muscle Mass and Muscle Strength

A direct relationship exists between bone mass and muscle mass (Ellis & Cohn, 1975). This bone/muscle mass connection was recognized by an insightful scientist, Wolff, as early as 1892 (Schapira, 1988; Martin, 1987). Bone responds to the mechanical stresses imposed upon it (Schapira, 1988; Martin, 1987; Ellis & Cohn, 1975). Riggs et al. (1986) declared that muscle contraction and loadbearing stimulated osteoblast activity.

The reaction of bone mass and its internal architecture to mechanical load is one of hypertrophy and reorganization in order to reduce the strain to an optimal level (Martin & McColloch, 1987). Several authors (Burr et al. 1989; Gordon et al. 1989; and Marguelies et al. 1986) have reported on the varying levels of strain exerted on bone and its effect on bone tissue kinetics in both human and animal models. Lanyon's classical work in 1984 showed the effect of repetitive, cyclic strains on an avian model. The optimal dynamic load in this particular example proved to be the 36 cycle protocol which enhanced bone formation by some 40%. Cycles up to 360 or even 1800 per day did not improve upon this level of bone accretion. Alternatively only 4 cycles a day was sufficient to prevent bone loss.

Some authors (Smith, 1988; Lanyon & Rubin, 1984; Hert et al. 1971) concurred that whereas dynamic loads enhanced bone accretion, static loads did not appear to have this same kind of salubrious effect. When static as opposed to dynamic load was implemented by Hert et al.(1971) in their rabbit models, no bone remodelling occurred. Lanyon & Rubin (1984) showed that while bone hypertrophied as a result of dynamic loading, it did not respond similarly to an isometric force of the same magnitude. Smith (1988) contended that this principle is reflected by tennis players who tend to show hypertrophied bone in the humerus which is dynamically loaded but not in the ulnar or radius which is statically loaded.

Physical activity enhances bone formation in the limbs of ungulates where studies show a decrease in bone mineral content in the ribs and antlers of deer but not in the forelegs and hind legs of these animals (Yeater & Martin, 1984). Trabecular bone density was shown to increase in the femoral neck of sheep that walked on concrete versus sheep that spent their lives in pastures (Radin et al. 1982). Gordon et al. (1989) documented benefits accrued to the bone of mice femora dependent on the type of exercise regimen. High intensity, short duration loads enhanced the internal structure of trabecular bone whereas lower intensity, chronic exercise improved cortical cross sectional area by 27%. Both regimens improved the breaking strength of the femur by 64% in comparison to controls.

What remains elusive is how these loads signal changes to be wrought in the bone cell itself (Schapira, 1988; Martin & McColloch, 1987; Smith, 1985). Evidence (Martin & McColloch, 1987; Editorial, **The Lancet**, 1983; Aloia, 1981) suggests that muscular action augments bone formation through piezo electrical activity in the hydroxyapatite crystals. The bone itself acts as a transducer (Schapira,1988). Reid (personal communication; 1991) suggested that it is more likely the micro-movement of the bone and hence collagen with its multiple charged side chains which direct calcium deposition.

Bone responds to altered environments through processes of both modelling and remodelling (Mosekilde & Viidik, 1989; Burr et al. 1989). Mosekilde & Vidiik (1989) emphasized that these are two very distinct events. Modelling enhances active formation of bone in response to altered mechanical load. In remodelling, the osteoclasts resorb bone; that is they dig a trench in bone and it is this trench or concave area of bone where new bone matrix is deposited (Smith, 1988). Bone resorption and formation can occur continuously as osteoblasts and osteoclasts evoke alterations independently of each other.

Equated with the modelling process is peak bone mass, which is said to attain maximum levels somewhere in the mid-twenties for both women and men (Mosekilde & Viidik, 1989). McColloch et al. (1988) and Stevenson et al. (1989) maintained that bone mass reaches its peak following the cessation of linear growth and Marguelies et al. (1986) opined that bone continues to be amassed, reaching maximum values somewhere in the period between 30 and 50 years of age. Researchers (Martin & Houston, 1987; Marguelies et al.1986; Talmage & Anderson, 1984; Nilsson & Westlin, 1971) agreed that peak bone mass is augmented through a program of physical activity, preferentially one involving loadbearing.

Following the attainment of peak bone mass, an age related decline in bone is initiated. Unlike bone formation where osteoblasts and osteoclasts evoked alterations in bone independently of each other in time and space, in bone resorption these two distinct types of cells are tightly linked (Mosekilde & Vidiik, 1989; Smith, 1985). Osteoclasts dig a trench in the surface of the bone to a depth of 50-60 mm. Osteoblasts fill this trench, but in the process each time a small amount of bone is lost.

Although there is this depletion of bone mass and muscle mass as we age, the ratio of total body calcium to total body potassium remains fairly constant throughout life (Aloia, 1981; Cohn, 1977). Doyle et al. (1970) showed in an anatomical study that the ash weight of the third lumbar vertebrae was related to the weight of the left psoas muscle. He suggested that the weight of the muscle was a reflection of the force applied to the bone and consequently muscle weight positively influenced bone accretion.

Cohn et al. (1977) speculated on the impact of racial differences on bone mass. He showed that black women in the U.S. experienced a lower prevalence of osteoporosis and subsequent fractures compared to Caucasian women. He attributed this to their larger skeletal and muscular mass.

Another researcher, Cooper et al. (1989) also showed that a group of blacks, the South African Bantu, display a much lower incidence of osteoporotic hip fractures than do their white counterparts. More recently, Sparling et al. (1991) identified 100 black women, aged 18 to 38, as more mesomorphic than a group of similarly aged Caucasian women. The methods employed by this group of researchers to determine body composition and build were hydrostatic weighing and somatotyping. Sparling et al.(1991), Cooper et al. (1989), Aloia (1981) and Cohn (1977) speculated that the greater muscle mass in the black population could be attributable, at least in part, to a greater degree of physical activity.

In conjunction to racial differences, authors Aloia (1981) and Cohn (1977) reported that for a given amount of muscle mass, women reflect 20% less bone mass than do men. Mosekilde and Viidik (1989) and Mazess (1982) declared that bone mass was 30 to 40% lower in young women compared to young men. However, whereas Mazess (1982) stated that bone density was 15% lower in women compared to men, Riggs et al. (1986) found that in young adults vertebral densities were the same, regardless of gender.

Given that there are individual variations in amount of bone in the skeleton, bone mass, at least in younger individuals, appears to diminish in a similar fashion in both sexes. However, according to Plunkett & Gold (1991) the bone loss seen in women is differentiated from that seen in men by not only the total amount of bone that is lost but also the rate at which that bone is diminished-particularly around menopause. In general, men who are eighty years old may reflect a bone loss of some 14% in contrast to women in this age group who show bone losses of 47% (Plunkett & Gold, 1991).

Cortical bone, which comprises approximately 80% of the skeleton, (Bilanin et al. 1989), begins to deplete around the fourth decade of life whereas trabecular bone (20% of the skeleton) is said to be lost a decade earlier (Mazess,1982). Some authors, (Mosekilde & Viidik, 1989; Riggs et al. 1986), alleged that this diminution of trabecular bone occurs earlier. Riggs et al. (1986) stated that based on anatomical studies, trabecular bone depletion is initiated in young adulthood. He further reported that approximately 50% of vertebral bone is lost in the postmenopausal period. Mosekilde & Viidik (1989) contended that trabecular bone loss with age occurs in an identical fashion in both women and men.

Whereas trabecular bone mass diminishes by approximately half in the time spanning twenty to eighty years, trabecular bone strength is lessened by as much as 80% over the same period (Mosekilde & Viidik, 1989). Mazess (1982) suggested that the current body of knowledge supports the conclusion that trabecular density begins to decline in early adulthood (i.e. age 20 to 40) regardless of gender. The decrement in trabecular bone density amounts to 6 to 8% per decade following this earlier diminution. In addition, as indicated by Mazess (1982), trabecular bone is particularly responsive to a decrement in physical activity.

In contrast, cortical bone, which tends to be lost in a later period of life (age 40+), represents a greater contribution (greater than 50%) to the bone strength (Mazess,1982).

This researcher reported that the strength of a bone is directly related to its mass and internal architecture. Thus, those individuals with a larger skeletal frame, i.e. larger bones, have a significant advantage over the smaller boned individual.

When weight and height were examined as factors influencing skeletal strength, it was found by Elders et al. (1989) that vertebral mineral density was related to body weight in postmenopausal women. Stevenson et al. (1989) agreed that body weight was positively related to vertebral bone density but only in postmenopausal women. In the premenopausal category no relationship between bone density and weight was established. However, in the younger group of women, height was correlated with vertebral bone density.

Cooper et al. (1989) asserted that bone mass is a primary constituent of bone strength. While he maintained that there is no correlation between the density of bone and its compressive strength, other factors affect the bone mass strength relationship. He cited these as fatigue, derangement of internal architecture, age changes and osteoid accumulation. He concluded that a difference in bone mass accounts for about half of the variation in bone strength. Mazess (1982) stated unequivocally that 80% of the variance in the compressive strength of trabecular bone and 90% of the variance in compact bone is associated with bone mass.

C. Physical Activity and Its Effect in Counteracting Bone Loss

Numerous authors (Cooper, 1989; Mosekilde & Viidik, 1989; Ross et al. 1989; Stevenson et al. 1989; Francis et al. 1988; Hedayati & Zuzga, 1988; McColloch, 1987; Riggs & Melton, 1986; Walker,1972) imputed low physical activity as a significant contributor to the loss of bone. In 1971, Nilsson & Westlin reported that bone density in athletes was enhanced through the application of dynamic mechanical loads to the skeleton. Throwers, weight lifters, and top rank athletes evinced both pronounced quadriceps force and high bone densities. An editorial writer (Anonymous, **The Lancet**, 1983) declared that this increment in bone mass in athletes was directly proportional to the stress imposed upon the limbs by the sport. Nilsson and Westlin (1971) speculated that moderate physical acitivity may elicit positive changes in bone mass.

Interestingly, although Japanese women reflect lower bone mineral content than do their Caucasian counterparts, they still, as a group, do not reflect the same high incidenct of femoral neck fractures. As reported by Norimatsu et al. (1988) the fracture rate of Japanese women was one half to one third that of American women. The authors imputed these significant differences to variations in lifestyle, explaining that the Japanese have homes furnished not with chairs, but tatami (woven mats) on the floor upon which they kneel and arise frequently over the course of a day. Moreover, while 52% of the American population own cars, onl 20% of the Japanese own a vehicle (Norimatsu et al. 1988).

Talmage and Anderson (1984) who looked at the bone density of a group of 1200 women aged 19-98 in a cross sectional study indicated that women who were active in secondary school athletics or participated in farm chores as they were growing up, reflected higher bone densities at age 25. They emphasized that women who engage in regular exercise during adolescence, as well as maintaining this activity regime, reflected denser bones than those who did not engage in such pastimes.

Similarly, McColloch's et al. (1988) and Bailey's et al. (1988) evaluation of the effect of lifestyle on bone density as measured in the os calcis of 500 young, Saskatchewan women aged 20-35 years showed that physical activity undertaken during adolescence significantly affected bone density. Calcium intake, irrespective of high, medium or low values did not affect bone density readings in this particular age group. Nor did other independent variables such as smoking, caffeine ingestion, use of the birth control pill or vocational physical activity. They concluded that exercise undertaken during the growth years is a central factor influencing bone density in young women.

Whereas most authors recognized that exercise enhances bone density, Stevenson et al. (1989) in a study of 284 British women, aged 21-68 years, found no positive benefit to bone density accrued through the intake of calcium, or participation in regular exercise-the type of exercise was not specified. However they did concede that others (Kanders et al. 1988) have found a positive effect on skeletal mass in premenopausal women dependent on calcium intake and physical activity.

An editorial writer (Anonymous) in **The Lancet** (1983) suggested that the relationship between physical activity and bone density is subject to criticism because it is difficult to quantitate physical activity. Also, it is difficult to measure bone density. However, the author of **The Lancet** article argued that, in comparison to other treatments for loss of bone mass, exercise is a benign one and hence should be pursued with some vigour.

Marguelies et al. (1986) examined the effect of a rigorous physical training program for 14 weeks undertaken by 268 male recruits, age 18 to 21 years and assessed the impact of this regime on the bone mineral content of the right and left tibia. They found increments of bone mineral content of 11.5% in the left leg and 5.2% in the right leg of those recruits who were able to complete the program. They could offer no explanation to account for the differences in the right and left lower extremities. They suggested that the rate of change in bone accretion in a relatively short period of time was due to the high intensity of the program in terms of loading as well as the number of repetitions and maturity of the bone. Marguelies et al. (1986) indicated that those sporting activities which entail substantial loading on the lower extremities result in an increase of bone mass.

Westlin and Nordin (1971) found that athletes, age 20 to 25 years, reflected significantly higher bone mineral content in the distal portion of the femur than did a group of controls. Nilson and Anderson (1978) showed that in ballet dancers the proximal end of the tibia showed higher than normal bone mineral content. Notwithstanding these findings, Reid (1989) reported that ballerinas have 77% of the weight predicted norms for lower limb strength and reflect values that are lower than other athletic populations. He contended that while stress fractures of the femur do not constitute a major problem in the dancers, clinicians should not rule out the possibility, as the result of failure to diagnose this problem may result in a debilitating complete fracture.

Schoutens et al. (1989) argued that whereas muscular strength is more readily measured versus muscle mass, there is not as clear-cut a relationship between muscle strength and bone mass. However, Senaki et al. (1986) found that the bone mineral density of the lumbar vertebrae was correlated to the back extensor strength of 68 women aged 49 to 65 years. Schoutens et al. (1989) reported, that in a group of twenty 19 year old students, bone mass of the femur and vertebrae were correlated to quadriceps strength. In contrast, Nordin and Westlin (1971) depicted no correlation between the strength of the quadriceps and bone density of the distal end of the femur in a 103 athletes.

Martin and Houston (1987) averred that rather than an overall effect, which is reflected in compressive loading, muscle tension exerted a local effect. Like Nordin and Westlin (1971), Martin and Houston (1987) substantiated that high degrees of physical activity are affiliated with enhanced bone mass. They, as well as Aloia (1981), commented that exercise which enhances bone mass of the axial skeleton should be determined. They suggested that the ideal exercise mode is unlike the usual endurance routine the recreational enthusiasts engage in.

Martin and Houston (1987) were unequivocal in their assertion that exercise must be weightbearing, although others (Swissa-Sivan et al. 1989) disputed this. Swissa-Sivan et al. (1989) showed that when they induced 20 rats to swim 5 days a week for 1 hour per day over a period of 4 months that bone was amassed and attributed this phenomena to the effect of pulling forces, moments and torques applied to bone by muscle contractions. From the data derived from Nordin and Westlin (1971) the bone density of swimmers was not distinguishable from that of nonathletic controls.

Researchers (Gordon et al. 1989; Martin & McColloch, 1987; Martin & Houston, 1987) recommended that a bone enhancing exercise protocol should involve activities that not only reflect a variety of loading situations but similarly entail optimal strain rates. Three groups, weight trainers, body builders, and football players integrate these principles in their training programs and it is speculated that this partially explains why these participants tend to evince such healthy bone densities. Several authors (Martin & McColloch, 1987; Schoutens et al. 1989) emphasized that the most favourable gains in bone mass and cross sectional area are accrued through activity with high loading but few repetitions. In a similar fashion, where muscle mass is hypertrophied by applying significant loads to the various muscle groups, so in turn, does bone respond positively to loads from various directions (Martin & McColloch,1987). Hence endurance training will not result in the substantial accretion in bone mass that will occur with activities such as weight training.

In contrast to Aloia's et al. (1978) findings where they reported that bone mineral content was non-significantly elevated in 30 marathon runners, Bilanin et al. (1989) found that the bone mineral content in vertebrae was actually reduced in their group of male marathon runners. Conversely, other researchers (Brewer et al. 1983) showed that bone density increased in the middle phalanx of the fifth finger and of the mid shaft of the radius in a group of 30 to 49 year old premenopausal women who had been involved in a running program for 24 months. They reported that trabecular bone in the os calcis and in the distal radius was not affected.

Trabecular bone seems to be a sensitive barometer of physical activity. Moderate levels of exercise appear to enhance bone density; conversely, extreme endurance activities - represented as such by marathon training appear to deplete trabecular bone. This alteration in trabecular bone is due not only to the imposed stresses induced by marathon running but are also due to an altered endocrine status. Other authors are in agreement- Martin & McColloch (1987) attributed this diminution in bone mineral content to a lack of loading of bone in a variety of directions. Bilanin et al. (1989) ascribed lowered bone mineral content in vertebrae to an altered hormonal milieu.

A load force limited in only one direction will affect the bone strength so that its response is directional as well. In other words, the bone is protected in that one particular direction because its strength is directional, but the bone may be subject to undue stresses from opposing directions (Martin & McColloch, 1987; Aloia, 1981).

D. Effects of Intense Physical Exercise and the Possible Ramifications on Bone

While it was recognized by the work of Drinkwater et al. and Cann et al. in 1984 that some women subjected to extremely rigorous exercise programs could become amenorrheic, and hence suffer from bone mineral depletion especially in the axial skeleton, it was not until 1986 that MacConnie et al. found that male endurance athletes could suffer from the same phenomena of hypogonadotrophic hypogonadism. Later, in 1989, Bilanin et al. reported that male long distance runners reflected vertebral bone densities that were significantly lower (9.7% less) than a group of non-running controls. These differences persisted even when age, height and weight were controlled. The body weight of the runners was not significantly different from that of the sedentary controls. Bilanin et al. (1989) stated that the bone mineral densities of the vertebrae of these male runners was similar to the vertebral bone densities found in amenorrheic runners. Drinkwater et al. (1984) alleged that the distance ran was a crucial variable affecting hormonal status and thereby, in turn, vertebral bone density. In their study, women, who were amenorrheic, ran a significantly greater number of miles than a group of runners who were classified as eumenorrheic (41.8 versus 24.9 miles per week). In a later study (1986), Drinkwater et al. showed that if previously amenorrheic runners modified their exercise program, their pronounced lower vertebral bone densities could be reversed. Through modification of a training program, weight gain and a resumption of menstruation, six of the seven previously amenorrheic runners evinced a significant increase in vertebral bone density. The authors indicated that they expect these effects to be interactive rather than one variable being causative. Interestingly, one of the runners, when tested, remained amenorrheic yet still evinced bone mineral densities significantly above that of regularly menstruating athletes. She had suffered from amenorrhea for five and a half years and reflected a peak estrogen level of 32 pg/ml (versus 211 pg/ml in normals) indicating that amenorrhea, by itself, is not responsible for decrements in bone density.

Marcus et al. (1985) examined the vertebral bone density in seventeen women who ran over 64.4 km per week. Of the eleven who were characterized by low estrogen levels and amenorrhea, vertebral bone densities were significantly lower than a group of non-athletic controls. Moreover, amenorrheic runners also suffered from a higher incidence of stress fractures. In comparison, normally menstruating runners reflected vertebral bone densities which were higher than normative values.

Heath (1985) stressed that the intensity of the activity appears to be more critical than the actual type of exercise undertaken. Hall (1985) pointed out that in those young women who were characterized by suppressed levels of estrogen, risk level of compromising skeletal integrity increased. Shephard (1989) reported that in middle age, long distance runners were more subject to stress fractures in spite of a calcium intake that was four to five times the recommended level.

While authors (Shephard, 1989; Hedayati & Zuzga, 1988; Schapira, 1988; Riggs & Melton, 1986; Smith, 1985) concurred that moderate levels of activity conferred benefits to bone, intense physical activity, in both genders, appears to be detrimental to skeletal health. Shephard (1989) suggested that there appears to be a maximum strain somewhere around fifty to sixty kilometers of jogging per week, beyond which the incidence of stress fractures rises sharply. Swissa-Sivan et al. (1989) reported that the forces exerted on lower limbs while running are on the order of six to twelve times body weight.

While intensive exercise appears to compromise the integrity of bone, researchers have found differences in the type of bone affected. Drinkwater et al. (1984) recounted that trabecular bone, as represented by vertebrae (L2-L4) was diminished but cortical bone in the radius was unaffected. In contrast, Lindberg et al. (1984) found that both types of bone, trabecular and cortical, were adversely affected in the amenorrheic runner. These researchers indicated that stress fractures were a problem for 50% of the amenorrheic runners in this study compared to no incidence of fractures in the control group or normally menstruating athletes.

Others (Shephard, 1989; Riggs & Easteil, 1986; Marcus et al. 1985) have found similar fracture rate occurrences in their amenorrheic subjects. Heath (1985) suggested that this lower bone density had a deleterious effect on skeletal integrity in the amenorrheic runner. He concluded that based on the findings of several researchers (Marcus et al. 1985; Drinkwater et al. 1984 and Lindberg et al. 1984), the women typified as amenorrheic were suffering from relative poverty of bone (osteopenia).

One of the central questions that researchers are pondering is: What are the long term effects on bone after an athletic career that involves highly intensive exercise and perhaps a prolonged period of amenorrhea? Drinkwater et al. (1986) showed that with a modification of training, some weight gain and a resumption of menstruation, bone mineral density, in previously amenorrheic runners, increased significantly. This alteration occurred over a time span of fifteen and a half months.

Rigotti et al. (1984) confirmed that in a group of eighteen anoretic women, those who averred that they had a high participation rate in an exercise program also reflected a higher bone density than did those who were inactive. Various factors, such as differences in age, weight and serum estradiol levels, could not account for the variance in bone density between the two groups. Hence the authors concluded that high level exercise confers a protective advantage to the skeleton of, in this instance, anoretic women.

Other authors (Mack, LaChance & Vose, 1976; and Issekutz et al. 1965) observed that bone regain after bone diminution which occurred during immobilization, took longer than expected - certainly a longer period of time than it took for the bone to be lost. Moreover, although bone density was improved, it was still inferior compared to its initial level.

E. Etiology of Stress Fractures

Orava et al. (1978) stated that stress fractures are attributed to an imbalance between the strain or load applied to the bone and the strength of the musculoskeletal tissues. Matheson et al. (1987) attributed stress fractures, which they claim should be properly titled "bone strain" (as it is load applied to the bone), to muscular weakness which compromises the shock absorption ability of the lower extremity. The force is then transmitted along various focal points of the bone. The other theory, they discuss, is that the repetitive force induced through muscle pull across a bone is sufficient to cause a stress fracture. They agreed that both mechanisms may operate to cause a stress fracture, although the etiology remains a conundrum.

Stress Fractures: a Reflection of a Compromised Skeleton

It was the German army physician, Breihaupt, who in 1855 identified stress fractures in soldiers (Orava, 1978). Many years elapsed before stress fractures were recognized in the athletic population (Matheson et al. 1987). Veterinarians were also cognizant of the problem of stress fractures that can occur in both the greyhound and the race horse. Interestingly, veterinarians recognize that stress fractures are prone to occur during the last lap of the race, when the bone is often no longer able to accomodate the strain imposed upon it.

For those individuals, regardless of military or athletic pursuits, who undergo a rigorous training procedure, some will be afflicted by one or several stress fractures. In an editorial published in **The Lancet** (Anonymous,1986) the author stated that the army training procedures seem calculated to induce as many stress fractures as possible. Stress fractures in a military population have been reported by numerous authors (Pouilles et al. 1989; Giladi et al. 1987; Martin & McColloch, 1987; Milgrom et al. 1985; Giladi et al.1984; Greaney et al. 1983; Orava et al. 1978; Darby, 1967).

Pouilles et al. (1989) in a study of 41 military recruits showed that the bone density level of those with one or more stress fractures was significantly lower than in a control group of 48 military recruits matched for age, height, and weight. Although stress fractures occurred in various locations - femur,calcaneus, fibula,tibia and metatarsus, bone mineral content was only significantly reduced in those who suffered from stress fractures of the calcaneus and femur.

Greaney et al. (1983) discussed scintigraphic abnormalities that could be interpreted as stress induced changes to the bone in a group of 250 Marine recruits, mean age 20.25 years. The scintigraphic abnormalities were primarily evidenced in trabecular bone (77%) versus cortical bone (23%). The deleterious effect was only slightly more noticeable in the leg (51%) than in the foot (49%). Matheson et al. (1987) reported that the so called "tibial stress syndrome" is a distinct entity from the clinically diagnosed stress fracture. They asserted that although the stress syndrome via biopsy may entail inflammation, vasculitis and periosteal new bone, the bone scan remains negative.

Over the period of 9 weeks of intensive training in the Greaney et al. (1983) study, the fracture total was highest during the initial two weeks. The protective effect of moderate exercise was appreciated when it was noted that those recruits who had a prior history of long distance running (one mile/day; 4 days/week or more) reflected a significantly lower number of stress fractures than those who did not engage in similar, previous activity. Other researchers have likewise emphasized the link between previous sports participation and reduced likelihood of sustaining a stress fracture (Orava et al. 1978).

The most frequently stressed bone in the study by Greaney et al. (1983) and Matheson et al.(1987) was the tibia, specifically the primarily weight bearing medial proximal condyle. In the foot, the most afflicted bone was the posterior tuberosity of the calcaneus. The authors stated that the metatarsals were also significantly affected, but did not display the classic "march" fracture that usually typifies the soldier who marches long distances wearing combat boots (Greaney et al. 1983).

Various authors have speculated about the factors which might precipitate a stress fracture in a particular individual. Giladi et al. (1987) identified tibial bone width as being significantly related to the possibility of sustaining a stress fracture either in the femur or in the tibia. They reported that whereas cortical thickness did not influence this risk, a narrow tibial width was a significant contributor. Certainly bone mass has been implicated as a variable affecting the possibility of developing a stress fracture.

Brudvig et al.(1983) showed that black soldiers had a lower prevalence of stress fractures compared to white soldiers. In a similar vein, they reported that women in the army have a 5 to 10 times higher prevalence of stress fractures than do army men. The training program was ostensibly the same for both groups. In an earlier study, Protzman and Griffis (1977) found the same high incidence of stress fractures in female soldiers versus male subjects. Again both groups underwent similar training regimes. However in a study by Jones et al. (1991) where 124 male and female recruits were studied over an eight week basic training regime, the lack of weight bearing aerobic fitness accounted for the difference in stress fracture incidence.

Pouilles et al. (1989) characterized stress fractures as "insufficiency" fractures (diminished bone mass) or as "fatigue" fractures (increased bone strain). He detailed three variables affecting bone strength: bone mineral content, internal architecture and bone size. Pouilles et al. (1989) reported that their subjects reflected lower femoral bone mineral density than did a group of age matched controls. This higher incidence of stress fractures was also found in other than army populations who showed lower than normal readings for bone mineral density (Bilanin et al. 1989; Marcus et al. 1985; Lindberg et al. 1984). These authors reported that in approximately 50% of their subjects who were characterized as amenorrheic, their skeletal structure was compromised to the extent that they suffered from stress fractures in the lower extremities. While Reid (1989) reported that a stress fracture of the hip was not a common problem in ballet dancers generally, it can easily be overlooked - the danger being that these "silent" fractures could evolve into a displaced fracture with consequent disability (Milgrom et al. 1985). Reid (1989) accounted for the lowered incidence of hip stress fractures in dancers due to their gradually increasing activity and to their nonparticipation in repetitive exercises such as running. Furthermore, ballet dancers are highly trained athletes.

The incidence of stress fractures recorded in different armies around the world is variable. Brudvig et al. (1983) noted an incidence of approximately 2% in American recruits. In contrast, Milgrom et al. (1985) stated that 31% of an infantry group in the Israeli army were afflicted by stress fractures. Brudvig et al. (1983) also reported that women reflected a higher percentage of stress fractures (12%) than did a group of male recruits (2%) who were involved in the same training program. Whereas, Jones et al. (1991) indicated a 4.7 times higher incidence of stress fractures during basic training in the female recruits versus the male recruits, this difference could be accounted for by the variability in aerobic, weight bearing fitness. There is some speculation that the female recruits who suffer from stress fractures may be at a greater risk of developing osteoporosis in later years

(**The Lancet**, Anonymous, 1983). Physical training and fitness level are generally considered as fundamental for the preservation and/or enhancement of bone strength and hence the avoidance of the deleterious effects of osteoporosis.

Pouilles et al. (1989) stated that it is well known that strenuous physical activity can deplete bone mass, especially in women (Lindberg et al. 1984; Marcus et al.1985) but also in men (Bilanin et al. 1989). They emphasized the phenomeon of individual skeletal adaptation to stress, irrespective of gender.

Several authors (Milgrom et al. 1985; Giladi et al. 1984; Greaney et al. 1983) averred that stress fractures of the calcaneus are a particular problem for the Marines in the American army. This increased incidence of calcaneal stress fractures is related to the specific marching drills. They similarly stated that stress fractures of the metatarsus afflicts those in the navy.

In contrast, Giladi et al. (1984) reported that fractures of the calcaneus were not a problem in the Israeli Defence Force. They stated that 80-97% of the stress fractures in this group occurred in the femur and tibia. This high occurrence of stress fractures in this region could be attributed to running training over hard ground.

Pouilles et al. (1989) showed similar stress fracture rates of the femur, calcaneus and tibia in a group of 41 military recruits in his study. Darby et al. (1967) reported that in a series of 300 stress fractures diagnosed in young American soldiers in basic training, 43% were located in the calcaneus; the next highest percentage occurred in the metatarsal. Giladi et al. (1984) speculated about why the Israeli army recruits should suffer from a predominance of femoral and tibial, but not calcaneal fractures. He suggested that one of the influencing factors is the difference in training programs between the Israeli versus the American army. Also the differences in stress fracture locations between armies may be attributable to the wearing of large boots and close order parade square drills versus running training.

Matheson et al. (1987) asserted that a military population is unlike an athletic one in that soldiers who are afflicted by stress fractures are characterized by a lower musculoskeletal fitness level at time of injury and are required to march in combat boots on nonyielding surfaces. They concluded that the location of the stress fracture will reflect the type of activities the military recruit performs. Similarly, Nilsson and Westlin (1971) confirmed that the physical condition and skeletal strength was superior in the athletic compared to the military recruit. Jones et al. (1991) concurred that a low level of aerobic weight bearing physical fitness was a precipatating factor for stress fractures in an army population.

Matheson et al. (1987) speculated that 10% of sports injuries may be attributable to stress fractures. The most common site affected was the tibia (49.1%) in their study of 320 athletes. However, the data from the B.C. Sports Medicine Clinic is likely biased because over eighty percent of their patients are runners.

F. Women and Muscle Strength

Women, in many different cultures, according to Anderson and Zinser (1988) prevail over men in their performance of heavy labour. An example is the women of Sri Lanka who carry baskets of tea leaves weighing 40% of their body weight as they wend their way up steep mountain trails at an altitude of over 5000 feet. The men are involved in the much less arduous task of plantation maintenance (Falls, Baylor and Dishman, 1980). Hermanssen (1970) compared two distinct cultures, the Lapps and the South Pacific Pascuans to dramatically illustrate how factors such as a stressful climate and physical activity patterns improve human's capacity for prolonged, intense muscular activity. The nomadic Lapps, particularly the young women and men, work with reindeer and are walking and running for long periods of time on almost a daily basis. In contrast, the people of the Easter Island community live a relatively sedentary existence.

Strength is obviously an important consideration for those military personnel in both combat and combat support groups. For many years women have been denied the opportunity to fulfil many occupational roles, particularly those typified by physical labour, because they have been deemed too weak to be able to accomplish the job (Rodgers, 1988; Pheasant, 1983). There are, of course, exceptions to the rule - during World War II, when there was a shortage of "manpower", the obvious recourse for the munitions factories and ship building yards was to recruit women. Hence "Rosie, the Riveter" personified the women who patently were quite capable of performing a job entailing arduous physical labour.

Historically, there appears to be little evidence of muscular women being regarded with esteem. Spartan women were encouraged to be physically active and strong because society considered women in good condition to be better at giving birth to children. The only figures carved in stone by the artist Michelangelo depicting women with some degree of musculature are "Dawn and Night", which adorn the Medici tombs.

Roberta Pollock Seid (1989) attested that women, in as recent a period as the past five years, are reclaiming their muscles - that there is now a desire to emulate the Giacometti sculptures. The likes of Jane Fonda and Victoria Principal are proponents of the weight training trend (Seid, 1989; Fonda, 1984). However, in spite of this seeming preoccupation with the enhancement of lean tissue and the diminishment of fat stores, so that women, as Seid (1989) admonished, look like "anorexics with barbells", weight training, nevertheless, precipitates gains in strength.

G. Gender Differences in Muscle Strength

What has been keenly pursued in the literature is female/male differences in strength potential (Pheasant, 1983; Baechle, 1981; Morrow & Hosler, 1981; Wilmore et al. 1974). Wilmore et al. (1974) demonstrated that after a 10 week training program college aged women and men showed similar percentage gains in strength. However, when absolute levels of strength were compared, the male subjects were approximately 30% stronger in the upper extremities and around 5% stronger in the lower extremities. These differences in absolute strength are attributed to the difference in muscle mass between the sexes (Kosmahl et al. 1989; Knapik et al. 1980).

Baechle (1981) asserted that there is no qualitative difference in muscle tissue between women and men. Cureton et al. (1988) reported that the percentage increase in muscle area and strength after training was equivalent for women and men. As alleged by Morrow and Hosler (1981), when lean muscle mass is controlled for, women reflect force outputs that are similar to or greater than men in the lower extremities. Several authors (Baechle, 1981; Knapik et al. 1980; Wilmore et al. 1974) imputed these similarities in strength of the lower body to the pursuance of the same activities that involve lower body musculature - i.e. most people, regardless of gender, climb stairs, walk, cycle, etc. In contrast, Bishop et al. (1989) contended that the probable explanation for upper body strength differences between women and men is attributable to variability in habitual physical activity.

Wilmore et al. (1974) stated that women's lower extremity strength was actually greater than men's when strength to lean body weight ratio was considered. Where the differences appear more extreme between the sexes is upper body strength (Morrow & Hosler, 1981; Wilmore et al. 1974). It is undeniable that cultural influences affect upper body strength and that if women were encouraged to pursue activities that enhance strength, gender differences, even when absolute strength was considered, would be diminished (Wells, 1985; Zapata & Stamper, 1985; Knapik et al. 1980).

Davis et al. (1988) reinforced that there was no difference in response between women and men to a 6 week isometric training program of the elbow flexors. Isometric force increased in both groups by 14.5±5.1%.

Knapik et al. (1980) in a study of female and male recruits reported that both groups showed similar percentage strength gains of their leg extensors (12.4% and 9.7% respectively) but women reflected higher percentage gains than did men in their upper torso (9.3% vs 4.2%) and trunk extensors (15.9% vs 8.1%). Wilmore et al. (1974) attributed this phenomenon to the consideration that women, in opposition to men, generally begin further from their potential.

Cureton and Collins (1987), when examining absolute strength values of 49 female and male swimmers and 48 female and male nonathletes aged 15-28 years, found much smaller strength differences between women and men than has generally been reported. They concluded that, when comparing the sex differences in muscular strength in equally trained women and men, the differences can be accounted for by muscle size. They suggested, therefore, that for occupations where strength is an important variable, free fat weight and limb free fat weight cross sectional area are more significant than is gender. These authors confirmed that when free fat weight and limb cross sectional area are controlled, the sex differences in muscular strength are very small. Furthermore, in this particular study, there appeared to be little variability in the magnitude of the sex differences for upper body strength compared to that of lower body strength.

In a later study (Bishop et al. 1989) when 25 female swimmers were compared to 24 male swimmers (age 15-28 years), there were no free fat cross sectional area differences between the genders when adjustment was made for body size. This similarity persisted for measurements of both the upper and lower body regions in the athletes. However, significant differences were observed in a group of nonathletic controls where men had notably larger free fat cross sectional areas of both the forearm and upper arm in comparison to women. The measurements of the thigh revealed no significant differences, though, between the women and men.

Cureton et al. (1988) found in a group of 22 women and men aged 22 to 37, that after a 16 week heavy resistance training program, percentage changes in muscle hypertrophy were similar for the women and men. Percentage increases in upper arm cross sectional area, as determined by computed tomography, was not significantly different when women (23%) were compared to men (15%). Hence, due to the work of Cureton et al. (1988) who showed an increase in muscle area and Mayhew and Gross (1974) who found that women, consequent to a weight training program, increased their fat free mass, it is no longer thought that muscle hypertrophy is the singular purview of men.

Animal studies corroborate that skeletal muscle hypertrophy is not necessarily more pronounced in males over females. Interestingly, female cats display greater muscle hypertrophy subsequent to a weight training program than do male cats (Mikesky et al. 1986). In addition, no difference in muscle hypertrophy has been observed in female and male rats or mice (Timson et al. 1985; Max & Rance, 1984; Marchetti et al. 1980). The variable most highly correlated with strength is muscle hypertrophy which is dependent on the percentage of type II fibers (Jackson & Dickinson, 1988).

Cureton et al. (1988) questioned the much touted belief that there is a sex difference in muscle hypertrophy (i.e. men increase muscle bulk to a greater extent than women), although it is conceded that women and men display similar relative increases in strength (Lewis et al. 1986). The proposed and widely accepted mechanism for this greater degree of muscle hypertrophy has been ascribed to the higher levels of testosterone in men (Carlson et al. 1988; Zapata & Stamper, 1985; Baechle, 1981). Although blood testosterone levels are approximately ten times higher in men compared to women, Cumming (1987) reported that testosterone levels were elevated in a small group (n=7) of women who underwent strength training. Notwithstanding these findings, however, evidence of the importance of testosterone in enhancing muscle hypertrophy has been recently questioned (Holloway & Baechle, 1990).

Authors Westerlind et al. 1987 and Hetrick & Wilmore, 1979 concur that in spite of lower levels of blood androgen, muscle hypertrophy in women occurs to the same relative extent as it does in men. In other words, some men will show greater absolute muscle hypertrophy changes, but many women actually evince greater percentage changes.

While Carlson et al. (1988), in a study of 16 female Australian body builders and non-weight trained controls conceded that women have the ability to significantly increase their strength (29.2% absolute strength and 31.5% in relation to fat free mass), they did not believe women can significantly alter the appearance of their physiques through muscle hypertrophy without the benefit of anabolic steroids. In spite of the widespread use of this substance in the world of body building, particularly of the male, but probably also the female body builder, the Australian and former ballet dancer, Bev Francis by virtue of her notable upper and lower body hypertrophy, lays to rest the pronouncement that women are unable to significantly increase the size of their musculature through weight training.

Carlson et al. (1988), in spite of overt evidence to the contrary, staunchly maintained that female body builders reflect no greater muscle mass than any other female athlete. They speculated that this lack of muscle development was attributable to women's naturally lower levels of testosterone as well as shorter training periods.

In contrast, Walberg (1989) contended that while significant muscle hypertrophy was once thought to only occur in men, it is now generally recognized that women also reflect significant increases in lean mass (Mayhew & Gross, 1974) and muscle area (Cureton et al. 1988). While some authors (Falls, Baylor and Dishman,1980) have attributed an increase in strength in women predominantly to neural factors, Moritani and DeVries (1979) asserted that the relative contribution of neural and hypertrophic adaptations to strength increases were the same regardless of gender.

Cureton et al. (1988) speculated that the primary reason that sex differences in muscle hypertrophy were thought to exist was due to the use of crude measurements which only yield a gross indirect measure of muscle size - such as body weight, free fat weight or body circumference measurements. In their experiment, a computed axial tomography scanner was used to determine cross sectional areas of both upper and lower extremities. Cureton et al. (1988) averred that this method provided an accurate, direct measurement of muscle cross sectional area and should more validly quantify muscle hypertrophy subsequent to heavy resistance weight training.

Notwithstanding the significance of the findings of the above cited studies, Holloway and Baechle (1990) emphasized the limitations inherent in the extant research. Overall, they suggested that there is a scarcity of data existing on the effects of weight training, (particularly heavy resistance weight training) on women. Additionally, those researchers who do use women as subjects tend to select those who are either untrained (Kosmahl et al., 1989; Bishop et al.,1987; Knapik et al., 1980) or "trained" athletes such as basketball and volleyball players (Morrow & Hosler, 1981). Koshmal et al. 1989 admitted to using a "sample of convenience" i.e. college students, 18 to 23 years of age who alleged they had not participated in university sport activities nor a training program over the past three months.

Most authors (Kosmahl et al. 1989; Bishop et al. 1987; Morrow & Hosler, 1981; Wilmore et al., 1974) reported the mean age of their subjects to be around twenty. Cureton et al. (1988) were an exception. Their subjects ranged in age from 22 to 37 years. There appears to be a virtual paucity of literature detailing the effects of weight training in the older populace-particularly older women. However some authors, such as Brown and Harrison (1986), have addressed some of the benefits accrued through weight training in a group of middle aged and older women.

Also, while some authors proffered detailed descriptions of their weight training programs or muscle strength testing protocol, (Kosmahl et al., 1989; Cureton et al., 1988; Bishop et al., 1987; Morrow & Hosler, 1981), others were less meticulous in their explanations (Bond et al, 1985; Knapik et al., 1980; Hetrick & Wilmore, 1979). Further, the one characteristic that seems to pertain to all of the reviewed studies was the brevity of the training sessions. For example, Kosmahl et al. (1989), O'Shea & Wagner, (1981) and Hedrick & Wilmore (1979) reported a training period of seven, eight and nine weeks, respectively. Cureton et al. (1988) were the exception when they conducted a weight training program designed to hypertrophy the muscles of the upper arm and thigh in a group of eight women and seven men over a period of 16 weeks. Jones et al. (1989) underlined the importance of the training period lasting about 12 weeks in order to induce muscle hypertrophy.

Several authors {Cureton et al. 1988; Bishop et al. 1987; Morrow & Hosler, 1981; O'Shea & Wegner, 1981} have addressed the previous training status of their subjects. However, Cureton et al. (1988) alleged that whereas both the men and women in their experimental population professed that they had no previous heavy resistance training there was no definitive means of verifying this declaration. Also, "training status" appears to be fairly broadly defined. For instance, Morrow & Hosler, (1981) in a study which distinguished strength between a group of "trained" women and "untrained" men identified the former as basketball and volley ball players and the latter as college students in elective or required physical education classes.

Hetrick & Wilmore (1979) in one of the initial papers addressing the amount of natural steroid released through a bout of weight training, reported that for both women and men, plasma androgen levels remained unchanged following eight weeks of heavy resistance exercise. However, in a later study conducted by Cumming [illegible] (1987), data confirmed that not only did women who we[illegible]in evince higher pre-exercise levels of testoste[illegible]one [illegible] their untrained counterparts, but that testosterone levels were increased in women following a bout of heavy resistance exercise. Overall, researchers appear equivocal about the importance of naturally released hormone and its impact on muscle hypertrophy (Holloway & Baechle, 1990; NSCA, 1989).

The use of anabolic steroids, although not addressed in many of the earlier papers discussing women and muscle strength, has been recognized as problematic in the NCSA position paper on strength training in female athletes. These authors (NCSA, 1989) concurred that anabolic steroid use is endemic not only in the male weight training populace but also in the female one.

Sharkey (1988) recounted that the principle of specificity in testing should be applied by all evaluators. He suggested that in earlier studies, isometric tests were implemented to ascertain changes in isotonic strength. This is an errroneous practice because the correlation between isometric strength and isotonic strength is only moderate (i.e. r=.77) (Sharkey, 1988). While several of the reviewed authors (Kosmahl et al. 1989; Bishop, Cureton and Collins, 1987; Morrow and Hosler, 1981) were careful in applying this principle, others (Jette et al., 1987) were not. In a study examining the effects of a heavy resistance weight training program on the upper body strength of 80 university women, Jette et al. (1987) had his subjects train on the Marcy Fitness Trainer and evaluated on the incremental lift machine.

Numerous researchers (Bishop et al.,1987; Morrow & Hosler, 1981; Wilmore et al.,1974) have reported on the isotonicstrength of both the upper and lower body musculature. Of the studies reviewed, only Knapik et al. (1980) examined the isometric strength of the trunk and leg extensors of a group of young (mean age: 23.9 years) women and men reporting for army training. He observed that after a period of seven weeks of basic training that leg extensor strength improved similarly in the recruits, regardless of gender. The women reflected a 12.4% and the men a 9.4% improvement in lower body isometric strength. However, the women recruits evinced a higher percentage improvement in the strength of the upper torso and the trunk extensors relative to the men. The authors concurred that the reason the women demonstrated this superior performance was that their initial strength levels were lower. When strength was measured relative to lean body mass, women and men reflected similar values for both the lower extremities and trunk extensors.

Similarly, when Wilmore et al. 1974 examined the strength of a group of college students (mean age:20 years), he found that while women exhibited inferior upper body measures both in relative and absolute terms, they were stronger than men when measures of relative lower body strength were considered. In contrast, Morrow & Hosler (1981) concluded that untrained college aged men displayed greater upper and lower body strength both in relative and absolute terms in comparison to a group of 160 female basketball and volley ball players. What could explain the discrepancy in this finding in comparison to other mentioned research is that whereas Morrow & Hosler analyzed isokinetic data, most authors evaluate isotonic or isometric measurements.

Bishop et al. (1987) alleged that the gender differences in absolute strength were notably smaller in a group of swimmers (age 15 to 26 years) compared to nonathletes. They reported that strength measures controlled for fat free weight and/or fat free cross sectional area eradicated gender differences in lower body measures of strength. However, in spite of this correction, men reflected superior upper body strength as reflected by their performance of the arm curl and bench press.

Bond et al. (1985) compared the strength differences between a small group of women body builders (n=8) and a group of college aged men who were significantly taller and heavier than the women. Although neither height nor weight were controlled for, the women were as strong as the men in lower body strength. They were, however, weaker in terms of upper body strength. Nevertheless, when strength was measured in relative terms the women and men in this study were equal.

A summary of gender differences in muscle strength as described by several authors including Cureton et al. (1988 and 1987); Davies et al. (1988); Carlson, (1986); Knapik et al. (1980) and Wilmore et al. (1974) is presented in Table 1.

Table 1: Gender Differences in Muscle Strength

Author	Yr	Subjects	Training	Comments
Wilmore et al.	1974	University students	10 wks	*Similar % in strength gains *♂ 30% stronger upper limbs *" 5% stronger lower limbs * Difference in muscle mass * ♀ lower extremity strength 〉♂ if only lean/body wt compared
Davies et al.	1988	♀ and ♂ elbow flexor	6 wks. isometric training	*similar for both groups-14.5±5.1
Knapik et al.	1980	♀ and ♂ leg extensors torso		*similar for both groups *leg extensors 12.4 vs 9.7% *upper torso 9.3% vs 4.2%
Cureton et al.	1987	48 ♀; 49 ♂ age:22-37 yrs		*very little difference because both groups equally trained *corrected for X-sect. area, fat
Cureton et al.	1988	22 ♀; 22 ♂ age:22-37 yrs	16 heavy resistance program	*confirmed good muscle tissue *gains with tomography
Carlson	1986	16 ♀ body builders	isotonic strength bench pres squat bicep curl	* good gains in strength * less gains in bulk

H. The Importance of Strength for Women in the Workforce

As various authors have indicated (Cureton et al. 1988; McDonagh & Davies 1984; Moritani & DeVries, 1979), the potential for developing strength is partially linked to the potential for muscle hypertrophy. As women enter the more physically demanding jobs in the police, firefighting and military occupations it becomes very apparent that those individuals who evince higher strength values have an advantage over those who are weaker.

A cultural bias against women rivalling Charles Atlas has been very apparent in our society probably since the curves of the "Gibson Girl" were extolled as the epitome of womanhood in the 1890's (Pollock Seid, 1989). This bias has precluded women from the hallowed halls of the weight training room (Baechle,1981). However, more and more women are eschewing the weak is synonymous with feminine image and are following the lead of Katie Sandwing, who is now reputed to be the strongest woman in the world. Needless to say, strength is a critical component, not only for the performance of some occupations, but, additionally, for health and well-being.

Pheasant (1983) addressed the problem of how much variability can be based on gender when sex differences in strength are considered. He reported that the distribution of the strength of women and that of men often is found to overlap. He refuted the commonly quoted aphorism that women are approximately two-thirds as strong as men. He determined, after a review of 112 data sets that the female/male strength ratio for tests of lifting,pushing or pulling ranged from 38%-90%. This range, he speculated, may be attributed to differences in direction of exertion, postu and selection of subject . He reported, in addition, that the proportion of variance in strength ascribed to sex can range from 3% to 85%. Hence, he maintained that the oft repeated maxim that women are 66% as strong as men is essentially meaningless. Overall, variation in strength is generally considered to be dependent on three main factors: {1} subject {2} ultimate strength possible with training and {3} strength and endurance versus skill required for the job.

While Jacobs et al. (1988) noted significant gender differences in a group of college students who participated in a maximal operational lifting test, Beckett and Hodgdon (1987) claimed that gender did not determine task performance. They reported that after controlling for muscle mass and measures of physical capacity such as run time and push-ups, age and gender were incidental.

Baechle (1981) and Knapik et al. (1980) were unequivocal in their assertion that women can improve their strength considerably with an appropriate training program. They stated that in addition to a basic training program as implemented in the military, the strength of women can be improved for designated jobs by a specific type of training program.

Celentano et al. (1984), in a study which examined the relationship between size, strength and task demands, found through multiple regression analysis of a lifting task (weight of block = 47 kg) that body weight and lifting strength accounted for 76% of the variance. Gender accounted for only 16% of the variance. The women, without exception, were unable to accomplish the designated tasks. The obvious problem with this particular study was the very small sample size - the performance of 18 women was compared to that of 23 men.

The authors concluded that specific training must be provided to those women undertaking arduous physical labour. The long term solution, they suggested, is to redesign equipment - something that would ultimately benefit both women and men.

Nygaard et al. (1988), in an investigation of muscle strength and muscular work load of middle-aged women and men, discussed the implications of their findings that a high muscular work load (duration and intensity) coincided with lower muscular strength and endurance than those typified by a low muscular load. An earlier report (1987) by these same authors showed that those individuals engaged in physical labour at the municipal level reflected lower strength values than those occupied by primarily mental tasks. Why this curious phenomenon exists as observed by several authors (Nygaard et al. 1987,1988; Hukinnen et al. 1984) is conjectural. Nygaard et al. (1988) speculated that one of the reasons a difference exists in strength between the high and low load groups is due to the manifestation of symptoms and diseases of the musculoskeletal system. These authors indicated that in some occupations, especially home care and auxiliary workers, the incidence of musculoskeletal disorders in women is high (44.0% and 44.6% respectively).

Tuxworth et al. (1986) conjectured that physical capacity may be related to physical activities pursued during leisure hours. Another Finnish author (Malkia,1983) corroborated this finding when he claimed that individuals who are physically active during leisure hours also reflect higher levels of muscle strength than do those who are sedentary. It is well known, furthermore, that as occupational workload increases, physical exercise during off hours decreases (Health & Welfare Canada, 1981).

I. Resistance Training and Its Value in Reducing Rate of Injury

Several authors (Fleck & Falkel, 1986) concurred that resistance training benefits bone by enhancing bone mineral content and hence may help to prevent skeletal injury. Sharkey (1988) stated that bone mineral content is augmented when an individual engages in regular, moderate exercise such as jogging and weight training.

Partlow (1982) suggested that stress fractures are a particular problem in the army as evidenced by the high number of recruits who, particularly after a bout of running while wearing combat boots, are afflicted by stress fractures. While Zapata & Stamper (1985) described a stress fracture incidence of 0.5% for male recruits and 1-2% for female recruits in the American army, Zahger et al. (1988) reported an occurrence rate of 11.4% of Israeli female soldiers engaged in basic and advanced military training. Schwellnus et al. (1990) attributed the disparity in stress fracture incidence between the American (0.9% to 2.0% of U.S. male recruits) and the Israeli (31% of recruits) to the use of a more sensitive bone scan. Black (1982) reported a stress fracture incidence of the calcaneus and metatarsals in female soldiers ranging from 10.5% in Marine Corps recruits to 12% in Army Basic Trainees. However, their own two year retrospective study showed a lower stress fracture incidence of 5.5% which approximated that of a group of female cadets at the U.S. Military Academy at West Point.

Overuse injuries which encompass knee pain, shin splints, tendonitis and stress fractures affect one quarter of the men and one half of the women in the army (Zapata & Stamper, 1985). These authors and Partlow (1982) admonished against the wearing of combat boots as this type of non-yielding footwear is a contributory factor in sustaining a stress fracture. This is a lesson comprehended in Sports Medicine but not assimilated by the military.

Partlow (1982) recounted the experience of an American female platoon at an American training centre. The soldiers, during their third week of training, were to embark on a 4 mile road march, the third such march in two days. Only 13 of the 42 soldiers assigned to march were actually able to undertake this task. Of the 13 women, two were noticeably limping. Twenty of the group were unable to march due to foot and leg complaints.

Du Rant et al. (1988) in a study of adolescent females and their readiness to participate in sports suggested that due to a high incidence of overuse injuries, that they should engage in regular bouts of weight training. Similarly, Reid (1988) in a study of hip and knee injuries in ballet dancers who were characterized by lower limb strength values which were 77% of normative athletic levels, recommended strength training to help reduce the incidence of injuries. Fleck and Flakel (1986) affirmed that resistance training may enhance the structural integrity of both connective and bone tissue and thereby mitigate injury.

Martin et al. (1981) demonstrated that the bone mineral content increased significantly in the tibia of adult beagles following a five days per week, 2 year training program. The beagles, wearing weighted jackets, walked for an hour and a quarter at a speed of 3.3 kph on a carousel - type treadmill. Four months prior to the cessation of the experiment, the beagles were carrying over 130% of their body weight. The authors concluded that resistance training, in particular, augmented bone mineral content in healthy individuals.

J. Body Composition Changes Induced through Weight Training

Probably the most dramatic representation of body composition alterations that can be induced in women (and men) are the changes wrought through body building. Sandoval et al. (1989) reported that in a group of 11 competitive body builders (six women and five men), both women and men reflected notable increases in muscle mass in comparison to a reference model. The lean/fat ratio for the body builders was two to four times greater than the reference woman or man. In this particular study, the female body builders were relatively as lean as their male counterparts. Elliot et al. (1987) reported similar findings in a group of 15 women body builders. The authors ascribed the relative leanness in their female subjects to the somewhat larger training volume vis a vis men. They reportedly trained for 4 hours longer than did the male subjects and executed 2-10 more sets per body region.

Bale and Williams (1987) discussed an anthropometric prototype of 7 British female power lifters. They described competitive women power lifters of the 1985 "British Women's Power Lifting" championships as characterized by stocky, endomesomorphic physiques. These power lifters were identified by short limb lengths, a low height to weight ratio and large limb circumferences. They professed that these substantial circumferences and low body fat levels are an indication of notable muscle hypertrophy, particularly in the shoulders, chest and limbs. The circumferences measured at various sites: (biceps, forearm, shoulders, thigh and calf) were significantly larger than those measurements reflected by sedentary women. It is generally acknowledged that the person identified as having a short, stocky build is biomechanically the most proficient candidate to "power lift".

Ross and Ward (p.194, 1984) stated that "strength is increased as a function of body mass to the power two thirds". Although they conceded that a greater body mass enables an individual to lift a heavier weight, it is not a linear relationship. The power lifters benefit from a body mass predominantly comprised of lean tissue rather than fat.

Pardue and Eisenman (1988) reported that the strength increments (specifically knee extension and flexion) in a group of college age women were significant after a relatively short training period of six weeks. However, no significant change was elicited in somatotype ratings and skinfold readings (with the exception of the calf skinfold measurement). The training regimen consisted of 2 days per week of one set (8-12 repetitions) using Nautilus equipment. These two days of weight training were supplemented by 2 days of high intensity interval training - specifically jumping and sprinting exercises. Interestingly, the women who were classified as predominantly endomorphic predicated on the Heath

Carter somatotype rating were also the ones who showed the greatest gain in elbow extension strength (significant at $p<.05$).

K. The Effect of Body Weight on Muscle Strength

Evidence adduced from animal studies shows that there is a direct relationship between body weight and average fiber cross sectional area (Jackson & Dickinson, 1988). Tesch et al. (1985) reported a likewise relationship in humans. They observed a relationship between the mean fiber area of the vastus lateralis and the deltoid muscles and the body mass index of an individual. As would be expected, the largest fiber area and body mass index was evinced by the weight trainers; the smallest fiber areas and body mass index were displayed by the runners.

As purported by several authors (Tesch et al. 1985; Pavlou et al. 1985), the lean body mass of the overweight individual is greater than that of the individual of normal weight. Pavlou et al. (1985) reported that the enhanced muscle mass of the overweight or obese is an adaptive response to carrying the excess body weight.

It is reputed that at any given time almost half or 46% of women are on a diet (Seid, 1989; Jackson & Dickinson, 1988; Health and Welfare Survey: Promoting Healthy Weights, 1988). This contrasts with the lower 27% of men who are attempting to achieve weight loss during any given period (Health and

Welfare Survey: Promoting Healthy Weights, 1988). Notwithstanding the health benefits accrued through weight loss for the extremely obese (Canada Health and Welfare Survey: Promoting Healthy Weights, 1988), weight loss can impact negatively on lean tissue and consequently strength.

Pavlou et al.(1985) discussed the effects of dieting and exercise on lean body mass and strength in a group of 72 men who were classified as mildly obese. They showed, that when a group of these men dieted, 36% of the weight lost was comprised of lean tissue. The diet and exercise group lost a similar amount of weight over the 8 week period, but the weight loss was derived substantially from triglyceride stores. The increase in strength was reported to be 22% and was attributed primarily to neural factors.

L. Body Image and Weight Training

"Our society's current standard of the **perfect female body** is more discrepant from the norm than the **perfect male body.** For men, any discrepancy which does occur between real and ideal physique is more likely to foster attempts at weight gain rather than weight loss and to encourage **muscle building** physical activity rather than restrictive diets".(Conner-Greene, 1988, p.30)

Numerous authors (Conner-Greene, 1988; Canada Health and Welfare: Promoting Healthy Weights, 1988; Balogun, 1987) have discoursed on the overt pressures in our society which exhort women to pursue the often rocky road to what sometimes can be an elusive slenderness. Young girls are taught that to be feminine means a body shape that is both delicate and petite.

These messages are assimilated so well that a survey conducted in 1986 by researchers at the University of California revealed that half of all girls in grade four (nine year olds) and 80% of 10 and 11 year olds were on diets because they construed themselves as being too fat (Seid, 1989). Garner et al. (1980) observed that while beauty pageant contestants over the past 20 years have actually become thinner, the typical woman's weight has increased. This phenomena exaggerates the discrepancy between what then is considered an ideal weight and body shape and the more ordinary weight and shape that characterizes many women. Conner-Greene (1988) reported that 42% of women in the ideal weight range viewed themselves as overweight. This is consistent with the findings of the Canada Health and Welfare Survey: Promoting Healthy Weights (1988) and helps to explain why at any give time almost 50% of women are on some form of diet. Other researchers allege that the dieting practice is almost ubiquitous - Rossner (1984) declared that 70% of American women are on a diet at any particular time.

While it is generally recognized that weight training confers benefits to men, little research has been conducted on the relationship between strength training and body cathexis in women. Balogun et al. (1986) investigated the effect of muscle strength as it is related to a feeling of satisfaction or dissatisfaction with the various parts of the body in a group of university women (age range: 19-50 years).

Statistical analysis revealed that those women who were typified as relatively strong reported a higher degree of body cathexis (i.e satisfaction with their body parts) than did their physically weaker counterparts. Interestingly, multiple regression analysis showed that self-esteem and body cathexis can significantly be predicted from relative muscular strength. The author was in a quandary about this finding. He imputed the relatively stronger women's satisfaction with their bodies not to muscular strength (which he asserted was not readily observable in women in comparison to men) but to the endorphin generated "high" precipitated by physical activity.

In a similar vein, Synder & Kevlin (1975) concurred that elite athletes reported significantly more satisfaction with their bodies (i.e. a higher body cathexis score) than did their nonathletic counterparts. Tucker (1987) observed that those individuals who were comparatively weaker accrued a greater degree of satisfaction than did their stronger colleagues. He concluded that for those subjects who construed their body type as ideal or close to ideal, there was little enhancement of body satisfaction with a weight training program. However, for those subjects who rated their body type as different from ideal, the positive effect on body image was substantial following the course of a weight training program.

In a preliminary report, Brown and Harrison (1990), who studied women between the ages of 17 and 50 years who engaged in a 12 week weight training program, reported that although the womens' weight and body fat levels were maintained, psychological tests showed that these women felt better about themselves and their bodies. Brown claimed that "most of the women found participation in the weight training program to be very empowering".

Chapter III

Methodology

A. Subjects

Forty-five women volunteers employed as combat support personnel at the Canadian Armed Forces base located in Calgary, Alberta participated in the study. Prior to partaking in the field tests and laboratory procedures each subject completed an EXPRES screening form. (See Appendix I). Included in this form was a physical fitness standards testing advisory and a health appraisal questionnaire (CF Express, 1989). Additionally, the subjects were apprised of the possible risks or complications pertaining to the battery of field and laboratory procedures and requested to read and sign informed consent forms pertaining to these procedures. (See Appendix II).

B. Testing Stations

The subjects took part in the laboratory test battery at the University of Alberta. Bone scans were performed at the Bone Density Laboratory in the Garneau Center, Edmonton, Alberta. The field tests were conducted at the Canadian Armed Forces base located in Calgary, Alberta. The subjects were provided with instructions pertaining to both the field tasks and laboratory measures. (See Appendices III through IX). An emergency protocol was established in the event of any untoward circumstances. The subjects were advised to follow the normal recommendations prior to engaging in vigorous physical activity i.e. not to consume alcohol or caffeine beverages, nor to smoke or engage in vigorous exercise for at least 24 hours prior to their evaluation.

C. Testing Protocols for Laboratory Measures
Measurement of Bone Density

An accurate, non invasive method, Hologic QDR 1000 X-ray Bone Densitometer was used to assess bone density. This method is based on the attenuation of a collimated photon dual energy X-ray beam by bone. The central skeleton, specifically the lumbar (L2-L4) and femoral (Ward's triangle and trochanteric neck) regions were scanned while the individual was lying in a recumbent position on a plinth. A photomultiplier tube recorded transmission from a X-ray source situated under the plinth. The procedure was conducted over a period of thirty minutes for each individual and was comfortable and safe. Radiation exposure, using this method, was minimal and amounts to approximately one-tenth of the radiation of a chest X-ray. Bone mineral densities of the spine and femoral region were reported as g/cm^2.

The vertebrae, according to Bilanin et al. (1989) is comprised of 33-42% trabecular bone. Trabecular bone is eight times more metabolically active than cortical bone so that any changes in bone density are more readily apparent. Furthermore trabecular bone has often been studied in military recruits (Pouilles et al. 1989; Greaney et al. 1983; Darby, 1967).

In addition to undergoing the bone scan, each subject completed a questionnaire detailing certain risk factors said to be associated with lower bone density such as reproductive history and childhood participation in physical activity (Bailey & McColloch,1988). (See Appendix XII).

Procedure for the Determination of Body Image

Body image was determined by using the validated "Body Cathexis Scale". As indicated by Balogun (1986), a method to assess the validity of a psychological scale is to ascertain the relationship between the scale in question with other reliable psychological assessments. Balogun (1986, p.932) reported that the Pearson Moment Correlation Coefficients obtained between a well known psychological test, the Tennessee Self Concept, and the Body Cathexis Scale showed that "the Body Cathexis Scale has some construct validity in that the subjects perceive their body parts much like they perceive many other aspects of themselves." Balogun (1987) reported that not only does the Body Cathexis Scale reflect construct validity, it is also a reliable psychological measure.

The Body Cathexis Scale consists of 40 items pertaining to satisfaction or dissatisfaction with the various parts or processes of the body. (See Appendix XIV). From the "Body Cathexis Scale" an evaluation of personal traits such as feelings pertaining to physical skills and fitness, overall appearance, and weight preoccupations can be determined. The subjects rated these body characteristics on a five point Likert scale ranging from 1 (strongly negative) to 5 (strongly positive). By totalling responses to the 40 items a body cathexis score for each individual was determined. A greater satisfaction and confidence in body parts is indicated by a high score. Tucker et al. (1983) found that when stronger males were compared to their weaker counterparts, the stronger men were significantly more satisfied with their body parts, as well as more extroverted and confident. This scale addressed the relationship between muscular strength and performance on a variety of field tasks and the perception of body image by a group of women in combat support from the Canadian Armed Forces base in Calgary.

Hydrostatic Weighing

Hydrostatic weighing was undertaken in a rectangular tank six feet in height, four feet in width and ten feet in length. The subject sat on an aluminum chair in the tank which was suspended from a load cell. This load cell was connected to an IBM computer. Prior to entering the tank, the subject, wearing a swim suit, was weighed on a beam balance scale to the nearest tenth of a kilogram. Following weighing, the subject was instructed to shower. When the subject was in the tank, sitting on the chair, a 9.45 kg diver's belt was placed across the upper portion of their thighs.

The protocol for hydrostatic weighing as outlined by Ward et al. (1984) was as follows:

1. subject was advised to remove air bubbles from hair and body,
2. a nose clip was applied and subject was instructed to maximally inhale (to total lung capacity) and maximally exhale (to residual volume) into an autospirometer in order to determine vital capacity; this procedure was repeated three to five times. To estimate residual lung volume, 24% of vital capacity was used for the calculation (Morrow et al.1986; Wilmore, 1969).
3. following a maximal expiration (to residual volume) the subject was instructed to lean forward from the waist (while remaining sitting on the chair) until their body was completely submerged under water,
4. the subject, while cautioned to remain still, with their feet placed on the bottom rung of the chair, was submerged under water for approximately six seconds; when the computer beeped the subject was raised manually by a rope and pulley system. When the individual's head was out of the water they were instructed to exhale any remaining air into the autospirometer. This lung volume was entered into the computer.
5. The computer calculated the percent body fat based on the formula of Brozek et al. (1963),
6. The procedure was repeated minimally three times or until two similar (within ≤0.5%) percent body fat readings were recorded on the computer.

Residual Volume Determination

One third of the sample of forty-five women had their residual lung volumes determined directly through the helium dilution computerized method at the Garneau Pulmonary Lung Laboratory located in Edmonton, Alberta. Although Ostrove et al. (1982) reported that measuring residual lung volume in air results in slightly higher values than when the subject is submerged under water, Hsich et al. (1985) alleged that this practice does not compromise accuracy. According to McArdle et al. (1991), the difference between measuring residual lung volume while the subject is immersed in water compared to air has a negligible effect on calculated body fat.

Bioelectrical Impedance

Bioelectrical impedance (BIA) is another more recent indirect method of determining body composition. It is predicated on the principle "that the resistance to a mild electric current is related to total body water" (Jackson et al. 1988).

Electrical impedance is most pronounced in the relatively anhydrous adipose tissue (14-22% water; Brodie et al.1988) because the conductive pathway is directly related to the percentage of water. Alternatively lean body mass (muscle is 75% water; Ward et al. 1984) is relatively hydrous in comparison to fat and consequently it is a good conductor of electricity (Brodie et al. 1988) . Fundamentally, bioelectrical impedance is an index of **total body water**. From this index an extrapolation is made to body composition. BIA prediction equations are used to predict percent body fat. The prediction equation contributed by the manufacturer of RJL Systems, Detroit, Michigan estimates body density from the product of weight and resistance divided by height squared (Jackson et al.,1988). Gender specific equations are also available where free fat weight (FFW) is estimated from the ratio of height squared to bioelectrical resistance (Lukaski et al. 1986). Jackson et al.(1988) determined BIA correlations with hydrostatically measured body fat to be 0.788 for men and 0.792 for women. Lukakski et al. (1986) reported higher ations between hydrostatically measured FFW and FFW ated through the use of BIA (r=0.953 for women and 0.981 r men).

The protocol, as described by Pearman et al. (1989), used in determining body composition from bioelectrical impedance was as follows:

1. Subject instructed to drink two glasses of water and then void prior to undergoing BIA measurements. This procedure was implemented to control for hydration status as it is a factor known to influence the accuracy of BIA evaluation (McArdle et al. 1991).
2. Subject requested to remove all metal objects,
3. Height and weight of subject recorded,
4. Subject instructed to lie down on mat in supine position

with right arm and leg abducted,

5. Current injector electrodes attached to subject's right hand and foot (proximal to the right metacarpal and metatarsal joint III). Current detector electrodes centered between the distal protuberances of the ulna and radius and between the right medial and lateral malleoli,
6. Resistance and reactance from the BIA instrument recorded,
7. Data entered on the **body composition** program on the IBM computer.
8. Body composition report printed.

Skinfold Measurements

The rationale for implementing skinfold measurements was based on the assumption that approximately 50% of total body fat is located subcutaneously (Katch & Katch, 1983). All skinfold techniques are validated against underwater weighing (McArdle et al. 1991).

The instrument implemented was Harpenden skinfold calipers. The procedure as described in the Canadian Standardized Test of Fitness (1981) was followed. Other researchers (Song & Moore, 1989) who examined anthropometric and physical fitness characteristics of Canadian Infantry Militia have also followed this protocol and compared results with the Canadian Standardized Fitness Norms. Measurements were made on the right side of the body with the subject in an upright position. Skinfolds were measured at five different sites. Three measurements were taken at each site and the criterion measure was the mean of the two closest values. (Measurements recorded to the nearest 0.1 mm). The anatomical locations for the skinfold measures were as follows:

1. triceps - vertical fold measured halfway between the acromion process and the olecranon process of the elbow,
2. subscapula - oblique fold measured at the inferior tip of the scapula,
3. biceps - vertical fold measured halfway between the acromion and the olecranon of the elbow,
4. suprailiac - oblique fold measured three centimetres above the anterior superior iliac spine,
5. calf - vertical fold measured just above the level of the maximum calf girth,

Muscular Strength Testing Equipment

Isotonic Electronic Free Weight Dynamometer

This device, as described by Chahal & Singh (1988) was designed to eliminate the eccentric phase of isotonic endurance testing. The weight of this device is returned automatically to the starting position without any effort exerted by the subject.

The isotonic electronic free weight dynamometer was used in the assessment of muscular endurance - specifically the dynamic trapezius lift endurance test. The manoeuvre executed by the subject was that of "upright rowing". The weight of the bar (which corresponded to the weight of an ammunition box) was counterbalanced by an equatable weight which was located in the posterior position of the dynamometer. This instrument, enabled the subject to lift a submaximal load repetitively at a predetermined pace. The test was discontinued when the subject was unable to maintain this pace.

Isokinetic Electric Trunk and Leg Dynamometer

As detailed by Singh et al. (1972) and Chahal (1988), the isokinetic electric trunk and leg dynamometer which is interfaced with a computer through a load cell, measures isokinetic-concentric and isometric maximal strength. Results from the isokinetic-concentric strength testing of 45 women and 116 men demonstrated the validity of the instrument. That the dynamometer was also a reliable apparatus was reflected by the reliability coefficients which ranged between 0.85 to 0.96 (Singh & Chahal, 1991). Isokinetic-concentric strength tests (leg extension, trunk extension and trunk flexion), were administered implementing this device. Isometric strength tests consisting of trunk flexion and extension were also conducted using the dynamometer.

The components of the dynamometer were: an electric motor connected to a chain and a 1365 kg capacity steel cable which passed over two ball bearing pulleys. This cable, which was positioned in front and centered between the feet of the subject, was connected to a steel thigh bar. A four inch wide webbed belt coupled with an ordinary car seat belt was attached to the steel bar. This car seat belt was adjusted so that it fit comfortably around the subject's waist.

This instrument was altered to facilitate trunk extension by affixing a thigh bar to the end of a cable (Chahal, 1988). To allow the subject to perform trunk flexion, the cable was connected to two pulleys positioned on the posterior aspect of a backboard (Chahal, 1988). An adjustable shoulder harness was connected to the cable through the backboard.

To calibrate this instrument, a known free weight was attached to the dynamometer and the computer monitored to ensure the weight recorded corresponded to the free weight. This procedure was conducted on a daily basis prior to the testing sessions. Furthermore, a computer technician monitored both the electric leg dynamometer and the load cells throughout the testing sessions. A 1365 kg capacity load cell was used for the leg extension test. A 455 kg load cell was used for the other tests. The subjects were advised to avoid ballistic manoeuvres which artificially augment the peak force output during the evaluation. In order to obtain accurate data output, each load cell was interfaced with an IBM computer.

Additional Equipment and Human Resources Required

1. Cybex dynamometer
2. two handgrip dynamometers
3. two goniometers
4. three stop watches
5. two IBM computers
6. bench (for bench press)
7. five testers

I. Isometric Strength Tests

The isometric strength tests included handgrip, arm flexion (elbow flexion at 105 degrees), trunk flexion and extension at a hip angle of 160 degrees. Each of the angles corresponded to the angles of the joints in question when performing the designated field tests. Prior to exerting maximum effort, each subject was asked to perform two warm-up contractions (of an intensity approximately equivalent to 50-60% of the subject's maximum voluntary effort). Subsequent to this warm-up activity and rest interval of 3 minutes between contractions, each individual exerted two maximum voluntary contractions. The recorded data consisted of the force output generated during the maximum voluntary contractions.

1. Isometric Handgrip Strength Test

The handgrip dynamometer (Carolina Biological Supply Company, Burlington, North Carolina, U.S.A.) was used to determine the maximum force each subject exerted. The optimal value, following three trials per hand, was recorded.

2. Isometric Arm Flexion Strength Test

This test was performed at an elbow flexion angle of 105 degrees. This angle corresponded to the angle of the elbow when the subject was carrying a 20 kg box. To ensure the angle was maintained during the contraction, a goniometer was used by the tester and the subject was advised of any variation in angle.

3. Isometric Trunk Extension Strength

The hip angle corresponding to the angle of the individual's hip as they lift an object off the floor is 160 degrees (Chahal, 1988). Each subject was measured prior to the warm-up session, using a goniometer, to ensure that the specified hip angle was maintained. The subject was also advised to keep their back erect as this reduces error in the estimation of the hip angles (Chahal,1988). The subject's feet were placed shoulder width apart. Masking tape was applied to the standing surface to facilitate the correct position. The subject was reminded to use pronated (for the non-dominant hand) and supinated grip (for the dominant hand) on the thigh bar when performing the test. They were further advised to avoid the Valsalva manoeuvre induced through breath holding. Verbal encouragement was given to each subject to enhance performance.

4. Isometric Trunk Flexion Strength Test

A maximum abdominal strength test conducted at a hip angle of 160 degrees was exerted by each subject in the standing position. As reported by Chahal (1988), when an individual is lifting an object and positioned so that the hip angle is 160 degrees, the abdominal musculature acts to increase the intraabdominal pressure. To ensure accuracy of the angle, the hip angle was measured using a goniometer during the warm-up period. To facilitate measurement of abdominal strength, an adjustable shoulder harness was connected to the cable via two pulleys attached to the posterior aspect of the backboard. The shoulder harness, to which was attached a harness hook and pulley, was positioned at a level parallel to the axilla. The length of the chain was altered so that the cable corresponded to the height of the subject. Each subject stood with their feet positioned shoulder width apart as described in the previous section.

II. Concentric Isokinetic Strength Tests

This evaluation included the following strength tests: arm flexion, leg extension, trapezius lift (resembled the movement of lifting a 20 kg box from waist to shoulder height), bench press, trunk flexion, trunk extension and knee flexion and extension. The device implemented for the arm flexion, leg extension, trapezius lift and bench press was the Isokinetic Electric Dynamometer (at a cable velocity of 13 cm/s). According to Okoro (1987), the speed of 13 cm/s corresponded to an angular velocity of 30 degrees per second. Because trunk movements occur at a slower velocity than limb movements, 6.5 cm/s was the cable velocity at which trunk flexion and extension were conducted. Knee flexion and extension strength tests were conducted at an angular velocity of 180 degrees per second which corresponded to knee angular velocity in weight load marching (Dziados et al. 1987).

Prior to each test, the subject exerted two submaximal efforts, equivalent to approximately 50-60% of MVC. Following the warm-up, the subject exerted two maximal voluntary efforts. Interspersed between trial one and trial two was a three minute rest interval. Peak force was recorded.

1. Concentric-Isokinetic Arm Flexion Test

The subject was instructed to place her hands on the bar in the same position as described for the isometric arm flexion strength test. The elbow flexion contraction was performed through full range of motion. The subject was instructed to flex their elbows by pulling the bar in an upward direction. Upon the achievement of full flexion, the subject slowly extended her arms without encountering resistance. Simultaneously, the dynamometer returned the cable to the initial position.

2. Concentric-Isokinetic Trapezius Lift Strength Test

Subjects were instructed to assume a stance position and to grasp the specially designed handles attached to the weight bar. These handles were located 38.5 cm apart and were constructed to resemble the grasp used when lifting an ammunition box. From an extended arm position, the subject was instructed to lift the weight bar until the superior surface of the handles were parallel with the subject's clavicles. The bar was then returned automatically to its resting position. Following a rest interval, the subject performed another maximal exertion.

3. Concentric-Isokinetic Leg Extension Strength Test

Initially, the subject stood with knees flexed to ninety degrees, on the dynamometer in order to enable the tester to adjust the cable to their specific height. This cable was then connected to a webbed belt, which was wrapped snugly around the subject's waist. To ensure stability, the subject was advised to hold the thigh bar which was connected to the webbed belt. The subject was instructed to extend their knees while pulling up on the cable as it was released at the mechanically controlled speed of 13 cm/s. Upon assuming the standing position, the subject then returned to the original position with their knees flexed to ninety degrees.

4. Concentric-Isokinetic Knee Flexion and Extension Strength Test

Both concentric-isokinetic knee flexion and extension strength tests were conducted on the Cybex dynamometer at an angular limb velocity of 180°/s. Knee flexion angle ranged between 90° to 180°. The test was conducted on each limb separately. Upon the command to initiate the maximal contraction the subject first fully extended their knee and then fully flexed their knee.

5. Concentric-Isokinetic Trunk Extension Strength Test

The body position and handgrip for this test was the same as that described for the isometric trunk extension strength test. This particular test was performed through a hip angle range of 150 to 170 degrees. The subject was instructed to pull up on the bar as the cable was released. The speed of the cable was controlled so that it was released at the preset velocity of 6.5 cm/s. The subjects were advised to keep their back and legs straight. Upon reaching a hip angle of 170 degrees, the subject was returned automatically to the initial position. Following a three minute rest interval, they were instructed to exert another maximal contraction.

6. Concentric-Isokinetic Trunk Flexion Strength Test

The body position for this test was the same as that described for the isometric trunk flexion strength test. The test was conducted through a hip angle of 170 degrees to 150 degrees. The subject was instructed to pull forward and downward as the cable was released posteriorly at the preset velocity of 6.5 cm/s. Upon achieving 150 degrees of hip flexion, the subject was automatically returned, by the cable, to the original position. Following a three minute rest interval, the subject repeated the same manuever with maximal effort.

7. Concentric-Isokinetic Bench Press Strength Test

The isokinetic electric dynamometer was used for this test. The subject was instructed to lie in a supine position on a bench. The bar height was preset two inches above the chest, parallel to midsternal position. The subject, grasping the bar in a position corresponding to shoulder width, was directed to push up, attaining full elbow extension. The bar was then automatically returned to the initial position. Following a three minute rest interval, the subject once again performed a bench press exerting maximum effort.

III. Isometric Muscular Endurance Tests

The isometric endurance tests consisted of both handgrip and arm flexion endurance. The specific loads involved were predicated on those loads typically experienced by the infantry soldier while performing various common tasks.

1. Isometric Handgrip Endurance Test

Both right and left handgrip endurance was determined by using the handgrip dynamometer. The subject was instructed to maintain a 21 kg force output for as long as possible. Upon cessation of the designated force output, the endurance (in seconds) for both the right and left hand respectively was recorded. This test was representative of the handgrip endurance requirement for the ammunition box lift task.

2. Isometric Arm Flexion Endurance Test

The isometric arm flexion endurance test was performed on a free weight apparatus consisting of a 20 kg weight connected to a bar. To simulate the elbow angle of an infantry or combat support soldier carrying a box loaded with ammunition, the subjects were instructed to maintain an elbow angle of 105 degrees while holding the weight-loaded bar. The elbow angle was monitored by a tester using a goniometer. The distance between the subjects hands gripping the bar was the same as the handgrip position for the arm flexion strength test. The subject, while maintaining the specified elbow angle, was instructed to hold the weight-loaded bar for as long as possible. Verbal encouragement was given to assist the subject in this endeavour. Additionally, a spotter relieved the subject of the weight-loaded bar upon cessation of the test. The test was concluded when it was apparent that the subject was unable to hold the weight-loaded bar at the designated elbow angle. The time (s) each subject was able to hold the weight-loaded bar was recorded.

IV. Dynamic Muscular Endurance Tests

1. Concentric-Isotonic Trapezius Lift Endurance Test

The starting position consisted of the subject standing with feet comfortably astride with arms fully extended. The subjects were instructed to stand with their knees slightly flexed. The subjects were asked to lift the weight-loaded bar to the height where their thumbs touched their clavicles, as previously described in the trapezius lift strength test. The manoeuvre was performed on a dynamometer with a 21 kg weight bar (corresponding to the weight of an ammunition box). The subject was to perform ten contractions per minute up to a maximum of a hundred repetitions. The pace was facilitated by the use of a metronome. Following the lift, the weight bar was automatically returned to the starting position. The total number of repetitions the subject was able to accomplish was recorded.

D. Testing Protocols for Field Tests

Based on a review of the scientific literature and in consultation with military subject matter experts from the Canadian Forces Base in Wainwright, Alberta and the Forces Mobile Command Headquarters in Montreal, a number of representative field tasks were chosen. In the army, the experts concurred that the most rigorous tasks are those undertaken by the Infantry. Hence, the following tasks were chosen for the study: ammunition box lift, maximal effort jerry can task, casualty evacuation, maximal and submaximal effort digging tasks and weight load march.

1. Ammunition box lift task

Testing Protocol

Each subject was required to lift a box (weighing 20.9 kg) off the floor and place it on a shelf corresponding to the height of a truck bed (1.33 m). The sequence was adjusted so that 48 boxes were lifted onto the shelf. This task was performed at 70 % VO2 max. (Oxygen uptake values were derived from treadmill testing data during the laboratory evaluation). The time (seconds) taken to complete the task was recorded.

Equipment and Human Resources Required:

1. ten boxes weighing 20.9 kg each
2. one shelf (1.33 m in height)
3. two stopwatches
4. two sport testers
5. six pylons
6. three testers

2. Transport Jerry Cans

Testing Protocol

Subject was to pick up a jerry can full of water, weighing 35 kg and carry it a distance of 35 m. The jerry can was to be emptied into a funnel at a height of 1.3 m in a controlled fashion. The subject then set the jerry can down and repeated the entire process until twelve jerry cans were emptied. Heart rate was monitored every 30 seconds. The time (seconds) taken to complete the task was recorded.

Equipment and Human Resources Required:

1. six jerry cans
2. two simulator tables
3. two stop watches
4. ten pylons
5. one bucket and mop
6. two testers
7. floor mats

3. Casualty Evacuation

Testing Protocol

Subject was to perform fireman's lift of an individual of a similar weight and height and carry this said person 100 m. Each subject was to exert maximal voluntary effort. Time (seconds) taken to complete the task was recorded.

Equipment and Human Resources Required:

1. partner of similar weight and height
2. light fighting order equipment
3. three stop watches
4. four pylons
5. three testers

4.(i) Maximal Effort Digging Task

Testing Protocol

Two boxes, one of which was filled with washed gravel (size = 1 cm in diameter) were aligned side by side on the floor. The dimensions of the metal boxes were 1.8 m x 0.6 m x 0.45 m. The subject, provided with leather work gloves and a standardized shovel, was instructed to dig gravel from one box to the adjoining box as quickly and as efficiently as possible. The subject continued the task until the tester deemed that it was completed. The time (seconds) taken to complete the task was recorded.

Equipment and Human Resources Required

1. two 0.5 m (cubed) gravel boxes
2. four standard issue shovels
3. six pairs of leather work gloves
4. three stop watches
5. watering can
6. four testers
7. fan
8. mats

4.(ii) Submaximal Digging Task at 70% of VO2 max

The same metal boxes and gravel as described above were used in this task. The subjects were instructed to moderate their performance so that they were working at a pace equivalent to 70% of their VO2 max. (The submaximal intensity was predicated on the linear HR: VO2 relationship derived from the treadmill testing which was conducted during the laboratory session in the earlier part of the study). Time (seconds) taken to complete the task was recorded.

5. Weight Load March

Testing Protocol

A distance of 16 km was determined as the optimal marching distance by the army subject matter experts. Marching was performed on a 400 m indoor track. Fifteen subjects, at any given time, undertook this task. They were spaced 100 m apart. Each participant wore combat gear and carried a back pack weighing 24.5 kg. The distance marched (m) was the performance criterion.

Equipment and Human Resources Required

1. 100 m indoor track
2. full fighting order equipment
3. two metronomes
4. loud speaker
5. two testers

E. Sequence of Laboratory and Field Testing

Sequence of Laboratory Testing

The study group consisted of 45 women identified as combat support from the CAF base in Calgary. They were integrated with the 120 infantrymen from the base who were also participating in the evaluation. The subjects were provided with a number which, in addition to a group number, was to be attached to their shirt pocket. This method facilitated identification of each subject and ensured accuracy in recording. Both the female and male subjects were assigned to eleven testing groups (A-K). Each group consisted of approximately seven to ten subjects. Testing was conducted over a 2 day period for each group. (See Tables I and II in the appendices). Detailed overviews of the laboratory testing and travel schedules for day one and day two are depicted in Tables III and IV in the appendices. Twelve days were allocated for the laboratory testing.

Day one:

Each group departed from CFB in Calgary at 0700 hours and arrived at the University of Alberta at 1100 hours. At the university, the onsite co-ordinator informed the subjects of the purpose of the study and the details about the testing. A light box lunch was provided for each subject. During this time each subject reviewed the testing advisory (See Appendix I, A1). Promptness as well as adhering to rest schedules were emphasized to the subjects. Over the course of the introduction, the subjects were required to complete a consent form and an EXPRES health appraisal questionnaire (Appendix 1, A2). Testing for this particular group began at 1300 hours and was completed at 1900 hours. Test one represented the muscular strength test battery; test two represented underwater weighing and bioelectrical impedance, test three represented the muscular endurance test battery, test four represented determination of actual residual lung volume, test five represented bone density assessment and test six involved responding to the questionnaires on physical activity, perceptions of weight and physical fitness, menstrual history and the body cathexis inventory. Testing was scheduled so that passive activities such as body composition analysis was interspersed between activities requiring muscular exertion. During the maximal effort strength tests, each subject rested for three minutes prior to undertaking another maximal contraction. Moreover, each subject was asked if they had recuperated and were ready to repeat the test.

Day two:

Testing was initiated at 0700 hours and was completed at

1200 hours. The second day of testing for the first group was representative of the first day of testing for the second group. The same procedure (i.e. introduction, etc.) was followed as described previously. On day 2, Group A departed for CFB Calgary at 1300 hours. This format was replicated for each group.

Sequence of Field Testing

The common field tasks were scheduled over a period of six days. Each group completed all field testing in one day as requested by army officials. The tasks were ordered from the most facile to the most arduous. Table V {see appendices} represents the schedule for adminstration and briefing, casualty evacuation and weightload marching. Table V1 {see appendices} represents the schedule for casualty evacuation, maximal effort jerry can, submaximal effort digging task, ammunition box lift tasks and weight load marching. Lunch and dinner were scheduled between 1100-1300 hours and 1600-1800 hours respectively. The subjects were advised to adhere to their specific schedules so that prior to engaging in physical labour two hours had elapsed after the ingestion of a meal. Thirty minutes rest were allocated to each subject following the tasks of casualty evacuation and maximal effort jerry can tasks.

The weight load marching schedule is depicted in the appendices (Table VI). Groups, consisting of 15 subjects, marched for 3 consecutive hours, group one beginning at 0900 hours.

F. Statistical Analysis of the Data

The following statistical analysis was used (level of significance = 0.05).

1. Descriptive statistics including mean, median, standard deviation and range were reported for both laboratory and field variables.
2. Pearson product moment correlation coefficients were computed between the laboratory and field tests to determine the relationship between variables such as muscular strength, bone density, anthropometric measures and body cathexis scale scores and task performance.
3. Pearson product moment correlation coefficients were also computed to determine the relationship between certain laboratory measures such as bone density and muscular strength and anthropometric measures.
4. Pearson product moment correlation coefficients were determined to ascertain the relationship between body cathexis scores and relative and absolute values of muscle strength.
5. Stepwise multiple regression analyses were used to determine which explanatory variables were predictive of performance.

CHAPTER IV
RESULTS AND DISCUSSION

A. Subject Description

Forty five women participated in an evaluation of their muscle strength and endurance, body composition (including bone density) and a psychological measure of their self-esteem. The number of subjects who participated in five out of the six field tasks, which were performed at the Canadian Armed Forces base in Calgary, Alberta, was variable due to circumstances beyond the control of the researcher. Because of a time restraint, twenty-four of the subjects participated in the submaximal digging task. This particular study was done in conjunction with a larger study which was concerned with the performance standards of combat personnel.

Table 2 depicts the characteristics of the subjects.

Table 2: Characteristics of subjects

Demographics	Mean	Median	S.D.	Range
age (yrs)	26.1	25.0	4.5	19-36
height (cm)	164.3	164.6	5.8	151.7-175.7
weight (kg)	63.5	62.5	5.6	54.3-83.1
BMI (kg/m^2)	23.6	23.1	2.6	19.5-30.8
VO2 max (l/min)	2.7	2.7	0.4	2.1-3.8

The mean age of a sample of over two thousand female Canadian Forces personnel was 26.2 ± 5.1 yrs (Jette et al. 1990) - akin to that of the subjects. The average age of the

U.S. army women derived from the sample in 1946 (27.3 ± 5.8 yrs) was similar to the average age of the Canadian army women. In contrast the U.S. army women in the 1977 sample, where mean age was equal to 23.1 ± 5.4 yrs, were younger than the subjects.

Similar heights and weights have been demonstrated in other military populations. Beckett and Hodgdon (1987) reported that in a group of 38 active duty navy personnel mean body weight was 61.4±7.64 kg and mean height was 165.4±6.02 cm. Corresponding average height (164.3 ± 6.2 cm) and weight (60.1 ± 7.5 kg) was described by Robertson and Trent (1985) in a group of 259 female recruits in the later half of their training. Jette et al. (1990) showed an analagous average weight (62.7±9.8 kg) and height (164.3±6.4 cm) in their sample of over two thousand Canadian Forces personnel. However, in comparison with anthropometric data collected from eight thousand eight hundred U.S. army women in 1946 and one thousand three hundred army women in 1977, the subjects were both taller and heavier than their U.S. counterparts. Mean weight of the U.S. army women was 59.6 ± 9.0 kg in 1946 and 60.0 ± 8.7 kg in 1977. The mean height of these women was 162.1 ± 6.0 cm in 1946 and 163.0 ± 6.5 cm in 1977 (White, 1979).

The subjects reflected a BMI of 23.6±2.6 kg/m². According to the **Canadian Guidelines for Healthy Weights** (1988), this placed them in Zone B, which is classified as a good weight for most people. Other researchers (Jette et al. 1990) purported that a BMI in the range of 19-24 kg/m² was healthy. Jette et al. (1990) reported that the BMI of 2,087 female Canadian Forces personnel was 23.2±3.0 kg/m². In a group of 162 female soldiers, aged 18 to 39 years Vogel et al. (1988) determined body mass index to be 22.9±2.9 - comparable to the mean value shown by the C.A.F. women.

According to the classification of maximal oxygen uptake by Astrand (1960), the subjects reflected values which were high, both for the 20 to 29 year age range as well as the 30 to 39 year age range. Oxygen uptake values of the subjects surpassed those of American recruits who showed oxygen uptake values of 1.3 ± 0.7 l/min and also those of female soldiers (1.9 ± 1.0 l/min) who were involve in basic training (DiBenedetto, 1989). However, these oxygen uptake values were no doubt underpredicted because the step test was utilized to determine cardiovascular fitness.

The anthropometric meausurements of the subjects are displayed in Table 3.

Table 3: Anthropometric measures of subjects				
Parameter	Mean	Median	S.D.	Range
chest girth (cm)	79.0	77.8	5.6	71.0-99.0
waist girth (cm)	69.6	68.2	6.4	59.0-90.0
hip girth (cm)	97.7	96.6	6.2	89.8-115.2
R thigh girth (cm)	60.1	59.9	4.7	51.0-71.8
waist/hip ratio	0.7	0.7	0.1	0.6-0.8
sum of 5 skin-folds (mm)	63.3	66.8	17.1	27.2-100.2
% body fat (hydrostatic)	29.0	29.1	6.2	12.3-42.5
fat weight (kg)	18.4	17.9	5.2	7.4-33.4
lean weight (kg)	44.4	44.0	3.9	36.4-55.3
%body fat (BIA)	27.5	27.0	4.6	18.0-39.0

Percent body fat was determined by hydrodensitometry, using estimated residual lung volumes. Sixteen subjects had their lung volumes measured directly using the helium dilution method. However, due to the variance between the estimated and measured residual lung volumes, a regression equation was not developed. (See Table VII in Appendices). The subjects were characterized by mean percent body fat measures of 29.0 ± 6.2% compared to 28.8% ± 6.3% reported by Vogel et al. (1988). Similarly, Vogel et al.'s (1988) subjects were drawn from a military population who were described as Casucasian, aged 18 to 39 years. Beckett and Hodgdon reported lower values of percent body fat (26.3 ± 4.86) for their group of female navy personnel. However, this may be accounted for because of the different method used to determine percent body fat. Instead of using hydrodensitometry, body composition was assessed using body circumference measures and height based on regression equations developed by the researchers.

When the subjects were questioned about their body weight (Appendix 13), 57.1% claimed they felt they were overweight. Perhaps they have assimilated the message, espoused by Jette et al. (1990), that the army does not want overweight, pearshaped persons who don't match the military image of the soldier primed for fighting.

The mean value for lean body mass (45.0 ± 3.75 kg) of the navy personnel did correspond to the value reflected by the military subjects in this study. Interestingly, when the waist and hip measurements of the subjects were compared to the data derived from the anthropometric survey conducted by the Army Quartermaster Corps in 1946 and again in 1977 (White, 1979), the subject's mean waist circumference was approximately midway between the two previously determined values (67.0 ± 6.2 and 71.0 ± 6.9 cm).

In contrast, the subject's hip girth was notably larger than the mean value measured in 1946 (95.1 ± 6.7 cm) and also in 1977 (95.5 ± 6.4 cm). White (1979) alleged that whereas the common perception that North Americans are growing in size and stature is simply not true, he did maintain that body proportions are changing. In as much as White (1979) reported that mean weight, height and hip circumference increased marginally over a period of about thirty years, the most substantial increment was reflected by mean waist circumference.

In comparison to the circumference measures described by Jette et al. (1990), whereas mean chest girth (79.3 ± 7.1 cm) was alike that of the subjects, the Canadian Forces personnel of their study showed smaller hip (95.7 ± 7.2 cm) and thigh (57.3 ± 5.6 cm) measurements. However, mean waist circumference was notably reduced in the subjects in contrast to the average waist girth of 73.2 ± 8.3 cm reflected by those who participated in the study by Jette et al. (1990).

The mean waist/hip ratio of the subjects was 0.7 ± 0.1. Based on the findings of Bjontorp (1985) a value of 0.8 or above places an individual at an increased cardiovascular health risk. The data on the American soldiers (Vogel et al. 1988) showed that their mean waist/hip ratio (0.78 ± 0.06) more closely approximated this zone of risk. Jette et al. (1990) also revealed that the waist/hip ratio (0.76 ± 0.06) of their larger sample of Canadian women in the Armed Forces more closely approached the risk zone.

Table 4 depicts the descriptive results for the maximal static strength tests.

Table 4: Descriptive results for Maximal Static Strength Tests (kg)

Parameter	Mean	Median	S.D.	Range
Right Handgrip	33.1	34.0	4.2	26.0-45.0
Left Handgrip	30.8	31.0	4.3	23.0-43.0
Average Handgrip	31.9	32.0	4.1	26.0-44.0
Arm Flexion	35.4	34.8	14.2	14.4-83.9
Trunk Flexion	48.7	50.1	7.5	28.5-61.8
Trunk Extension	109.5	106.1	15.7	84.9-154.9

In a group of similarly sized female navy personnel, Robertson and Trent (1985) reported a mean handgrip strength (40.9 ± 4.9 kg) which was greater than that reflected by the subjects. The differences in handgrip strength could not be accounted for by a dissimilar measuring device because a handgrip dynamometer was also used by Robertson and Trent. However, unlike the subjects, the group studied by these researchers consisted of 259 recruits who were in the process of undergoing intensive strength training.

In contrast, the handgrip strength values of women in an industrial population (27.0 ± 6.0 kg) were less than those typifying army personnel (Kamon et al. 1978). Nevertheless, Anderson (1988) emphasized that handgrip strength was the most important limiting factor for women in the Armed Forces, especially for those who wished to pursue careers as firefighters or members of the emergency rescue team.

Isometric strength of the arm flexors of a group of a 152 female flight attendants (41.0 ± 11.0 kg) was also greater when compared to the subject's average value (Hunt, 1979). A somewhat different measuring protocol was used (static arm lift was measured 100 cm from the floor) which might account for the discrepancy in mean strengths.

The average static trunk extension value (74.2 ± 21.8 kg) of the flight attendants was less than that shown by the subjects. The difference in mean strength may be explained by the dissimilarity in measurement protocol. Also the author reported that the flight attendants were taller and weighed less than the average CAF subject population. Furthermore, 9.2% of the flight attendants did not participate in the evaluation of static back strength because of recent back injuries or back pain.

The back strength of a group of 205 women students was measured isometrically using a dynamometer by Bale et al. (1985). They reported similar mean values in comparison to the data reflected by the flight attendants (77.9 ± 21.3 kg). Although the mean height and weight of these subjects corresponded to that of the army sample, the students were significantly younger. Also a detailed explanation of the strength measuring protocol was omitted in this study.

Troup and Chapman (1969) described the static strength of the flexor and extensor muscles of the trunk in a group of 132 female physical education students (aged 18-23 yrs) who were typified by mean height (164.0 ± 5.6 cm) and weight (61.0 ± 5.7 kg) indices which were not unlike those of the subjects. When compared to the subjects, the physical education students revealed analogous static trunk flexor strength (47.0 ± 10.4 kg) but dissimilar static trunk extensor strength (66.0 ± 12.9). Dissimilarities between the two groups may be explained by the different static strength measuring instruments used-a dynamometer incorporating a strain gauge was implemented by Troup and Chapman (1969) and that the physical education students were relatively younger and probably not "work hardened" in comparison to the Armed Forces personnel.

In another group of young (mean age: 20.0 yrs) female students, Nordgren (1972) described trunk flexion (39.7 ±8.6 kg) and extension (52.3 ± 9.1 kg) static strength values which were markedly less than those reflected by the subjects. However, static strength values of the upper body as reflected by arm flexor (32.8 ± 4.7 kg) and right (31.0 ± 6.4 kg) and left (28.6 ± 5.5 kg) handgrip strength were similar in comparison to that of the army personnel.

In an industrial population, Chaffin et al. (1978) examined the arm, leg and torso lifting strengths of women workers. They reported mean strengths of 20.4 ± 8.0 kg, 42.6 ± 20.2 kg and 27.2 ± 14.1 kg for arm, leg and torso lifting strengths respectively. The arm, leg and torso strength of one hundred and five women workers was evaluated in order to develop population strength data based on height, body weight and age. They demonstrated that the younger, heavier and taller women were stronger. Predicted standard torso strengths ranged from 22.9 to 47.9 kg in the younger age range. Similarly predicted arm strength varied between 18.7 to 29.2 kg and leg strength ranged from 37.4 to 68.9 kg. All of these values were surpassed by the army subjects. Discrepancies in strength measures again could be attributable to the differing strength testing protocol, the type of equipment used and variations in the subject population.

Pedersen et al.(1989) alleged that the static back muscle strength should be at least equivalent to the load being carried. They reported that those workers who were characterized by static back strengths which were less than the load carried have three times the risk of incurring low back pain. In this study static measures of back strength exceeded both the load lifted (ammunition box: 20.9 kg) and the load carried (jerry can: 35 kg).

Table 5: Descriptive Results for Maximal Isokinetic-Concentric Strength Tests (kg)				
Parameter	Mean	Median	S.D.	Range
Right Knee Flexion	70.3	71.0	11.1	42.0-91.0
Left Knee Flexion	69.4	68.5	10.1	47.0-88.0
Average Knee Flexion	69.9	70.0	10.0	44.5-89.5
Right Knee Extension	99.7	98.5	11.8	72.0-129.0
Left Knee Extension	99.6	94.5	15.2	65.0-136.0
Average Knee Extension	99.7	99.0	12.7	68.5-129.0
Trunk Flexion	50.9	51.1	7.4	37.2-66.6
Trunk Extension	101.1	97.5	15.5	57.7-138.0
Leg Extension	154.5	148.8	43.5	83.1-241.2
Trapezius	44.5	43.7	9.7	21.6-67.8
Bench Press	69.2	66.9	17.4	30.4-111.2
Arm Flexion	46.2	43.5	15.2	25.7-87.1

Although strength values are reported in the literature for the female athletic population, very little information is available for the working populace. Morrow and Hosler (1981) reported strength values for bench press at 20° in a group of one hundred and sixty basketball and volleyball players (43.2 ± 11.7 kg and 40.7 ± 10.3 kg) to be less than the mean value evinced by the subjects. Wilmore et al. (1974) showed that bench press strength increased from 24.5 kg to 31.8 kg after a ten week weight training session in a group of college aged students. These values are considerably lower than those of the subjects who were probably stronger than the college athletes because of the training effected by their occupational demands.

In a group of 129 female recruits, DiBenedetto (1989) reported that bench press strength as determined by the one time maximum lift score using Nautilus equipment was equivalent to 31.8 ± 4.1 kg. This score fell withing the lower range of scores reflected by the subjects. Arm flexion strength values (22.7 ± 3.6 kg) were also lower in this population in comparison to the subjects. Differences in testing protocol, equipment and work experience of the soldiers may help explain the variation in results.

In contrast to upper body strength measures where the athletic population in these studies reflected lower strength values than did the subjects, knee flexor and extensor strength in a group of female athletes as measured on the Cybex 11 dynamometer (60°/s) was greater (Dibrezzo et al., 1988 and Bond et al. 1985). In a group of 21 female subjects (aged 21-36 yrs), knee flexor strength was 79.4 ± 18.0 kg and knee extensor strength was 137.4 ± 24.3 kg. Likewise, Bond et al. (1985), using the Cybex dynamometer at an angular velocity of 30°/s, reported greater knee flexion strength (83.4 ± 5.4 kg) and knee extension strength (159.1 ± 12.6 kg) than that shown by the subjects. The isokinetic strength test of the present investigation was conducted at a limb angular velocity of 180°/s. It is known (Heyward, 1984) that the faster speed results in a lower force output. Furthermore, the experimental group in Bond et al.'s study consisted of eight body builders who had strength trained over the past year.

In a group of one hundred and fifty female firefighter applicants (age: 20 to 42 years) Misner et al. (1988) reported a mean leg extension strength of 143.5 kg. This value fell within the range exemplified by the subjects. Misner et al. (1988) recounted that the leg extension strength of the reference woman is 76.2 kg, a value well below that which characterized both the firefighter applicants and the CAF subjects.

The descriptive results for the muscular endurance tests are shown in Table 6.

Table 6: Descriptive Results for Muscular Endurance Tests

Parameter	Mean	Median	S.D.	Range
Static Right Handgrip (s)	38.7	34.5	20.9	6.0-91.0
Static Left Handgrip (s)	31.2	30.0	23.0	6.0-109.0
Static Average Handgrip (s)	36.9	31.8	20.5	6.0-89.5
Static Arm Flexion (s)	42.6	40.5	23.8	11.0-104.0
Dynamic Trapezius Lifts (repetitions)	23.3	10.0	28.8	1.0-100.0

Table 6 displays endurance scores for the upper body. Although Knapik (1989) asserted that muscular endurance is axiomatic in the performance of army tasks such as lifting sand bags, crates and weapons, no previous army related studies have examined the push-up endurance capacity of women. Typically, those endurance measures which were evaluated in the military setting consisted of the number of push-ups, sit-ups and pull-ups that male soldiers could complete (Knapik, 1989).

Table 7 reflects the descriptive results for the field tasks.

Table 7: Descriptive Results for Field Tasks

Task	n	Mean	Median	S.D.	Range
Ammunition Box Lift (s)	34	368.5	325.5	171.9	165.0-979.0
Maximal Effort Jerry Can (s)	37	285.2	285.0	28.9	238.0-356.0
Maximal Effort Digging (s)	36	428.1	431.0	63.7	296.0-553.0
Submaximal Digging (s)	24	1362.0	1341.0	314.5	899.0-2460.0
Casualty Evacuation (s)	36	69.6	67.8	17.5	47.5-123.5
Weight Load March (m)	37	9924.3	9200.0	4278.4	3200.0-16000.0

m=meters

All of the above tasks were timed to determine performance level with the exception of the weight load marching task where distance marched was the performance criterion.

B. Bone density measurements of the lumbar and hip regions

Table 8 depicts the characteristics of the bone mineral density of the lumbar and hip region.

Table 8: Bone mineral density characteristics

B.M.D. (g/cm^2)	Mean	Median	S.D.	Range
L2-4	1.054	1.055	0.097	.796-1.259
Ward's	.749	.722	0.106	.486-
Femoral	1.003	.997	0.096	.827-

Over forty percent of the subjects showed bone mineral densities of the lumbar and hip region which were similar to age matched norms. (These normative values were derived from bone density measures obtained from women residing in California; Gantz, 1990). Only one of the subjects evinced a bone mineral density reading of both the lumbar and hip region which was significantly below the age matched norm (that is more than two standard deviations below what is considered a typical bone density for her age). Nevertheless, 56.8% of the sample revealed bone density values that were less (i.e. within one to two standard deviations) than those values of their age matched controls. This finding was evidenced not only in the data derived from the subjects lumbar region but also from bone density readings of the hip. Why this phenomenon exists is, at the present time, speculative. Possible reasons suggested for the differences in bone density between the two groups were the sunny climate in California, and varying patterns of physical activity (personal communication, Heslip,1991 and Gantz, 1990).

Riggs et al.(1981) defined the fracture threshold of the vertebrae to be 0.965 g/cm². When the vertebral bone densities of the subjects from this study were compared it was found that six of this group exhibited bone densities which were below the fracture threshold. Overall 29.5% of the sample evinced vertebral bone densities that were either below or close to the fracture threshold.

When the mean values for vertebral bone density (1.054 g/cm²) of the women from the Canadian Armed Forces were compared to various other groups it was seen that higher values were reflected by both amenorrheic and eumenorrheic athletes of the Drinkwater et al.(1984) study (1.12 ± 0.04 g/cm² and 1.30 ± 0.03 g/cm² respectively). (See Table 9). With the exception of one subject (who reported that she has been amenorrheic for the past 10 years) the other women in this study alleged that they experienced regular menstrual cycles. Hence menstrual status did not account for the differences reflected by the two groups. Drinkwater et al.(1984) further postulated that exercise has a salubrious effect upon the skeleton and hence this may be one of the reasons why her group of athletes showed higher bone density values in comparison to the combat support group in this study which consisted of both active and inactive members.

In contrast to the findings of Drinkwater et al.(1984), Davies et al.(1990) reported lower bone density values of the lumbar vertebrae in a relatively young, nonathletic group of women. The group of women who reflected particularly low mean bone densities of the lumbar vertebrae were those who were classified as either anorexic or bulemic (0.898±0.136 g/cm² and 1.006±0.129 g/cm² respectively).

Although aging and menstrual status is supposed to have a more or less deleterious impact on bone density, the mean values (1.06±0.18 g/cm²) evinced by Sinaki's et al.(1986) group of postmenopausal women (aged 45-65 years) were not significantly different from the mean values (1.054±0.97 g/cm²) of the younger (age range:19-36 years) premenopausal CAF women. Why these differences were not more pronounced may be attributable to the relatively small sample sizes in both groups and that various factors known to influence bone density (such as calcium/protein ingestion, physical activity levels, etc.) were not controlled for.

The same or similar instrumentation was used in all four studies to measure bone mineral density. Dual photon absorptiometry as reported by Drinkwater et al. (1986) has a reliability coefficient of 0.97 and a standard error of measurement of 0.03 g/cm².

Table 9: Comparison of vertebral bone densities of study group with other values reported in the literature.

AUTHOR	SUBJECTS	MEAN AND STD.DEV. BONE DENSITY OF L2-4 (G/CM)^2
present study	44 CAF women (19-36 yrs)	1.054±.097
Davies et al.1990	150 healthy non-athletes (18-25 yrs)	1.039±0.106
	26 anorexic women	0.898±0.136
	26 anorexic/bulemic women	0.936±0.145
	11 bulemic women	1.006±0.129
Sinaki et al.1986	68 healthy postmen-opausal women (45-65 yrs)	1.06±0.18
Drinkwater et al. 1984	14 amenorrheic athletes	1.12±0.04
	14 eumenorrheic athletes	1.30±0.03

C. Other Parameters Correlated with Bone Density

Table 10 depicts correlation coefficients between selected demographic factors, body composition, weight loss, amount of weight lost, birth control pills and parity and bone density of both the lumbar and hip region.

Table 10: Correlation coefficients between bone mineral densities of the lumbar and femoral regions and selected parameters.

Parameter	Bone density (L2-4)	Bone density (Ward's triangle)	Bone density (femoral neck)
age	r=.1386	r=-.2721*	r=.0265
height	r=-.2206	r= .2069	r=-.1436
body weight	r=.2008	r= .1455	r=.1652
%body fat	r=-.2589*	r=-.3089*	r=-.4419*
lean weight	r=.4171*	r=.4992*	r=.4990*
weight loss	r=.2102	r=.2241	r=.4450*
amount of weight loss	r=.3825*	r=.0053	r=.4116
birth control pills	r=.1979	r=-.0339	r=.1416
parity	r=.3971*	r=.0003	r=-.5454*
BMI	r=.3141*	r=-.0786	r=.2275

*level of significance: $p \leq 0.05$

Bone Density and Age

Given that the age span was small (age range: 19-36 years) in the CAF group and that several authors (Davies et al.1990; Rodin et al.1989) purported that individuals continue to accumulate bone into the third decade of life, it is not surprising that a strong positive correlation does not exist between age and bone density in this particular sample. There are, however, age related differences in peak bone mass depending upon whether vertebral bone density or the bone density of the femoral neck is examined. Rodin et al. (1989)

showed that in a group of 225 Caucasian women ages 18-52 that bone mineral density of L2-4 peaked in the mid-thirties. Conversely, femoral bone displayed no such peak and actually showed mineral depletion in this area beginning in the late twenties. Similarly a nonsignificant positive correlation (r=.1386) between age and lumbar bone density was reflected by the CAF women and a significant inverse correlation (r=-.2721) was evidenced between age and the bone density of the area known as "Ward's triangle" in the femoral neck.

Bone Density and Height

While some authors (Sinaki et al.1986) professed that there is a positive correlation (r=0.38) between bone mineral density of the spine and height in postmenopausal women, others suggested that this relationship is borne out only with younger premenopausal women (Stevenson et al. 1989). Contrary to these findings the CAF women showed a nonsignificant inverse relationship (r=-.2206) between height and spinal bone density. Nonsignificant correlations were also demonstrated between height and:(1) Ward's triangle (r=.2069) and (2) femoral bone density (r=-.1436).

Bone Density and Body Weight

Stevenson et al.(1989) showed that body weight was positively correlated with femoral and spinal bone density only in postmenopausal women but reported no evidence of a similar relationship in a group of 112 premenopausal women (median age

34.1 years). Cooper (1989) speculated that increased body weight (at least in menopausal women) will enhance bone mass through skeletal loading. Several authors (Davies et al.1990 and Rigotti et al.1984) have demonstrated that bone mineral is depleted in anorexic women. In the present investigation of 44 CAF women a nonsignificant positive correlation (r=.2008) existed between body weight and bone density of the spine. Similarly, a non-significant, positive correlation was apparent between femoral bone density and body weight.

Various Indices of Body Weight and Correlations to Bone Density

Body mass index, which is a more sensitive indicator of overweight than simply the body weight of an individual, showed a significant positive correlation (r=.3141) with spinal bone density in the group of CAF women. Conversely a nonsignificant relationship was revealed between femoral bone density and BMI.

Although several authors (Cooper,1989; Nomura et al.1989; Stevenson et al.1989) concurred that body weight is a significant determinant of bone density, none of these researchers looked at the correlations with spinal and femoral bone density based on the two compartment model of body weight. This study showed that whereas percent body fat (as determined by hydrostatic underwater weighing) reflected significantly negative correlations with bone density of both the femoral and spinal areas, lean body weight was significantly and positively associated with bone density of both regions. This finding corroborated the research of Doyle et al. (1970) who reported a significant relationship between the weight of the psoas muscle and the bone mass of the third lumbar vertebrae.

The instrument used to ascertain weight loss was a questionnaire and an inherent problem with this method is that recall is subject to error. However, given this limitation, over half of the sample (54.8%) reported a weight loss over the past year (ranging from 3 to 30 pounds; mean: 13.2±7.5 pounds; median 10.0 pounds). Although a nonsignificant correlation was evidenced between spinal bone density and weight loss, a significant positive correlation (r=.3825) existed between the amount of weight lost in the past year and spinal bone density. In contrast, weight loss (but not amount of weight lost) was significantly correlated with bone density of the intertrochanteric region. However, these relationships were not replicated for bone density measurements of Ward's triangle.

Relationship Between Birth Control Pills and Bone Density of Both the Lumbar and Femoral Regions

Various authors (Bilanin et al.1989; Martin & Houston,1987; Drinkwater et al.1984,1986) have imputed estrogen as a beneficial hormone which facilitates bone accretion, although no specific estrogen receptors have been found on bone (Hedayati & Zuzga, 1988). Drinkwater et al. (1984) while acknowledging that estrogen has a beneficial impact on bone status, does suggest that the mechanism by which this hormone affects bone mineralization, is unknown. Others (Rodin et al.1989; Avioli & Repa-Eschen, 1988; Riggs & Melton, 1986; Riggs et al.1986) have argued that there is unequivocal evidence of a declining vertebral bone mass while women are in the premenopausal stage of life. This contravenes the theory that simply because women are menopausal (and thereby estrogen depleted) that this generally predisposes them to osteoporosis. As Avioli & Repa-Eschen (p.29, 1988) were careful to emphasize, "some, but not all women" are subject to the debilitating effects of bone loss due to an "estrogen deficient state".

Several authors (Stevenson et al.1989; McCulloch et al.1988) have examined the relationship between bone density and the use of birth control pills. No one was able to show a significant relationship. Similarly, in this study, the correlations between bone density of both the femoral and lumbar regions and birth control pill use were non-significant.

Relationship Between Parity and Bone Density

The general consensus, as indicated by some researchers (Elders et al.1989; Lambke et al.1977; Goldsmith & Johnston 1975) is that parity confers a beneficial effect upon bone density. Lambke et al. (1977) reported that this attribute is not confined to humans but is evidenced in other members of the animal kingdom. (For example, in cattle bone mineral content is enhanced both during pregnancy and lactation. Similarly, in birds, an increase of preovulatory estrogen enhances calcium deposition in eggshells) Lambke et al. (1977). Elders et al.

(1989) cited nulliparity as a risk factor for the development of osteoporosis. However, unlike the present study, the earlier studies (Lambke et al.1977; Goldsmith & Johnston, 1975) did not examine the effect of pregnancy and bearing children on trabecular bone. In the group of 44 CAF women, a significant positive correlation was demonstrated between bone density of the lumbar region and those women who reported giving birth to children (r=.3971). In contrast, while no such relationship was evidenced between bone density of the femoral region known as Ward's triangle and childbearing (r=.0003), an inverse significant correlation (r=-.5454) was noted between the intertrochanteric region of the femur and parity. Hence, the results from this study were equivocal and the effects of parity on bone density remain a conundrum.

D. Relationship between Bone Density and Muscle Strength

The following tables depict the Pearson product moment correlation coefficients between the bone density of the lumbar and femoral areas and muscle strength and endurance of the upper, lower and trunk regions of the body. Table 11 represents the relationship between right, left and average handgrip strength and bone density of both the lumbar and femoral regions.

Table 11: Correlation coefficients between bone density and handgrip strength measures

Handgrip Strength	Bone Density (L2-4)	Bone Density (Ward's)	Bone Density femoral neck
R handgrip	r=.0892	r=.2650 *	r=.5471 *
L handgrip	r=.2105	r=.1429	r=.5866 *
Average handgrip	r=.1585	r=.2119	r=.6044 *

* level of significance: $p \leq 0.05$

Significant correlations existed between handgrip strength and femoral bone density. This same relationship was not replicated between handgrip strength and bone density of the lumbar region.

Table 12: Correlation coefficients between bone density and upper body endurance measures

Endurance Measures	Bone Density L2-4	Bone density Ward's	Bone density femoral neck
R handgrip	r=.2416	r=.5082 *	r=.5443 *
L handgrip	r=.2865 *	r=.4353 *	r=.5290 *
Av. handgrip	r=.2840 *	r=.5034 *	r=.6044 *
Trapezius lift	r=.1236	r=-.0074	r=-.0897
Static arm flexion	r=-.1537	r=-.0262	r=.0911

* level of significance: $p \leq 0.05$

When the relationship between right, left and average handgrip endurance and bone density of the femoral and lumbar regions was examined,it was found that all three measures of endurance were significantly correlated to bone density of the femoral region. (See Table 12). A similar, but not as strong a pattern was evidenced between measures of left and average handgrip endurance and lumbar bone density. Neither trapezius lift endurance, nor static arm flexion endurance revealed significant positive relationships with bone densities of the two regions.

Table 13: Correlation coefficients between bone density and knee flexor and extensor strength

Lower Body Strength	Bone Density L2-4	Bone Density Ward's	Bone Density femoral neck
R Knee Flexion	r=.1919	r=.3680 *	r=.5809 *
L Knee Flexion	r=.1193	r=.4148 *	r=.3230
Av. Knee Flexion	r=.1656	r=.4107 *	r=.5134 *
R Knee Extension	r=.1317	r=.3355 *	r=.1175
L Knee Extension	r=.0133	r=.3384 *	r=.1578
Av. Knee Extension	r=.0690	r=.3581 *	r=.1534

* significance: $p \leq 0.05$

Positive significant relationships were evident between the strength measures of both the knee flexors and extensors and the bone density of the femoral region (Ward's triangle) but not the lumbar region. (See Table 13). This was not an unexpected finding because it is now generally recognized that there is a positive relationship between bone density and the strength of muscles anatomically related to region of the bone in question (Martin & McCulloch,1987; Ellis & Cohn,1975).

However, not all researchers (Rilki & McManis,1990; Sinaki et al.1976; Nilsson & Westlin,1971) have found a significant positive correlation between anatomically related muscle strength and bone density. For example, Nilsson & Westlin (1971) reported that there was no correlation between strength of the quadricep muscles and bone density of the distal femoral area. Similarly, Sinaki et al.(1976) did not find a significant correlation between the maximal isometric strength of the elbow flexors and bone density of the mid and distal radius.

Rilki & McManis (1990) alleged that no significant differences in relation to bone density of the distal third of the radius of the nondominant arm existed between a group of women (aged 57-83) who engaged in a general aerobics exercise class (40-50 minutes, 3x/week for 10 months) and a similar group of women who, in addition to partaking in the aerobics class, also participated in a progressive resistance exercise program to strengthen the upper body. The exercise groups, however, did display a significantly higher bone density than did the controls. They concluded that exercise has a general, rather than a specific effect on bone density.

Perhaps this general as opposed to specific effect of exercise on bone density explains why, in the female infantry soldiers, the nonanatomically related muscular strength of the forearm was significantly correlated with femoral bone density. Moreover, work in the armed forces often entails lifting and carrying tasks (Knapik et al. 1989 and 1990) which would not only enhance upper body strength but would increase the load applied to the femur.

Table 14: Correlation coefficients between bone density and static and dynamic measures of upper and lower body strength

Static and Dynamic Strength Tests	Bone Density L2-4	Bone Density Ward's	Bone Density femoral neck
Static arm flexion	r=-.1112	r=-.0281	r=.0324
Dynamic arm flexion	r=-.0453	r=.1678	r=.3955 *
Dynamic leg extension	r=.0344	r=.2732 *	r=.2798
Dynamic trapezius lift	r=.2166	r=.1667	r=.1307
Bench press	r=.2113	r=.1744	r=.0080

* significance: $p \leq 0.05$

Table 14 reveals a significant positive relationship only between the strength measurements of dynamic leg extension and dynamic arm flexion and bone density of the femoral region (Ward's triangle). Positive non-significant correlations exist between dynamic trapezius lift strength and bench press and the bone density of the lumbar region. A nonsignificant, inverse correlation is evident between static and dynamic arm flexion and bone density of the L2-4 region.

Table 15: Correlation coefficients between bone density and static and dynamic trunk flexion and extension

Static & Dynamic Trunk Strength	Bone Density L2-4	Bone Density Ward's	Bone Density femoral neck
Static trunk flexion	r=.1078	r=.2705 *	r=.2776
Dynamic trunk flexion	r=.0556	r=.2679 *	r=.2358
Static trunk extension	r=.0963	r=.1176	r=.4881 *
Dynamic trunk extension	r=-.0474	r=.0263	r=.3476

* level of significance: $p \leq 0.05$

Table 15 shows a positive, significant correlation between static and dynamic trunk flexion strength and femoral bone density (Ward's triangle). A stronger significant correlation (r=.4881) was demonstrated between static trunk extension strength and bone density of the femoral neck. Unexpectedly, these static and dynamic measures of trunk strength did not show a positive correlation with bone density of the lumbar region. This is contrary to the findings of Sinaki et al. (1986) who showed a significant positive correlation between the muscle strength of the back extensors and the bone density of the lumbar area (L2-4) in a group of 68 postmenopausal Caucasian women. These authors postulated that the strength of the back extensors may be a factor influencing vertebral bone mineral density. Why the findings of the present study do not conform to those of Sinaki et al. (1986) may be because the women in this investigation were not in the menopausal age group.

E. Relationship between Bone Density of the Lumbar and Femoral Regions and Field Tests

The significant correlations evinced between bone density and the field tests were the inverse correlations between the ammunition box lift task and Ward's triangle and the submaximal and maximal effort digging tasks and bone density of the femoral neck. (See Table 16). Casualty evacuation, maximal effort jerry can task and weight load march displayed a nonsignificant relationship with both femoral and lumbar bone densities.

Table 16: Correlation coefficients between bone mineral density measures and field tasks

Field Tasks	Bone Density L2-4	Bone Density Ward's	Bone Density femoral neck
Ammunition box lift	r=-.1038 n=(33)	r=-.3413 * n=(33)	r=-.4489 n=(12)
Submaximal dig	r=-.2604 n=(24)	r=-.3025 n=(24)	r=-.5848 * n=(10)
Maximal Dig	r=-.1972 n=(35)	r=-.2054 n=(35)	r=-.5306 * n=(16)
Casualty Evacuation	r=-.0202 n=(35)	r=-.0602 n=(35)	r=-.2340 n=(15)
Maximal Effort Jerry Can	r=.1373 n=(36)	r=.0592 n=(36)	r=.2817 n=(16)
March	r=-.0333 n=(37)	r=.0141 n=(37)	r=-.3331 n=(16)

* level of significance: $p \leq 0.05$

F. Stepwise multiple regresssion of several demographic related to lumbar and femoral bone density

Table 17 displays several variables which were significantly related to lumbar bone density and also that explanatory factor which was predictive of bone density in this region.

Table 17: Stepwise multiple regression of several demographic variables related to lumbar bone density

Multiple R	R Square	Adj. R Square	Standard Error	F	Sig F
.444	.197	.155	.093	4.68	.043
Variable	**B**	**SE B**	**Beta**	**T**	**Sig T**
lean body weight	.012	.005	.444	2.16	.043
% body fat	.168	.158	.714	.679	.506
amount of weight lost	.272	.303	.999	1.35	.193
parity	-.267	-.298	1.00	-1.32	.202

Stepwise multiple regression showed that the relationship between lean body weight and lumbar bone density was strong enough to be predictive of density in this region. The R square value revealed that lean body weight explained 19.7% of the variance in lumbar bone density. None of the other variables, including percent body fat, amount of weight lost or parity were predictive of lumbar bone density.

Several variables significantly correlated with femoral bone density, as well as the one predictive explanatory factor are displayed in Table 18.

Table 18: Stepwise multiple regression of several variables correlated with Ward's triangle

Multiple R	R Square	Adj. R Square	Standard Error	F	Sig F
.492	.242	.222	.096	12.47	.001
Variable	**B**	**SE B**	**Beta**	**T**	**Sig T**
lean body weight	.014	.004	.492	3.53	.001
age	-.191	-.216	.970	-1.36	.180
% body fat	-.078	-.077	.740	-.475	.637

As with lumbar bone density, the relationship between lean body weight and femoral bone density was strong enough to be predictive of bone density. Lean body weight explained 24.2% (R square value) of the variance in Ward's triangle. Neither age, nor percent body fat could further account for the differences in the bone density in this area.

When the variables of lean body fat, percent body fat, weight loss and parity were incorporated in the stepwise multiple regression equation it was shown that none were predictive of bone density of the trochanteric neck region.

Table 19 delineates some of the strength and endurance variables which were significantly related to Ward's triangle and the endurance measure which was predictive of bone density in this area.

Table 19: Stepwise multiple regression of strength and endurance variables related to Ward's triangle

Multiple R	R Square	Adj. R Square	Standard Error	F	Sig F
.554	.307	.288	.088	16.35	.000
Variable	**B**	**SE B**	**Beta**	**T**	**Sig T**
handgrip endurance	.003	6.78	.554	4.04	.000
R handgrip strength	-.101	-.089	.536	-.534	.596
knee flexion strength	.239	.272	.899	1.70	.098
knee extension strength	.233	.271	.939	1.69	1.00
leg extension strength	.116	.136	.946	.822	.416

Stepwise multiple regression revealed that only the relationship between average handgrip endurance and femoral bone density was sufficiently strong enough to be predictive of bone density. Average handgrip endurance explained 30.7% (R square value) of the variance in femoral bone density. Although the other variables with the exception of handgrip strength were anatomically related to the area none of the relationships further explained the variance in femoral bone density.

Stepwise multiple regression shows the most powerful explanatory strength variable which was predictive of bone density in the trochanteric neck. (See Table 20).

Table 20: Stepwise multiple regression of strength and endurance variables related to bone density of the trochanteric neck

Multiple R	R Square	Adj.R Square	Standard Error	F	Sig F
.604	.365	.328	.080	9.78	.006
Variable	**B**	**SE B**	**Beta**	**T**	**Sig T**
handgrip strength	.016	.005	.604	3.13	.006
handgrip endurance	.316	.289	.531	1.21	.245
knee flexion strength	.349	.412	.886	1.81	.089

Whereas the relationship between average handgrip endurance and bone density of the femoral r. jion (Ward's triangle) was sufficiently strong to be predictive of bone density, it was the relationship between average handgrip strength and bone density which was predictive of bone density in the trochanteric area. Average handgrip strength explained 36.5% (R square value) of the variance in the bone density of the trochanteric neck. The anatomically related knee flexor strength did not enhance the explanatory power.

G. Summary of Factors Associated with Bone Density

Bone density measurements of the femoral and lumbar regions indicated that, with the exception of one subject (i.e. approximately 2% of the sample) who reflected bone mineral density values which were significantly below normal, the values of the majority of subjects were comparable with those derived from normative data in the southern United States. The one subject who reflected lower than normal values, evinced this compromised bone density not only in the lumbar region but also in the femoral area. Notwithstanding the finding that most of the subjects were characterized by bone densities which fell within two standard deviations of the norm, 56.8% of the sample showed bone densities which were lower than age matched controls. These lower values were evidenced in the femoral as well as the lumbar region. If the fracture threshold for the vertebrae (0.965 g/cm² as defined by Riggs et al. 1981) is accepted, then 29.5% of the sample reflected vertebral bone densities which were either below or close to this fracture threshold. Several authors (Sinaki et al. 1986; Drinkwater et al. 1984) reported vertebral bone densities of amenorrheic athletes (mean: 1.12±0.04), eumenorrheic athletes (mean: 1.30±0.03) and postmenopausal women (mean: 1.06±0.18) which were higher than the vertebral bone density of the CAF women (mean: 1.054±0.97). However, Davies et al. (1990) showed lower vertebral bone densities (mean: 1.039±0.106) in a group of 150 healthy nonathletic women aged 18 to 25 years. As emphasized by Drinkwater et al.(1984), participation in athletic activity seems to have a salubrious effect on bone.

When other parameters, age, height, weight, body composition, weight loss, amount of weight lost, birth control pills and children were correlated with lumbar and femoral bone densities, the strongest relationship was evidenced between lean weight and lumbar and femoral bone densities (r=.4171, and r=.4992, respectively). Amount of weight lost (r=.3825) and children (r=.3971) were also significantly correlated with the bone density of L2-4.

In this sample of women (aged 19-36), age was not significantly related to lumbar bone density but was inversely correlated with femoral bone density (r=-.2721). While Stevenson et al.(1989) suggested that height was correlated with lumbar bone density in premenopausal women, no significant relationship was evidenced in the CAF women. Also akin to the findings of several authors (Stevenson et al.1989 and McColloch et al. 1988) no significant correlation was found between the use of birth control pills and bone density in the femoral and lumbar regions. However, the relationship between childbearing and lumbar bone density was significant (r=.3971). This finding corroborated the work of Elders et al.(1989), Lambke et al.(1977) and Goldsmith et al.(1975). When the relationship was examined between muscular strength and endurance and bone density of the femoral and lumbar densities, the strongest correlations were evidenced between right, left and average handgrip endurance and the bone density of Ward's triangle (r=.5082; r=.4353 and r=.5034 respectively). The strength measures of left and average knee flexion also showed significant correlations with this same area (r=.4148 and r=.4107). Similarly, the handgrip endurance measures evinced the highest correlations ($p \leq 0.05$) of all the strength and endurance measures with the bone density of the lumbar region. However these particular correlations, in contrast with those associated with the femoral region, were much weaker (eg. left handgrip endurance: r=.2865; average handgrip endurance: r=.2840).

While some authors (Martin & McColloch, 1987; Sinaki et al. 1986; Ellis & Cohn, 1975) purported that there is a positive relationship between bone density and the muscles which are anatomically related to the area, this was evidenced only between the muscles of the lower limb and femoral bone density in the subjects of the CAF study. No such relationship was demonstrated between the strength of muscles in the trunk and lumbar bone density. This is in contrast to the findings of Sinaki et al. (1986) who demonstrated a significant positive correlation between the strength of the back extensors and bone density of the L2-4 region in a group of 68 postmenopausal women. The possible explanation for this finding is that Sinaki et al. (1986) investigated an older group of women where notable bone density diminution was already in progress.

When the relationship between bone density and field task performance was examined significant correlations were evident only with femoral bone density. A significant inverse relationship existed between femoral bone density and the ammunition box lift task and both the maximal and submaximal effort digging tasks. This suggested that those women who were characterized by higher bone densities of the femoral region were able to perform the ammunition box lift and digging tasks more successfully (i.e. in less time). Bone density of the femoral area was also positively correlated ($p \leq 0.05$) to muscle strength of the lower limbs. These muscles were obviously used in the performance of both these field tasks. Hence it is probably the strength of these lower limb muscles which augmented the bone density of the femoral region.

H. Relationship between Various Measures of Muscle Strength and Field Tasks

Table 21 illustrates the relationship between the field tasks and static and dynamic measures of trunk flexion and extension strength.

Table 21: Correlation coefficients between field tasks and static and dynamic trunk flexion and extension strength

Field Tasks	Static Trunk Flexion	Static Trunk Extension	Dynamic Trunk Flexion	Dynamic Trunk Extension
Casualty Evacuation	r=.0073 n=(36)	r=-.4401* n=(36)	r=.0128 n=(36)	r=-.5813* n=(36)
Ammunition Box lift	r=-.5602* n=(33)	r=-.1845 n=(33)	r=-.4774* n=(33)	r=-.3210* n=(34)
Maximal Effort Jerry Can	r=-.3004* n=(36)	r=-.1583 n=(37)	r=-.3135* n=(36)	r=-.0690 n=(37)
Maximal Dig	r=-.2972* n=(36)	r=-.4819* n=(36)	r=-.3583* n=(36)	r=-.3107* n=(36)
Submaximal Dig	r=-.4084* n=(24)	r=-.5335* n=(24)	r=-.3881* n=(24)	r=-.4148* n=(24)
March	r=.2457 n=(37)	r=-.0203 n=(37)	r=.3665* n=(37)	r=.1202 n=(37)

* level of significance: $p \leq 0.05$

As evidenced in Table 21, both static and dynamic trunk extension strength were significantly and inversely correlated with casualty evacuation. In other words, those individuals who were characterized as having stronger back extensors, were able to accomplish this specific field task in a shorter period of time in comparison to their weaker counterparts. It was obviously more efficient if the individual, carrying another person, was more or less able to assume an upright posture compared to the subject so heavily burdened that they were doubled over, with their trunk almost parallel to the floor. A similar pattern was evinced by the relationship between trunk flexion and extension strength and the ammunition box lift task. However, in this particular example, static and dynamic trunk flexion strength were more strongly correlated with performance of the ammunition box lift than was dynamic trunk extension strength.

Poulsen (1970) alleged that the strength of the back muscles is decisive when considering the amount of weight an individual can lift and hold. Moreover, Jorgensen & Poulsen (1974) stated that back muscle strength was a limiting factor when they examined factors related to repetitive lifting of loads from floor to table height. The ammunition box lift task represented repetitive lifting of a load from the floor to a high shelf.

The maximal effort jerry can task showed an inverse, significant correlation with static and dynamic trunk flexion strength. The jerry can task necessitated lateral flexion of the trunk as the subject carried only one jerry can at at time. To effect this maneuvre, external and internal oblique muscles on the ipsilateral side contracted simultaneously.

Both the maximal and submaximal dig tasks were inversely and significantly correlated with static and dynamic measures of trunk flexion and extension strength. Whenever the trunk is in a forward flexed posture, the abdominal muscles contract to mitigate the load on the spine. Kapandji (1974) reinforced that while the abdominal muscles do not support the vertebral column at rest, they are activated when heavy weights (such as a box loaded with ammunition, a shovel full of gravel and a filled jerry can) are lifted and carried with the trunk flexed. Moreover, as reported by Tyldesley & Grieve, 1989), the abdominal muscles (including quadratus lumborum) stabilize the pelvis and vertebrae so that heavy work can be undertaken with the upper trunk and limbs.

The strongest correlations were observed between static trunk extension strength and the maximal and submaximal digging tasks (r=-.4819 and -.5335 respectively). Tyldesley & Grieve (1989) explained that the trunk extensor muscles counteract the forward bending moment seen in digging.

Cook & Neumann (1987) maintained that the anterior carrying position, as evidenced by the ammunition box lift task and particularly the digging tasks, elicited the highest EMG activity of the paraspinal muscles. Furthermore, when the results of the twelve women (aged 21-35 years) were compared to those of the male subjects, it was shown that low back muscles were used to a greater extent by the women. The probable explanation for this phenomenon was that the female subjects were weaker in the upper back and limbs vis a vis the male subjects. Stronger arm muscles would mean that the load would be more equitably distributed.

Erector spinae muscles, while counteracting the forward bending moment, act strongly to lift the body from a flexed position to an upright stance, as noted when subjects assumed standing to place the ammunition box on the shelf or when they stood during the digging task to throw gravel into an adjacent container or to manipulate the gravel with their feet.

Of all the trunk strength measures, only dynamic trunk flexion strength was significantly correlated with the total distance covered in the march (r=.3665). The importance of the strength of these particular muscles in terms of performance was undoubtedly related to the stress imposed by the 24.5 kg of weight the participants had to carry in their ruck sack for the duration of the march. Neither static nor dynamic measures of trunk extension strength were significantly related to performance of this task. Cook & Neumann (1987) explained that carrying a backpack provides an extensor moment which counteracts the forward flexed posture and hence minimizes the load of the paraspinal muscles.

Table 22: Correlation coefficients between field tests and static and dynamic measures of upper and lower body strength

Field Tasks	Static Arm Flexion	Dynamic Arm Flexion	Dynamic Leg Extension	Dynamic Trapezius Lift	Bench Press
Casualty Evacuation	r=.0267 n=(35)	r=-.1054 n=(34)	r=.4057* n=(34)	r=.1259 n=(35)	r=.0309 n=(34)
Ammunition Box Lift	r=-.0498 n=(32)	r=-.1916 n=(36)	r=-.2175 n=(32)	r=-.1809 n=(32)	r=.2020 n=(31)
Maximal Effort Jerry Can	r=.1527 n=(35)	r=-.1332 n=(35)	r=-.0638 n=(35)	r=-.3630* n=(35)	r=.0968 n=(34)
Maximal Dig	r=.2246 n=(35)	r=-.4217* n=(35)	r=-.2462 n=(34)	r=-.2679 n=(35)	r=.2914* n=(34)
Submaximal Dig	r=.0118 n=(24)	r=-.4576* n=(24)	r=-.5066* n=(23)	r=-.3847* n=(24)	r=.2502 n=(23)
March	r=.0162 n=(36)	r=.0075 n=(36)	r=.0383 n=(35)	r=.1147 n=(36)	r=.1111 n=(35)

* level of significance: $p \leq 0.05$

Of the correlations between static and dynamic strength and field tasks depicted in Table 22, dynamic leg extension strength was significantly correlated with performance of the casualty evacuation (r=-.4057) and the submaximal digging tasks (r=-.5066). In conjunction with the gluteus maximus, which acts powerfully to extend the hip, the quadricep muscles contract strongly as an individual assumes an upright stance from a squatting position. This posture was apparent when the subjects performed the casualty evacuation task. The quadricep muscles display a propulsive force (Tyldesley &

Grieve, 1989) which would be of obvious benefit in the execution of this task.

When considering tasks such as the ammunition box lift task and the digging tasks, Jorgensen & Poulsen (1974) indicated that in repetitive lifting tasks, the extensor muscles of the legs perform submaximal, dynamic contractions. However, they suggested that an individual's endurance was not limited by their muscular strength, but rather the capacity of their oxygen transport system.

None of these measures of strength correlated significantly with the ammunition box lift task. Stevenson et al. (1990) showed that lifting effectiveness was compromised when using the standard straight back, bent knees technique advocated by the Armed Forces. In this study, although the subjects were advised to use their legs for lifting to reduce the strain on their lower back, the standard lifting protocol was not enforced.

In contrast to the findings in this study, Beckett & Hodgdon (1987) and Robertson & Trent (1985) found that static upper body strength in conjunction with body weight reflected the highest correlations with shipboard task performance. Beckett & Hodgdon (1987) reported that arm strength was a limiting factor in the performance of a lifting task, using standard lifting protocol, by thirty-eight female navy personnel. Robertson & Trent (1985) pointed out that in a group of 184 female navy personnel, an isometric measure of strength (arm lift) was significantly correlated with nine shipboard carrying tasks (r= 0.25 to 0.44; $p \leq 0.05$) and three lifting tasks (r= 0.15 to 0.28; $p \leq 0.05$). The correlation between the five gallon can carry task and arm lift strength was 0.35. The jerry can weighed thirty-five pounds and the subjects carried this can a distance of one hundred and seventy feet on level ground.

In contrast to the findings of Beckett & Hodgdon (1987) and Robertson & Trent (1985), static arm flexion endurance (and not strength) was significantly correlated with the maximal effort jerry can task. (See Table 23). Why endurance was a limiting factor in performing this task was that not only were the subjects required to carry the jerry can a distance of 35 m but also lift it and empty it (in a controlled fashion) into a funnel located at a 1.3 m height. The entire process was conducted over a series of twelve shuttle runs. Although endurance is certainly a component of strength (Heyward, 1984) muscular endurance of the arm flexors figured more importantly in the execution of this task.

In conjunction with arm flexion endurance, dynamic trapezius lift strength was inversely and significantly correlated with the maximal effort jerry can (r=-.3630) and the submaximal effort digging tasks (r=-.3847). In other words, those individuals who reflected stronger trapezius musculature were the ones who were able to perform these tasks at a faster rate. As reported by Tyldesley & Grieve (1989) the trapezius muscle actively supports the shoulder when an individual is carrying a heavy load and prevents the collapse of the shoulder girdle.

Both the maximal and submaximal dig tasks showed a significant inverse correlation with dynamic arm flexion strength (r=-.4217, r=-.4576, respectively). Also the maximal effort digging task was significantly correlated with the bench press (r=-.2914). The dynamic strength of the pectoralis and anterior deltoid muscles (as reflected in the bench press) was significantly related to the performance of this task. When the pectoralis major is considered as a whole, it functions to medially rotate the shoulder and adduct the arm across to the opposite side of the body. This maneuvre was evidenced by the subjects engaged in the digging task. As well, the deltoid muscle is involved in all movements which entail reaching forward - such as shovelling. Moreover, this muscle has a supportive function for the shoulder, especially when an individual carries a heavy load (Tyldesley & Grieve, 1989).

Table 23: Correlation coefficients between field tests and upper body endurance

Field Tasks	Trapezius lift Endurance	Static Arm Flexion Endurance
Casualty Evacuation	r=-.1824 n=36	r=-.1799 n=36
Ammunition box lift	r=-.1828 n=34	r=-.1998 n=34
Submaximal Dig	r=-.2930 n=24	r=-.2445 n=24
Maximal Dig	r=-.3250 * n=36	r=-.5074 * n=36
Maximal Effort Jerry Can	r=-.3368 * n=37	r=-.3695 * n=37
March	r=-.1695 n=37	r=-.1459 n=37

*level of significance: $p \leq 0.05$

Trapezius lift endurance and static arm flexion endurance, as revealed in Table 23, were significantly correlated with only two of the field tasks - the maximal dig and the maximal effort jerry can task. The most notable correlation was reflected between static arm flexion endurance and the maximal effort digging task where r=-.5074. Trapezius lift endurance was also significantly and inversely correlated with the maximal effort digging task (r=-.3250). Similarly, both trapezius lift endurance and static arm flexion endurance were inversely and significantly related to the performance of the maximal effort jerry can task. In other words, those individuals who performed well on these endurance measures also tended to complete the jerry can and digging tasks in a shorter period of time.

Tyldesley & Grieve (1989) reinforced that the trapezius muscle acts to support the shoulder - especially when an individual is lifting and carrying a heavy load. The heavy load in the digging task constituted not only the standard issue shovel, but also the 0.5 cubic meter of gravel which had to be transferred to the other container. The weight of the jerry can was substantial - 35 kg and was carried a distance of 35 m before it was hoisted and emptied into a funnel located at a 1.3 m height.

The three muscles (biceps brachii, brachialis and brachioradialis) act to flex the elbow. The brachioradialis is most activated when the forearm is pronated and when contracting isometrically holds the elbow in a flexed posture (Kapandaji, 1990). Prolonged elbow flexion was evidenced in both the digging and jerry can tasks.

Knapik et al. (1989) asserted that muscular endurance is central in the performance of military tasks such as lifting artillery shells, sandbags, crates and weapons. However, in this study, upper body endurance measures were not affiliated with all the lifting and carrying tasks. Nevertheless, they were inversely correlated with two tasks involving components of lifting and carrying - the maximal effort digging task and the maximal effort jerry can task.

Table 24: Correlation coefficients between field tests and handgrip strength.

Field Tasks	n	R Handgrip Strength	L Handgrip Strength	Av.Handgrip Strength
Casualty Evacuation	36	r=-.0451	r=-.0341	r=-.0052
Ammunition Box Lift	34	r=-.1448	r=-.2821 *	r=-.2230
Maximal Effort Jerry Can	37	r=.0759	r=-.0694	r=.0027
Maximal Dig	36	r=-.3961 *	r=-.4526 *	r=-.4428 *
Submaximal Dig	24	r=-.3221	r=-.2845	r=-.3139
March	37	r=-.0123	r=-.1337	r=-.0777

*level of significance: $p \leq 0.05$

Left handgrip strength and endurance were inversely and significantly correlated with the performance of the ammunition box lift task (r=-.2821; r=-.3280). (See Tables 24 and 25). The handgrip strength and endurance measures were not significantly correlated with several of the field tasks, including casualty evacuation, maximal effort jerry can and total distance marched. Conversely right, left and average strength measures of the hand were significantly correlated with the maximal effort digging task. As reported by several authors (Kapandaji, 1990; Tyldesley & Grieve, 1989) the power grip, where all the fingers are flexed around an object, such as the handle of a shovel, is very effective as it unites powerful control with easy manipulation.

Knapik et al.(1990) endorsed the importance of upper body strength when they showed that in a group of thirty-four infantry soldiers, isometric handgrip strength, upper torso strength, upright pull and dynamic lift were significantly correlated with field exercise operations. They emphasized that not only female, but male infantry soldiers required upper body strength training because of the number who experienced difficulties carrying backpacks, radio equipment and stretchers.

Table 25: Correlation coefficients between field tests and handgrip endurance.

Field Tasks	n	R Handgrip Endurance	L Handgrip Endurance	Av. Handgrip Endurance
Casualty Evacuation	36	r=-.0876	r=-.0289	r=-.0252
Ammunition Box Lift	34	r=-.0674	r=-.3280 *	r=-.2202
Maximal Effort Jerry Can	37	r=.0754	r=.1017	r=.0957
Maximal Dig	36	r=-.2126	r=-.2955 *	r=-.2755 *
Submaximal Dig	24	r=-.3700 *	r=-.4096 *	r=-.4107 *
March	37	r=-.0808	r=-.1473	r=-.1243

*level of significance: $p \leq 0.05$

Similar to the correlations between handgrip strength and the performance of the field tasks, handgrip endurance measures evinced a significant relationship with the ammunition box lift task (where r=-.3280 with left handgrip endurance) and with the maximal effort digging task (r=-.2955 and r=-.2755 with left and average handgrip endurance respectively). (See Table 25). Contrary to the correlations between the handgrip endurance measures and the submaximal field task (where r=-.3700; r=-.4096; r=-.4107 with right, left and average handgrip endurance respectively), the handgrip strength measures were not significantly correlated with the performance of the submaximal dig task.

Table 26: Correlation coefficients between field tests and knee flexion strength

Field Tasks	n	R knee flexion	L knee flexion	Av. knee flexion
Casualty Evacuation	36	r=-.2455	r=-.1479	r=-.2125
Ammunition Box Lift	34	r=-.5201 *	r=-.3053 *	r=-.4403 *
Maximal Effort Jerry Can	37	r=-.1061	r=-.1886	r=-.1532
Maximal Effort Dig	37	r=-.3947 *	r=-.3513 *	r=-.3974 *
Submaximal Dig	24	r=-.2728	r=-.2479	r=-.2753
March	37	r=.1490	r=.2710 *	r=-.2189

* level of significance: $p \leq 0.05$

Table 27: Correlation coefficients between field tasks and knee extension strength

Field Tasks	n	R Knee Extension	L Knee Extension	Av. Knee Extension
Casualty Evacuation	36	r=-.1372	r=.0896	r=-.0069
Ammunition Box Lift	34	r=-.3111 *	r=-.3374 *	r=-.3510 *
Maximal Effort Jerry Can	37	r=-.1079	r=.0793	r=.0007
Maximal Effort Dig	36	r=-.1915	r=-.1685	r=-.1917
Submaximal Dig	24	r=-.0415	r=-.0438	r=-.0456
March	37	r=.1401	r=.0266	r=.0822

*level of significance: $p \leq 0.05$

When referring to Tables 26 and 27 it is evident that several of the field tasks did not display significant correlations between strength measures of right and left knee flexion and extension strength. Included in this particular group of tasks were casualty evacuation, maximal effort jerry can and submaximal digging tasks. Conversely, the ammunition box lift task showed an inverse and significant relationship with all of the strength measures of knee flexion and extension. The strongest relationship was evinced between the strength of the right knee flexors and the performance of the ammunition box lift (r=-.5201).

Knee flexion and extension strength figure prominantly in the ammunition box lift task as the individual repetively squats to pick the box off the floor and then assumes a standing position to place this ammunition box on a high shelf. Whereas the quadricep muscles operate more effectively when the hip is extended, the hamstring muscles are most efficient when the hip is flexed (Kapandji, 1989). Additionally, the quadriceps act in conjunction with the gluteus maximus to raise the body from a squatting position (Tyldesley & Grieve, 1989).

Jorgensen & Poulsen (1974) described a repetitive lifting task as a highly inefficient activity that is performed at a considerable physiological cost. They stated that both static and dynamic muscular work is involved in repetitive lifting and that the large muscles of the legs perform submaximal, dynamic contractions.

Unlike the submaximal effort digging task where no significant relationships were detected, right, left and average knee flexion strength showed an inverse, significant correlation with the maximal effort digging task. Obviously, the "crouched" position is more effective for digging. Knee flexion is dependent on the degree of hip flexion and Kapandji (1989) reported that the efficiency of the hamstring muscles is compromised with extension of the hip.

The only positive significant correlation evidenced in this battery of knee flexor and extensor strength tests was apparent between left knee flexion strength and total distance marched (r=.2710). Dziados et al. (1987) reported a similar finding in a group of fourty-nine infantry soldiers who performed a ten mile march. They alleged that the most interesting result of their investigation was that of all the physiological parameters examined, including aerobic capacity, it was only knee flexion strength (defined as a measure of brief duration and high intensity) that was predictive of the performance of a protracted activity - the ten mile march.

I. Laboratory Muscle Strength and Endurance Tests Which Were Predictive of Performance

Of all the laboratory measures of strength and endurance only three particular tests were significantly correlated to the casualty evacuation field task namely: static and dynamic trunk extension and dynamic leg extension (r=-.5813,-.4401 and -.4057 respectively).

Table 28: Regression analysis of strength tests significantly related to the performance of the casualty evacuation field task

Covariate	B	Beta	Std.Err.	t-value	Sign.of t
DLE	-.09375	-.25502	.09544	-.98236	0.338
DTE	-.60485	-.62118	.22975	-2.6327	0.016 *

Regression analysis, as illustrated by Table 28 showed that of the two laboratory tests (dynamic leg extension and dynamic trunk extension strength) which were correlated with the performance of the casualty evacuation task, only the correlation between dynamic trunk extension strength and casualty evacuation was strong enough to be predictive of performance.

Eleven laboratory measures of strength and endurance were significantly correlated with the ammunition box lift task. While static and dynamic trunk flexion strength were both significantly related to this field task, static trunk flexion strength showed the stronger correlation (r=-.5602). Dynamic trunk extension [illegible] was also significantly correlated with this field [illegible]=-.3210). Of the upper body strength and endurance measurements only left handgrip strength and endurance evinced a significant relationship with the ammunition box lift (r=-.2821 and r=-.3280 respectively). With respect to the lower body measurements, knee flexion strength showed a stronger correlation than knee extension strength. The significant correlation between the ammunition box lift task and the strength measurement of average knee flexion was r=-.4403 in comparison to the significant correlation of r=-.3510 represented by average knee extension strength.

Table 29: Regression analysis of strength measures significantly correlated with the performance of the ammunition box lift task

Covariate	B	Beta	Std.Err	t-value	sign.of t
DTF	-15.3155	-.57186	6.17070	-2.48198	0.022 *
DTE	-5.51285	-.48414	3.24474	-1.69901	0.105
av. knee flexion	-5.31625	-.30971	4.04101	-1.31557	0.200

Regression analysis of the three measures of strength viz. dynamic trunk flexion strength, dynamic trunk extension strength and average knee flexion strength which were significantly correlated with the performance of the ammunition box lift task demonstrated that only the relationship between dynamic trunk flexion strength and this task was of sufficient magnitude to be predictive of performance. (See Table 29).

Several upper body and trunk measures of strength and endurance correlated significantly with the maximal effort jerry can task. Significant correlations were reflected by dynamic trapezius lift (r=-.3630) and static arm flexion endurance (r=-.3695). With regard to the trunk musculature, both static and dynamic trunk flexion strength showed correlation values which were significantly ($p \leq 0.05$) related to the maximal effort jerry can task (r=-.3004 and r=-.3135 respectively).

Table 30: Regression analysis of the strength and endurance measures correlated with the performance of the maximal effort jerry can task

Covariate	B	Beta	Std. Err	t-value	sign.of t
trap.lift endurance	-.31593	-.28699	.23627	-1.33717	0.193
DTF	-.51080	-.11219	1.16903	-.43695	0.667
DTL	-1.5705	-.42983	1.14590	-1.37054	0.186
static arm flexion endurance	-.44129	-.31846	.33074	-1.33427	0.194

When examining whether dynamic trunk flexion or dynamic trapezius lift strength had an important bearing on the outcome of the maximal effort jerry can task, it was found that the correlations were of insufficient strength to be predictive of performance. Similarly, based on regression analysis, neither trapezius lift nor static arm flexion endurance were predictive of the performance of this field task. (See Table 30).

More of the laboratory measures of strength and endurance were significantly correlated with the maximal effort digging task than to any of the other tasks included in the field test battery. Specifically 16 of the laboratory tests reflected a significant relationship. Both static and dynamic measures of trunk flexion and extension strength were significantly related to the performance of the maximal effort digging task. However, static trunk extension strength showed the strongest correlation with this particular field task (r=-.4819).

Of the muscle groups comprising the upper part of the body, arm flexion and left and average handgrip strength showed the strongest correlations with the maximal effort digging task (r=-.4217; r=-.4526; r=-.4428 respectively). In the lower body all of the strength measures of knee flexion (right, left and average) evinced a significant correlation with performance of this task (r=-.3947; r=-.3513; r=-.3937 respectively).

Table 31: Regression analysis of strength and endurance measures significantly correlated with the maximal effort digging task

Covariate	B	Beta	Std.err	t-value	sign.of t
DTF	-2.2430	-2.4073	2.24397	-.99957	0.329
DTE	-.31122	-.07856	1.17995	-.26376	0.795
BP	-.39109	-.10371	1.12657	.34716	0.732
av. knee flexion	.480346	.076228	1.23842	.38787	0.701
av. handgrip strength	-5.7705	-.38538	3.84901	-1.49924	0.146
av. handgrip endurance	.147857	.050506	.72617	0.20361	0.840
trap. lift endurance	-.64231	-.27332	.44021	-1.45911	0.157
static arm flexion endurance	-.86941	-.29390	.61623	-1.41086	0.171

When comparing the significance of three laboratory tests (specifically, dynamic trunk flexion and trunk extension strength and bench press) regression analysis showed that none of these three tests predicted the outcome of the maximal dig task. (See Table 31). Nor were the correlations between this field task and average knee flexion strength, average handgrip strength and endurance, trapezius lift and static arm flexion endurance of sufficient magnitude to be predictive of performance.

Although the musculature involved in performing the submaximal digging task would be akin to the musculature used while the subjects were digging with maximal effort, not as many of the laboratory strength and endurance tests were significantly correlated with the submaximal task. This could be explained, at least partially by the fewer numbers of participants executing the submaximal task (n=24).

Similarities, however did exist as evidenced by the finding that alike the maximal effort digging task, static trunk extension strength figured prominently as one of the strength tests that was significantly correlated with the performance of the submaximal effort digging task (r=-.5335). Static trunk flexion strength, conversely, showed a stronger correlation with the performance of the submaximal task than when the same task was performed with maximal effort (r=-.4084 vs. r=-.2972). Similarly, dynamic trunk flexion strength evinced a more notable correlation (r=-.4148) with the submaximal task than with the maximal task (r=-.3107). However, alike the relationship between muscle strength and endurance tests of the upper body and the performance of the maximal effort digging task, dynamic arm flexion and dynamic trapezius lift strength showed a significant correlation with the submaximal effort digging task (r=-.4576 and r=-.3847 respectively). Contrary to the relationships evidenced between the handgrip strength measures and the maximal effort digging task, the only handgrip measures which were significantly correlated with the submaximal effort digging task were those of endurance. Right, left and average handgrip endurance measures were all significantly correlated with the performance of the submaximal effort digging task (r=-.3700, r=-.4096, and r=-.4107 respectively).

Of the strength and endurance measures only two of the tests were significantly correlated with the performance of the march (i.e. total distance marched). These two tests included dynamic trunk flexion strength (r=.3665) and left knee flexion strength (r=.2710).

J. Relationship Between Several Demographic Variables and Field Task Performance

Several demographic variables including age, height, chest, waist and hip girth, waist/hip ratio and body mass index were affiliated with the performance of three of the field tasks - maximal effort jerry can, ammunition box lift and casualty evacuation tasks. None of the demographic features were significantly associated with the maximal effort digging task, nor the weight load march. Most of the demographic variables were correlated with the ammunition box lift task, followed by the casualty evacuation task. (See Tables 32 and 33). The maximal effort jerry can task was affiliated with only one demographic factor - chest girth, where r=-.3386.

Table 32: Correlation coefficients between the ammunition box lift task and several demographic variables.

Demographic variables	Ammunition box lift task
age	r=-.3229 *
chest girth	r=-.3509 *
waist girth	r=-.3664 *
waist/hip ratio	r=-.3471 *

* level of significance: $p \leq 0.05$

The relationship between age and the ammunition box lift task suggested that there was a tendency for older women to perform this task more efficiently compared to their younger counterparts. A possible explanation may be that certain sociocultural factors influenced the ability of older women. For instance, older women may have young children who require "lifting and carrying". Moreover, older women have more "double shift" experience - entailing physical labor inside and outside the home.

Other characteristics significantly and inversely associated with performance of this task were chest and waist girth and waist/hip ratio. In other words, those women typified by a larger chest and waist girth and a greater waist/hip ratio were inclined to accomplish this task with a greater degree of proficiency.

Table 33: Correlation coefficients between the casualty evacuation task and several demographic variables.

Demographic variables	Casualty evacuation task
height	r=-.4517 *
hip girth	r=-.3340 *
body mass index	r= .2939 *

* level of significance: $p \leq 0.05$

Height was significantly associated with the performance of the casualty evacuation task (r=-.4517). (See Table 33). While hip girth was inversely correlated with performance, body mass index was positively associated with performance.

K. Relationship Between Body Composition and Field Tasks

Body composition was determined both by hydrodensitometry and bioelectrical impedance assessment. Body weight, lean and fat weight and percent body fat derived from the underwater weighing method were significantly correlated with the performance of three of the tasks: ammunition box lift, casualty evacuation and slit trench digging tasks. None of the body composition variables were significantly associated with the weight load march or the maximal effort jerry can task.

The maximal effort digging task was affiliated with only one body composition component - lean mass, where r=-.4150. This inverse relationship suggested that those women characterized as relatively more lean tended to accomplish this task more adroitly than did their less lean companions.

Table 34: Correlation coefficients between the ammunition box lift task and body composition

Body composition variables	Ammunition box lift task
lean weight	r=-.5188 *
body weight	r=-.3636 *

* level of significance: $p \leq 0.05$

Lean weight was also significantly related to the performance of the ammunition box lift task. Moreover, those women characterized by a higher body weight (and therefore reflecting a higher lean body mass) tended to accomplish this task more effectively. (See Table 34).

Misner et al. (1987) confirmed that lean body weight had a positive influence on performance of tasks involving lifting and carrying. They showed that in a group of 62 subjects (25 women and 37 men) the correlation between firefighting simulated lift and carry task and fat free weight was -0.75. Also, Beckett & Hodgdon (1987) in a study of 38 female navy personnel, corroborated that body weight was significantly correlated with shipboard task performance which were comprised predominantly of carrying tasks.

Table 35: Correlation coefficients between the casualty evacuation task and body composition

Body composition variables	Casualty evacuation task
percent body fat	r= .4020 *
fat weight	r= .3919 *

* level of significance: $p \leq 0.05$

The performance of the casualty evacuation task was positively associated with both percent body fat and fat weight. The relationship revealed that those women characterized as having a higher percent body fat and fat weight tended not to perform as well as those who were relatively more lean. (See Table 35).

In conjunction with the analysis of their body composition, these women also completed a questionnaire detailing weight loss over the past year. The amount of weight loss was significantly and inversely related to the performance of the weight load march and significantly and positively related to the maximal effort digging task (r=-.3592 and r=.4526, respectively).

These relationships showed that those women characterized by greater weight loss tended to reflect poorer performances of both the march and the maximal effort digging tasks. Researchers (Beckett & Hodgdon, 1987) have emphasized the link between lean body mass and proficiency in lifting and carrying tasks in a group of navy personnel. Some authors (McArdle & Katch, 1991; Health & Welfare, 1988; Forbes, 1985) warn that weight loss typically entails loss of both fat and lean mass, dependent upon the weight loss strategy (i.e. dieting or dieting plus exercise) adopted. Forbes (1985) reinforced that typically a substantial proportion of weight loss evoked through dieting is lean body mass. He purported that lean body mass may account for almost 60 % of the total weight loss in individuals. Hence, it becomes obvious that anyone who engages in dieting (accompanied by loss of lean body mass) will probably compromise their ability to perform physical labor.

L. Body Cathexis

Body cathexis as defined by Secord & Jourard (p.343, 1953) "refers to the degree of feeling satisfaction or dissatisfaction with the various parts or processes of the body". The subjects responded to a 40 item Body Cathexis Scale which consisted of a Likert scale rating (from 1-corresponding to a strongly negative feeling to 5 which corresponded to a strongly positive feeling). The summation of these individual components comprised the total or body cathexis score. A score of 3 or more indicated satisfaction with body parts; conversely a score of less than 3 was indicative of dissatisfaction. The following Table 36 displays the mean, median, standard deviation and range of thirteen body cathexis variables. This selection of cathexis variables was considered in relation to muscle strength and endurance and field task performance.

Table 36: Mean, median, standard deviation and range of 13 cathexis variables

Cathexis Variables	Mean	Median	Std. dev.	Range
Physical Stamina	3.442	4.0	1.119	1.0-5.0
Muscle Strength	3.256	4.0	1.071	1.0-5.0
Waist	2.884	3.0	1.138	1.0-4.0
Body Energy	3.605	4.0	.955	1.0-5.0
Body Build	3.023	3.0	1.035	1.0-4.0
Height	3.535	4.0	.984	1.0-5.0
Width of shoulders	3.558	4.0	.825	2.0-5.0
Arms	3.372	4.0	.874	1.0-5.0
Chest	3.233	3.0	.972	1.0-5.0
Hips	2.674	2.0	1.040	1.0-4.0
Legs	3.093	3.0	1.109	1.0-5.0
Weight	2.558	2.0	1.076	1.0-5.0
Posture	3.395	4.0	.929	2.0-5.0

Using the criterion that a mean value above 3 indicated satisfaction with the variable in question and below 3 suggested dissatisfaction, examination of Table 36 showed that the CAF women were generally positive about their physical stamina, muscle strength, energy level, body build, height, width of shoulders, chest, legs and posture. The highest mean of the variables considered was exhibited by the body energy cathexis (mean:3.605). Conversely the CAF women indicated dissatisfaction with their waist cathexis (mean:2.884), hips cathexis (mean: 2.674), and weight cathexis (mean: 2.558). Considering the preoccupation with weight evinced by many women in society (Pollock-Seid,1989; Britton,1988; Balogun,1986; Rigsby et al.1986; Garner et al.1980), it was no surprise that the most negative perception of the body was associated with feelings about body weight. The other two variables (i.e. waist and hips cathexes) which were perceived negatively were also related to body weight.

M. Body Cathexis and Laboratory Measures of Strength and Endurance

In pioneering work, Tucker (1987) showed that those men who participated in a weight training program for four months displayed a heightened sense of body cathexis. Balogun (1986) found a similar phenomenon evinced by a group of 50 university women. He found that the relative strength of muscles of the upper body (but not lower body) were significantly related to body cathexis. Recently, Brown and Harrison (1990) reported that women (ages 17-50) felt themselves empowered after partaking in a 12 week weight training program. Generally, even in the lay press (Britton,1988), it is alleged that women desire a muscular body. A recent Gallup poll (American Health,1988) confirmed this. However, discrepancies appear when different groups are polled - it was found that whereas 65% of college educated women wanted to be more muscular, only 27% of those who did not attend post secondary education were desirous of a muscular body.

Table 37: Correlation coefficients between body cathexis and handgrip and leg strength and endurance measures.

Strength & Endurance Measures	Body Cathexis	
	absolute str.	relative str.
L knee extension strength	r=-.3522 *	r=-.2757 *
Av. knee extension strength	r=-.3251 *	r=-.2316
L handgrip endurance	r=-.2908 *	r=-.0290
R handgrip endurance	r=-.2908 *	r=-.2652 *
R knee flexion strength	r=-.3126 *	r=-.2407
knee flexion strength	r=-.3313 *	r=-.2380
Av. knee flexion strength	r=-.3382 *	r= -.2503

*level of significance:p≤0.05

Table 37 depicts the relationship between specific laboratory measures of strength and endurance and body cathexis. Unlike the findings of Balogun (1986) who reported no correlation between lower body strength and body cathexis, a significant inverse relationship was depicted between the absolute muscle strength of knee flexors and extensors and the relative muscle strength of the left knee extensors and body cathexis. (Relative muscle strength was determined by dividing the absolute values of muscle strength by body weight). The strongest inverse correlation was exhibited by the left knee extensors. No significant correlations were displayed between absolute measures of upper body strength and body cathexis. However, right and left handgrip endurance showed a significant inverse correlation with body cathexis (albeit a weaker correlation than the lower body strength measures). Similarly the relative measure of right handgrip endurance was inversely related to body cathexis.

The results from the CAF study showed that an inverse relationship existed between certain measurements of strength and endurance and body cathexis. These results contradicted the findings of Balogun, (1986). However, the populations were different - Balogun's subjects were university students. Hence, they as a group may have felt more positive about a strong body. Conversely the women from the Canadian Armed Forces appeared to reflect the stereotypical attitude about strong women and therefore those women who reflected higher strength values tended to show a lower body cathexis score. Also Balogun (1986) did not find a significant correlation between absolute strength and body cathexis. The correlations which were significant were between relative strength and body cathexis. He purported that if relative strength was not considered, then those individuals who were smaller would be at a disadvantage. Finally, he found that those measures of strength which were related to the upper body were significantly related to body cathexis. Lower body measurements of strength, he reported, did not reflect significant correlations with body cathexis.

Table 38: Correlation coefficients between muscle strength cathexis and several measures of absolute and relative muscle strength and endurance

Strength and endurance measures	Muscle strength cathexis	
	absolute str.	relative str.
Static arm flexion endurance	r=.3000 *	r=.3229 *
Trapezius lift endurance	r=.2762 *	r=.2767 *
Static trunk extension strength	r=.3619 *	r=.3247 *

*level of significance: $p \leq 0.05$

When the subjects' feelings about their muscle strength were ascertained, it was found that both relative and absolute determinants of muscle strength and endurance were correlated with muscle cathexis. As evidenced by Table 38, static trunk extension strength reflected the strongest correlation with muscle strength cathexis. The muscle endurance measures significantly correlated with muscle strength cathexis consisted of static arm flexion and trapezius lift endurance.

Table 39: Correlation coefficients between physical stamina cathexis and absolute and relative measures of strength and endurance

Strength & enduarance measures	Physical Stamina Cathexis	
	absolute str.	relative str.
Trapezius lift endurance	r=.2738 *	r=.2842 *
Static trunk extension strength	r=.2940 *	r=.3256 *
Dynamic trunk extension strength	r=.3147 *	r=.3195 *
L handgrip endurance	r=.2286	r=.2596 *
Dynamic leg extension strength	r=-.1112	r=.2636 *

* level of significance: $p \leq 0.05$

Physical stamina cathexis, as illustrated in Table 39 was significantly correlated with both the absolute and relative measures of trapezius lift endurance and static and dynamic trunk extension strength. The relative, but not absolute, values of left handgrip endurance and dynamic leg extension strength were positively related to physical stamina cathexis. The absolute and relative values of trapezius lift endurance and static trunk extension strength were correlated with both muscle strength cathexis and physical stamina cathexis.

Table 40: Correlation coefficients between energy level cathexis and absolute and relative measures of strength and endurance

Strength & endurance measures	Energy level cathexis	
	absolute str.	relative str.
Static arm flexion endurance	r=.3419 *	r=.3941 *
Dynamic arm flexion strength	r=.2917 *	r=.3246 *
Static trunk extension strength	r=.4191 *	r=.4169 *
Dynamic trunk extension strength	r=.3520 *	r=.3290 *
Av. knee flexion strength	r=.1525	r=.2766 *
R knee flexion strength	r=.1807	r=.3073 *
R knee extension strength	r=.1642	r=.2723 *
R handgrip strength	r=.2310	r=.2857 *
L handgrip strength	r=.1856	r=.2722 *
Av. handgrip strength	r=.2175	r=.2873 *

*level of significance: $p \leq 0.05$

Energy level cathexis was correlated with both absolute and relative values of static arm flexion endurance and dynamic arm flexion and static and dynamic trunk extension strength. (See Table 40). Relative measures of muscle strength significantly related to energy level cathexis included right and average knee flexion strength, right knee extension strength and handgrip strength. The strongest relationship between energy level cathexis and strength and endurance measures was evidenced by absolute and relative values of static trunk extension strength.

Trunk extension strength has figured significantly ($p \leq 0.05$) in all three components of body cathexes, namely: muscle strength cathexis, physical stamina cathexis and energy level cathexis. Similarly, muscle strength and energy level cathexes was significantly related to static arm flexion endurance.

Table 41: Correlation coefficients between posture cathexis and absolute and relative measures of strength

Strength Measures	Posture Cathexis	
	absolute str.	relative str.
L knee extension strength	r=-.2611 *	r=-.3030 *
Av. knee extension strength	r=-.2438	r=-.2850 *
Dynamic arm flexion strength	r=.2741 *	r=. [illegible]23
Static trunk extension strength	r=.3368 *	r=.2062

*level of significance: $p \leq 0.05$

Posture is alleged to be reflective of self-esteem (Brown & Harrison, 1990). Of the absolute strength measures, while left knee extension strength reflected a significantly negative association with posture cathexis, dynamic arm flexion and static trunk extension strength were significantly and positively correlated with the subject's feelings about their posture. (See Table 41). Relative strength measures which were significantly and inversely related to posture cathexis were left and average knee extension strength. Alike energy level cathexis, posture cathexis was significantly and positively associated with the absolute measure of dynamic arm flexion strength (r=.2741). The strongest (positive) correlation was reflected by the absolute value of static trunk extension strength (r=.3368). Thus this particular measure of strength was significantly associated with physical stamina cathexis, muscle strength cathexis, energy level cathexis and posture cathexis.

Table 42: Correlation coefficients between waist cathexis and absolute and relative measures of strength

Strength Measures	Waist Cathexis	
	absolute str.	relative str.
Static trunk flexion strength	r=-.3436 *	r=-.1154
Dynamic trunk flexion strength	r=-.3182 *	r=-.0667
Static trunk extension strength	r=.1064	r=.2531 *
Dynamic trunk extension strength	r=.0037	r=.2618 *
R handgrip strength	r=.1034	r=.2764 *
L handgrip strength	r=.2262	r=.2752 *

*level of significance: $p \leq 0.05$

Those absolute measures of muscle strength which were inversely and significantly correlated with waist cathexis consisted of static and dynamic trunk flexion strength. The relative measures of strength significantly and positively related to waist cathexis were static and dynamic trunk extension strength and right and left handgrip strength.

Table 43: Correlation coefficients between chest cathexis and absolute and relative measures of strength

Strength Measures	Chest Cathexis	
	absolute str.	relative str.
L knee extension strength	r=-.3804 *	r=-.4074 *
Av. knee extension strength	r=-.3159 *	r=-.3338 *
R handgrip strength	r=-.3709 *	r=-.3280 *
L handgrip strength	r=-.3027 *	r=-.3037 *
Av. handgrip strength	r=-.3517 *	r=-.3256 *
R knee flexion strength	r=-.3169 *	r=-.3652 *
L knee flexion strength	r=-.3128 *	r=-.3239 *
Av. knee flexion strength	r=-.3313 *	r=-.3605 *

*level of significance: $p \leq 0.05$

Both absolute and relative measures of knee flexion and extension strength and handgrip strength were significantly and negatively correlated with chest cathexis. These correlations show that there was a tendency for those women who felt best about their upper body to reflect lower strength values. Conversely those women who were stronger, as reflected by these specific measures of both upper and lower body strength, tended to display a more negative attitude toward their upper body.

Lower body cathexis was represented by hips and legs cathexes. (See Tables 44 and 45).

Table 44: Correlation coefficients between hips cathexis and relative and absolute measures of upper and lower body strength

Strength Measures	Hips Cathexis	
	absolute str.	relative str.
R handgrip strength	r=.2707 *	r=.3166 *
L handgrip strength	r=.2540 *	r=.3352 *
Av. handgrip strength	r=.2742 *	r=.3349 *
L knee flexion strength	r=.1230	r=.2547 *
static trunk extension strength	r=.2372	r=.3014 *
dynamic trunk extension strength	r=.2294	r=.2990 *
dynamic trunk flexion strength	r=.1337	r=.2826 *

* level of significance: $p \leq 0.05$

Both absolute and relative measures of handgrip strength were significantly and positively correlated with hips cathexis. When body weight was controlled for, a significant and positive relationship between relative measures of trunk flexion and extension strength and knee flexion strength and hips cathexis was evident.

Table 45: Correlation coefficients between legs cathexis and absolute and relative measures of strength and endurance

Strength & Endurance Measures	Legs Cathexis	
	absolute str.	relative str.
R knee extension strength	r=-.2776 *	r=-.2655 *
R handgrip strength	r=.2724 *	r=.1828
L handgrip strength	r=.3504 *	r=.2830 *
Av. handgrip strength	r=.3261 *	r=.2373
Trapezius lift endurance	r=-.3525 *	r=-.3563 *
Dynamic leg extension	r=-.2602 *	r=-.2436

*level of significance: $p \leq 0.05$

Both the absolute and relative measures of strength and endurance which were significantly correlated with legs cathexis consisted of right knee extension strength, left handgrip strength and trapezius lift endurance. (See Table 45). The relationship between left handgrip strength and legs cathexis was distinguishable because the correlation was positive. Other absolute measures of strength which were significantly related to legs cathexis included right handgrip strength, average handgrip strength and dynamic leg extension strength. The absolute values of handgrip strength were significantly and positively correlated with legs cathexis in comparison to right knee extension strength, trapezius lift endurance and dynamic leg extension strength which were significantly and inversely related to this particular cathexis variable.

Table 46: Correlation coefficients between weight cathexis and absolute and relative measures of strength

Strength Measures	Weight Cathexis	
	absolute str.	relative str.
R knee extension strength	r=-.2987 *	r=-.0680
L knee extension strength	r=-.2583 *	r=.0317
Av. knee extension strength	r=-.2932 *	r=.0150
R handgrip strength	r=.2821 *	r=.4848 *
L handgrip strength	r=.1952	r=.4476 *
Av. handgrip strength	r=.2490	r=.4806 *
static trunk extension strength	r=.1236	r=.3289 *
dynamic trunk extension strength	r=.2263	r=.4918 *
R knee flexion strength	r=-.2539 *	r=.0365

*level of significance:$p \leq 0.05$

The relationship between weight cathexis and absolute measures of strength of both the upper and lower body was an inverse one, with the exception of right handgrip strength which showed a significant positive correlation with the said cathexis variable. (See Table 46). The relative measures of strength showed a stronger and positive correlation with weight cathexis as evidenced by the significant correlations between handgrip strength and static trunk extension strength and weight cathexis. In other words, when body weight was controlled for, a positive and significant relationship between muscle strength of handgrip and trunk extensor muscles and weight cathexis was revealed. None of the lower body measures of relative strength were significantly correlated with this cathexis variable.

N. The relationship between body cathexis and field tests

Significant correlations were revealed between several dimensions of the body cathexis scale and five out of the six field tests. Of the 13 measures of cathexes which were considered only the cathexes of muscle strength, energy level, physical stamina, width of shoulders, posture and hips were significantly correlated with the field tasks. Body cathexis was significantly related to only one of the field tasks - the maximal effort digging task. Those cathexes variables which were not significantly related to the field tests consisted of the waist, body build, height, arms, chest, legs, and weight cathexes. The following tables display the relationship between the field tasks and various indices of body cathexis.

Table 47: Correlation coefficients between casualty evacuation and several cathexes variables

Cathexes Variables	Casualty Evacuation
muscle strength cathexis	r=-.3051 *
energy level cathexis	r=-.2845 *
body cathexis	r=.1038

*level of significance:p≤0.05

As revealed by Table 47, two components of the body cathexis scale (i.e. muscle strength and energy level cathexis) were significantly correlated with the field task of casualty evacuation. No significant correlation was evident between casualty evacuation and body cathexis.

Table 48: Correlation coefficients between ammunition box lift and several cathexes variables

Cathexes Variables	Ammunition box lift
physical stamina cathexis	r=-.3285 *
width of shoulders cathexis	r=-.3016 *
posture cathexis	r=-.3395 *
body cathexis	r=-.0474

*level of significance: p≤0.05

The three specific components of the body cathexis scale which correlated significantly with the ammunition box lift task were physical stamina, width of shoulders, and posture cathexes. Body cathexis was not significantly correlated with the ammunition box lift task. (See Table 48).

Table 49: Correlation coefficients between maximal effort jerry can field task and several cathexes variables

Cathexes Variables	Maximal Jerry Can
hips cathexis	r=-.3000 *
body cathexis	r=-.0109

*level of significance:p≤0.05

Table 49 shows that only one component of the body cathexis scale (i.e. hips cathexis) was significantly correlated with the performance of the maximal effort jerry can task. What is illustrated is that those women who were inclined to report more positive feelings about their hips also tended to perform better on this particular field task. No significant relationship was revealed between body cathexis and the maximal effort jerry can task.

Table 50: Correlation coefficients between the maximal effort digging task and several cathexes variables

Cathexes Variables	Maximal Dig
physical stamina cathexis	r=.-4485 *
muscle strength cathexis	r=-.4687 *
energy level cathexis	r=-.5361 *
body cathexis	r=-.2813 *

*level of significance: $p \leq 0.05$

The strongest correlations between the field tasks and the various measures of the body cathexis scale were apparent between the maximal effort digging task and physical stamina, muscle strength and energy level cathexes (r=-.4485, r=-.4687 and r=-.5361, respectively). Muscle strength and energy level cathexes were significantly correlated with both the casualty evacuation and maximal effort digging tasks. Moreover, the maximal effort digging task was the only field task which was significantly correlated with body cathexis (r=-.2813). (See Table 50).

Table 51: Correlation coefficients between the submaximal digging task and several cathexes variables

Cathexes Variables	Submaximal Dig
physical stamina cathexis	r=-.3876 *
width of shoulders cathexis	r=-.3963 *
posture cathexis	r=-.4181 *
body cathexis	r=-.1733

*level of significance: $p \leq 0.05$

Table 51 shows the correlations between the submaximal effort digging task and physical stamina, width of shoulders, posture and body cathexes Similar to the correlations between the maximal effort digging task and various cathexis measures, these correlations were stronger than those evinced between several cathexes variables and casualty evacuation, ammunition box lift and maximal effort jerry can tasks. Nevertheless, the same body cathexes variables which were significantly correlated with the submaximal digging task were likewise significantly related to the ammunition box lift task.

O. Stepwise multiple regression of selected variables related to field tasks

Table 52 shows several variables which were significantly correlated with the performance of the ammunition box lift task and the two factors which were predictive of performance.

Table 52: Stepwise multiple regression of selected variables related to the performance of the ammunition box lift task

Multiple R	R Square	Adj. R Square	Standard Error	F	Sig F
.669	.447	.407	137.6	10.9	.000

Variable	B	SE B	Beta	T	Sig T
static trunk flexion strength	-13.11	3.30	-.570	-3.98	.000*
lean body weight	-.312	-.362	.742	-1.98	.058
femoral bone density	-.192	-.247	.908	-1.30	.205
posture cathexis	-75.37	27.76	-.389	-2.72	.011*

The two explanatory variables which were predictive of performance of the ammunition box lift task included static trunk flexion strength and posture cathexis. These two factors, according to the R square value, explained 44.8% of the variance in performance. Neither lean body weight, nor femoral bone density added to the explanatory power. Contrarily, Beckett and Hodgdon (1987) in their study of thirty-eight female navy personnel demonstrated that lean body mass and push-up score were predictive of box lifting capacity. However, it is difficult to compare the results between the two studies because the testing protocol was different - in the Beckett and Hodgdon study the box lifted was of variable weight and the platform was placed at two different heights.

Stepwise multiple regression showed that in Table 53 that only static arm flexion endurance was predictive of the performance of the maximal effort jerry can task.

Table 53: Stepwise multiple regression of selected variables related to the performance of the maximal effort jerry can task

Multiple R	R Square	Adj. R Square	Standard Error	F	Sig F
.392	.153	.128	27.06	5.98	.020
Variable	**B**	**SE B**	**Beta**	**T**	**Sig T**
static arm flexion endurance	-.463	.189	-.392	-2.45	.020*
chest girth	-.293	-.311	.952	-1.85	.073
hips cathexis	-.256	-.276	.985	-1.63	.114

Static arm flexion endurance explained 15.3% of the variation in performance of the maximal effort jerry can task according to the R square value. The other variables, chest girth and hips cathexis did not enhance the explanatory power. Unlike the present study , Beckett and Hodgdon (1987) reported that in a group of thirty-eight navy female personnel, aged 20 to 35 years of age, lean body mass predicted carry task performance. In their study, arm flexion endurance was assessed by the incremental curl lift machine.

Dynamic trunk flexion strength as portrayed in Table 54 was the only factor which predicted performance of the weight load march.

Table 54: Stepwise multiple regression of selected variables related to performance of the weight load march

Multiple R	R Square	Adj. R Square	Standard Error	F	Sig F
38.24	.146	.120	4092.11	5.65	.023
Variable	**B**	**SE B**	**Beta**	**T**	**Sig T**
dynamic trunk flexion strength	236.56	99.51	.382	2.34	.023*
left knee flexion	.112	.101	.691	.574	.570
weight loss	-.164	-.175	.965	-1.00	.323

Based on the R square value, dynamic trunk flexion strength explained 14.6% of the variation in performance of the weight load march. Dziados et al. (1987) reported that in a group of forty-nine infantry soldiers that knee flexion muscle strength was the only significant predictor of the ten mile march. However, in this study, although left knee flexion strength was significantly correlated with the weight load march, it was not predictive of performance. One explanatory factor may account for these differences- the performance criteria in the Dziados et al. (1987) was time whereas in the present study, the criteria was distance marched.

Table 55: Stepwise multiple regression of selected variables related to the performance of the casualty evacuation task

Multiple R	R Square	Adj.R Square	Standard Error	F	Sig F
.577	.333	.287	13.50	7.24	.003
Variable	**B**	**SE B**	**Beta**	**T**	**Sig T**
dynamic trunk extension strength	-.424	.164	-.402	-2.56	.015*
height	-.998	.461	-.337	-2.17	.034*
% body fat	.062	.068	.806	.359	.72
muscle strength cathexis	-.096	-.115	.925	-.613	.54

Dynamic trunk extension strength and height were the two variables which reflected a relationship with the casualty evacuation task which was of sufficient strength to be predictive of performance. (See Table 55). These two variables accounted for 33.3% (R square value) of the variation in performance. Neither percent body fat, nor muscle strength enhanced explanatory power.

Robertson and Trent (1985) remarked that dynamic measures of strength (such as dynamic trunk extension strength) were superior predictors of performance which was typified by rigorous movement. Davis et al. (1982), in an investigation of a hundred male firefighters, found that lean body weight, maximum heart rate, age and percent body fat best predicted the performance of a simulated rescue. This rescue task entailed carrying or dragging a 53 kg dummy from the fifth floor of a training tower to the exit located at groung level. Misner et al. (1987), in an evaluation of performance differences between men and women on simulated firefigting tasks reported that height and weight were moderately correlated with task performance. Lean body weight was positively related to the dummy drag task which required the subject to drag a 142 pound dummy a distance of forty feet. Fat free weight, they suggested, is most important when an individual is lifting or carrying a weight.

None of the selected variables significantly correlated with performance of the maximal effort digging task, nor the submaximal effort digging task, reflected relationships of sufficient magnitude to be predictive of performance. Factors incorporated in the regression equation for prediction of the maximal effort digging task included static trunk extension strength, femoral bone density, amount of weight lost and muscle strength cathexis. The variables considered for prediction of the submaximal effort digging task were static trunk extension strength, bone density of the trochanteric neck, weight loss and posture cathexis.

P. Summary of Muscle Strength, Endurance, Body Composition and Psychological Variables Related to the Performance of Field Tasks

Maximal Effort Digging Task

Muscle strength testing revealed that the subjects who performed the maximal effort digging task with the greatest degree of proficiency tended to reflect a significant relationship with both static and dynamic measures of trunk flexion and extension strength. The lower body strength measure, average knee flexion strength and upper body strength: measures dynamic arm flexion strength, handgrip strength and bench press were significantly correlated with the performance of this task. Those measures of endurance related to this task were trapezius lift, static arm flexion and handgrip endurance. Although a significant relationship was revealed between numerous strength and endurance variables and the maximal effort digging task, multiple regression showed that none were predictive of performance.

The body composition variables which were correlated with the maximal effort digging task included both lean weight (r=-.4150) and bone density of the femoral neck (trochanteric region) (r=-.5306). The weight loss/gain questionnaire revealed that a significant, positive relationship existed between the amount of weight lost over the past year and the performance of the task.

Four body cathexis variables were significantly related to the performance of the maximal effort digging task. These included muscle strength, physical stamina level, energy level and body cathexes.

When several variables, including static trunk extension strength, femoral bone density, amount of weight lost and muscle strength cathexis, were incorporated in the stepwise multiple regression equation, none were shown to be predictive of performance.

Maximal Effort Jerry Can Task

Alike the woman who excelled at the maximal effort slit trench digging task, those women who were adept at the maximal effort jerry can task showed significant correlations with static and dynamic trunk flexion strength and dynamic trapezius strength. Also in conjunction with the woman who reflected a superior performance in the maximal effort slit trench digging task, these women too, showed a significant relationship between this task and upper body endurance measures which included static arm flexion and trapezius lift endurance. The only demographic variable which was relevant to this specific task was chest girth where r=-.3386. The psychological parameter which was significantly correlated with the performance of this task was hip cathexis (r=-.3003).

Stepwise multiple regression showed that whereas static arm flexion endurance was predictive of performance of the maximal effort jerry can task, chest girth and hips cathexis did not enhance explanatory power.

Ammunition Box Lift Task

Analogous to the two previously discussed tasks, those women who reflected superior performances inclined to show higher force outputs for both static and dynamic trunk flexion strength. These subjects were distinguished from those who performed the jerry can task in that they also evinced a significant correlation with dynamic trunk extension strength. Multiple regression analysis showed that the relationship between dynamic trunk flexion strength and the ammunition box lift task was strong enough to be predictive of task performance. The lower body strength measures which were significantly correlated with this task were knee flexion (r=-.4403) and extension strength (r=-.3510). The only upper body strength measure which reflected a significant relationship was left handgrip strength (r=-.2821). Of the endurance measures, only handgrip endurance was significantly correlated with the ammunition box lift task.

Of the demographic variables, chest girth was significantly correlated with performance. This characteristic also typified those women who best accomplished the maximal effort jerry can task. Other relevant demographic variables included waist girth, waist/hip ratio and age where (r=-.3644, r= -.3471 and r= -.3229 respectively) with the ammunition box lift task.

Of the relevant body composition indices, bone density of the femoral neck (Ward's triangle) was significantly correlated with the ammunition box lift task (r=-.3413). Body weight (r=-.3636) and lean weight (r=-.5188) (as determined by hydrostatic underwater weighing) were also significantly related to performance.

An analysis of the psychological parameters associated with this task revealed that a significant relationship existed between physical stamina, posture and shoulder cathexes and performance of the ammunition box lift task.

Stepwise multiple regression showed that static trunk flexion strength and posture cathexis were predictive of performance of this task. When lean body weight and femoral bone density were considered in the regression equation, neither one increased the explanatory power.

Casualty Evacuation Task

Those women who tended to evince a stronger performance in the casualty evacuation task also showed a greater force output of both static (r=-.4401) and dynamic (r=-.5813) trunk extension strength. In conjunction, they showed a significant correlation (r=-.4057) between dynamic leg extension strength and task performance. Multiple regression analysis of strength variables correlated with performance demonstrated that dynamic trunk extension strength was predictive of performance.

Demographic variables indicated that height (r=-.4517), hip girth (r=-.3340) and BMI (r=.2939) were associated with the casualty evacuation task. A statistical analysis of body composition indices showed that those women characterized as having a higher fat/lean ratio tended to perform more poorly. This was reflected by percent body fat and fat weight where significant correlations with task performance were r=.4020 and r=.3919 respectively.

The psychological variables significantly correlated with the execution of this task were muscle strength and energy level cathexes. When dynamic trunk extension strength, height, percent body fat and muscle cathexis were considered in the stepwise multiple regression equation, dynamic trunk extension strength and height were shown to be predictive of performance.none were shown to be predictive of performance.

Weight load March

Those women who demonstrated proficiency in the 16 km march tended to show strong trunk flexion force outputs. The only lower body strength measure significantly correlated with this task was left knee flexion strength where r=-.2710. Stepwise multiple regression analysis demonstrated that dynamic trunk flexion strength was predictive of performance. No other demographic, body composition nor psychological variables were affiliated with performance of the weight load march. However, as reflected by the questionnaire detailing weight loss over the past year, those women who reported the most weight loss tended to perform more poorly.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the relationship between laboratory measures of strength and endurance, body composition, body cathexis and five field tasks considered by military experts as representative of an infantry soldier's work. These tasks, unanimously approved of by the Forces Mobile Command of the CAF, consisted of casualty evacuation, maximal effort jerry can task, ammunition box lift task, maximal and submaximal effort slit trench digging task and weight load march. The subjects, 45 women (aged 19 to 36), were employed as combat support personnel at CAF, Calgary, Alberta. Results showed that these field tasks were significantly ($p \leq 0.05$) correlated with the laboratory strength and endurance, body composition and body cathexis tests.

The combat support volunteers participated in a series of laboratory tests which included muscle strength and endurance and body composition and five field tests: casualty evacuation, slit trench digging, 16 km march, ammunition box lift task and maximal effort jerry can task. The subjects also responded to a questionnaire revealing satisfaction or dissatisfaction with various parts and processes of the body (Secord and Jourard, 1953).

The strength tests consisted of both static, including handgrip, trunk flexion and extension, arm flexion strength and dynamic components - arm flexion, trunk flexion and extension, leg extension,trapezius lift, bench press and knee flexion and extension strength. With the exception of handgrip strength which was determined using a handgrip dynamometer and knee flexion and extension where the Cybex dynamometer at an angular velocity of 180°/s was implemented, the dynamic tests were conducted on the isokinetic electric dynamometer (Singh and Chahal,1991) at a cable velocity of 6.5 cm/s and 13 cm/s (Okoro,1987). The isometric endurance tests included both handgrip and arm flexion endurance which was performed on a weightloaded bar. The dynamic muscular endurance test (trapezius lift endurance) was conducted on a free weight dynamometer. Carrying angle of the elbow was held at 105° and resistance was 20 kg corresponding to the weight of a box loaded with ammunition.

Percent body fat, fat and lean weight were determined by bioelectric impedance assessment and hydrostatic weighing. In addition five skinfolds including triceps, biceps, suprailiac, medial aspect of the calf and suprailiac were measured using Harpenden skinfold calipers. The Hologic QDR 1000 X-ray Bone Densitometer was used to scan bone density (g/cm^2) of the lumbar and femoral neck region. Body image was ascertained by using the Body Cathexis Scale (Secord and Jourard, 1953).

Demographic features including age, height, weight and girth measurements of the chest, waist and hips were recorded for each subject. Additionally, the subjects completed consent forms and questionnaires (including the health appraisal questionnaire, CF Express, 1989) which pertained to both the laboratory procedures and field tasks.

Summary

The greatest number of muscle strength and endurance laboratory tests were significantly correlated with the maximal effort slit trench digging task, indicating that this was the best task overall to give a good indication of a woman's strength and endurance capabilities. However, multiple regression analysis demonstrated that none of these strength and endurance tasks were predictive of performance. Body composition analysis demonstrated that there was a significant correlation between lean weight and performance of the slit trench digging task. Also, a significant and positive relationship existed between reported amount of weight lost over the past year and task performance. In other words those women who were characterized as losing the most weight were inclined to reflect poorer performances.

Interestingly, bone mineral density of the femoral neck was also significantly and inversely correlated with the performance of this task. This may be explained by the general recognition that there is a positive relationship between muscle mass and bone density (Doyle et al., 1970) and a somewhat less definitive association between muscle strength and bone density (Martin and McColloch, 1987; Sinaki et al.1986; Lanyon and Rubin, 1984; Nilsson and Westlin, 1972).

The psychological variables which were significantly affiliated with the performance of this task included the following cathexes variables: physical stamina, energy level, muscle strength and body cathexes.

A significant correlation existed between five strength and endurance tests including static and dynamic trunk flexion strength, dynamic trapezius lift strength, trapezius lift endurance and static arm flexion endurance and performance of the maximal effort jerry can task. Stepwise multiple regression analysis demonstrated that static arm flexion endurance was predictive of performance. Body composition variables reflected no significant correlations with this task. There was, however, a significant relationship demonstrated between chest girth measurement and task performance. Of the psychological variables, hip cathexis was significantly and inversely associated with task performance.

The muscle strength and endurance tests significantly related to the performance of the ammunition box lift task consisted of static and dynamic trunk flexion strength, dynamic trapezius endurance, knee flexion and extension strength and left handgrip strength and endurance. Of these, the correlation between trunk flexion strength and the ammunition box lift was of sufficient strength to be predictive of performance.

A significant relationship was exhibited between bone density of the femoral neck and performance of both the slit trench digging task and the ammunition box lift task.

Interestingly, in both of these tasks, the muscle strength of the lower body (specifically the knee flexors) was significantly related to the performance of the tasks. This association was augmented when statistical analysis of the data revealed a significant relationship between the force outputs of the knee flexors and extensors and bone density of the femoral neck.

Further body composition analysis demonstrated that body weight and lean weight were significantly and inversely associated with task performance. The demographic variables which were significantly and inversely related to the performance of the ammunition box lift task consisted of age, chest and waist girth and waist/hip ratio. Psychological variables significantly affiliated with this task were posture, physical stamina and width of shoulders cathexes. Stepwise multiple regression analysis showed that posture cathexis was predictive of performance.

Trunk extension and dynamic leg extension strength were significantly related to the casualty evacuation task. Multiple regression analysis revealed that the relationship between trunk extension and height and this task was of sufficient magnitude to be predictive of performance. The demographic variables positively associated with this task consisted of height and hip girth. Stepwise multiple regression showed that height (in conjunction with dynamic trunk extension strength) was predictive of performance. Body composition analysis indicated that both fat weight and percent body fat were significantly and positively related to task performance. The psychological indices significantly and inversely affiliated with the casualty evacuation task were muscle and energy level cathexes.

Only two strength tests were significantly and positively associated with the 16 km march - dynamic trunk flexion and knee flexion strength. Stepwise multiple regression analysis demonstrated that dynamic trunk flexion strength was predictive of performance. The only other variable significantly and inversely related to this task was the reported amount of weight lost over the past year.

Conclusions

Trunk flexion and extension strength were significantly and inversely correlated with the performance of two out of the five field tasks, namely the slit trench digging and ammunition box lift tasks. Trunk flexion strength, alone, was affiliated with two different tasks - the maximal effort jerry can task and the 16 km march. In contrast, trunk extension was associated with the casualty evacuation task. Multiple regression analysis showed that the relationship between trunk flexion strength and two tasks viz. the ammunition box lift task and weight load march was of sufficient magnitude to be predictive of performance. Similarly, the relationship evinced between the casualty evacuation task and dynamic trunk extension strength was strong enough to be predictive of performance.

Lower body strength measures were significantly and inversely associated with four out of the five tasks - the one exception was the maximal effort jerry can task. Upper body strength and endurance measures figured prominently in two of the tasks, namely the slit trench digging and maximal effort jerry can tasks. Stepwise multiple regression analysis showed that static arm flexion endurance was predictive of the jerry can task performance.

Body composition analysis demonstrated that whereas fat weight was significantly and positively affiliated with the execution of the casualty evacuation task, a preponderance of lean weight was significantly and inversely correlated with the performance of the ammunition box lift and slit trench digging tasks. Interestingly, bone density of the femoral neck was significantly and inversely associated with the performance of both these tasks. Moreover, lower body muscle strength and ammunition box lift and slit trench digging task performance were significantly and inversely correlated with bone density of the femoral neck region.

An analysis of demographic features showed that a significant, inverse relationship existed between chest girth dimensions and performance of the maximal effort jerry can and ammunition box lift task. Other variables significantly and inversely correlated with the ammunition box lift task included waist girth, waist/hip ratio and age. Demographic variables significantly and inversely correlated with the casualty evacuation task included height and hip girth. Body mass index was significantly and positively related to this task.

The greatest number of cathexes variables were associated with the slit trench digging task where women reflected positive sentiments regarding their muscle strength, physical stamina level, energy level and overall satisfaction with body parts and processes. A significant, inverse relationship existed between the performance of the ammunition box lift task and posture, width of shoulders and physical stamina cathexes. Posture cathexis was demonstrated to be predictive of performance of the ammunition box lift task by stepwise multiple regression analysis. The casualty evacuation task was significantly and inversely correlated with muscle strength and energy level cathexes. Hip cathexis was significantly and inversely related to the maximal effort jerry can task. No psychological cathexes variables were affiliated with the 16 km march.

The two tasks reflecting the greatest number of significant correlations with the laboratory measures were the slit trench digging task and the ammunition box lift task. These two tasks provided good measures of muscle strength and endurance. In contrast, the laboratory measures significantly correlated with the 16 km weight load march and the casualty evacuation task were few in number signifying that performance on these particular tasks was not a very good indicator of muscle strength and endurance capabilities.

An analysis of body composition indicated that lean weight was significantly and inversely correlated with the performance of both the slit trench digging and ammunition box lift tasks. Fat weight was significantly and positively related to only one of the tasks- casualty evacuation.

Thus, overall, the two tasks which demonstrated the greatest number of significant and inverse correlations between task performance and physiological and psychological variables were the slit trench digging and ammunition box lift tasks. Hence, the performance of these two tasks, in particular, reflected the female infantry soldier's strength and endurance capacity and, as much as these variables are related to task performance, her job proficiency.

Recommendations for Further Study

1. Given that osteoporosis is, while manifested in old age, actually a disease of youth, further research should be undertaken to ascertain normal bone density values of the lumbar and femoral regions in young and middle aged Canadian women.
2. Although exercise appears to enhance the structural integrity of bone, some exercise regimes such as marathon training appear to have a deleterious impact on bone. Hence it appears prudent to investigate those levels of endurance

training that confer benefit to bone.

3. Research should be conducted to ascertain the varying effects of different forms of weight training on bone density in young, middle aged and older women.
4. Both Balogan (1986,1987) and Tucker (1987) have corroborated that there is an association between body cathexis and muscle strength in young men. Further research should be pursued to examine if a similar kind of relationship exists in middle aged and older women.
5. The relationship between muscle strength and women's job proficiency in nontraditional fields should be explored following a muscle strength training period of at least three to four months duration.
6. To increase the power of the study, a much larger number of subjects should be evaluated both in the field and laboratory setting.

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SEQUENCE OF LABORATORY TESTS

The subjects were randomly divided into 11 testing groups (A - K), each containing seven to ten soldiers. Each group was tested over a two day period (Tables I and II). A two and a half week time period was required to complete all the laboratory testing.

Day One

On day one, each group departed CFB Calgary by 0700 h and arrived at the University at 1100 h. Upon their arrival they received a briefing from the researcher overviewing the purpose of the study and the tests that they would complete. A light box lunch was provided and subjects reviewed the testing advisory (Appendix A) and were allocated a subject number (1 - 12). Group and subject number, were written on white tape and placed on the right pocket of each subject's uniform. The need to be on time for each test and the need for rest between testing sessions was emphasized. During the introductory briefing, each subject completed a consent form, an EXPRES health appraisal questionnaire (Appendix A), and a Par-Q Physical Activity Readiness Questionnaire. Testing for this group commenced at 1300 h and terminated at 1900 h {Tables III and IV}.

Day Two

On day two, testing for each group continued from 0700 h and terminated at 1200 h (Tables III and IV}. Day two of the initial group represented the first day schedule for the next group. For example, the second day of group A was day one of group B. They received a briefing similar to Group A on Day one. On day two group A was provided a box lunch and departed for CFB Calgary at 1300 h. Group B commenced testing at 1300 h as per the same schedule as Group A on day one. This process continue for a six day cycle as depicted in Tables I and II. Two six day cycles, for total of 12 days, plus one alternate day resulted in the laboratory testing of approximately 116 subjects. Thirteen groups (A - M) consisted of 7-10 subjects in each group. Five test units comprised the test battery:

1. Aerobic power test
2. Muscular strength tests
3. Underwater weighing test
4. Muscular endurance tests
5. Anaerobic power tests

The testing sequence is depicted in Tables III and IV.

Table I: Week one, Laboratory Group Testing Schedule.

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

Table II: Week two, Laboratory Group Testing Schedule.

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

Table III: Detailed Overview Laboratory Testing and Travel - Day One

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

Table IV: Detailed Overview Laboratory Testing and Travel -Day 2

	All subjects eat before 0630, board bus 0645		
Time	Underwater Weighing Test (Subject No.)	Muscular Endurance Test (Subject No.)	Anaerobic Power Tests (Subject No.)
0730-0745 0745-0800		12, 11, 10	
0800-0815 0815-0830 0830-0845 0845-0900	6	9, 8, 7	
0900-0915 0915-0930 0930-0945 0945-1000	5 4 3 2	6, 5, 4	12 11 10 9
1000-1015 1015-1030 1030-1045 1045-1100	1	3, 2, 1	8 7 6 5
1000-1115 1115-1130 1130-1145 1145-1200			4 3 2 1
0700-1100	Group B travels to University of Alberta		
1100-1300	Study briefing, assignment of subject numbers, light lunch, rest (before and between tests)		
1200-1300	Group A has lunch; departs for CFB, Calgary		
1300-1900	Group B testing as per day one above		
0700-1200	Group B testing as per day two		

SEQUENCE OF FIELD TESTS

Laboratory data on 116 subjects and field task data on 99 subjects was gathered during the study. Inevitably, for unforeseen and valid work and injury associated reasons, some subjects dropped out between laboratory and field testing. For the field tests, the subjects were randomly assigned to one of six testing groups (1 - 6), each consisting of 30 or less soldiers. Each group was subdivided into A and B groups with an equal number of subjects. Each soldier was assigned a subject number within the subgroup. For example, subject #5 in Group 2A read Group 2A5. This information along with the group number was placed on the soldier's uniform pocket. All testing for each respective group was completed within a single day. Testing of all groups was completed within six days.

Table V: Daily Schedule of Each Subgroup.

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

Table VI: Station Type and Subject Assignment at Testing Session

Station	Casualty Evacuation: All are tested from 0800 to 0830 h
Station 1	Maximal effort jerry can task Subject # 11,12,13,14 & 15 begin at this station in the stated order
Station 3	Maximal effort digging task Subject 4,5 and 6 begins at this station in the stated order
Station 4	Ammunition Box Lift Task
Station	Weight Load March: Group A begins in the morning and Group B in the afternoon Note: At Station 1,3 & 4, each subject will be tested in numerical order. For eg., for Station 1, the testing order for subjects is 11,12,13,14,1,2,3,4,5,6,7,8,9 and 10. Subject finishing the test at Station 1 moves to Station 2, 2 to 3, 3 to 4 and 4 to 1. Testers should ensure that each subject obtains at least 30 min rest prior to undertaking the next test.

Appendix I. Testing Advisory for Subjects During Field and Laboratory Testing

A1. FORCES MOBILE COMMAND- PHYSICAL FITNESS STANDARDS TESTING ADVISORY

TO: ALL PARTICIPANTS

Prior to your testing sessions, please note the following:

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

A2. HEALTH APPRAISAL QUESTIONNAIRE
(CF EXPRES, 1989)

Name: ______________________________ Group #: ___
___ Subject #: __________

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

To the best of your knowledge:

1. Do you have a restricted medical category which prevent you from being evaluated or participating in a progressive training program?

2. Do you have any recurring problems with your back, shoulders, hips, knees or ankles which may prevent you from being evaluated or participating in a progressive training program?

3. Do you suffer from such things as: bronchitis, emphysema, diabetes, epilepsy, arthritis or cancer?

4. In addition to the above is there anything which you feel should be discussed with a medical officer prior to assessment?

5. Are you taking medication (prescribed or otherwise) which may affect your ability to undertake a physical evaluation?

6. How are you feeling today?

Excellent Good Physically tired Mentally tired

Don't feel good at all

☐

Other (please specify)

☐ ______________________________

Appendix II. *(A) Informed Consent Form for Field Tests*

(B) Informed Consent Form for Laboratory Tests

- *(i) Aerobic Test*
- *(ii) Muscular Strength and Endurance Tests*
- *(iii) Hydrostatic Underwater Weighing*

(C) Informed Consent Form for Bone Density Assessment

A. INFORMED CONSENT FORM FOR FIELD TESTS

I, ______________________________ authorize Dr M. Singh of the University of Alberta, and Major Wayne Lee of the Canadian Forces to administer and conduct testing on field measures. These measures consist of casualty evacuation for 100 m, digging at a maximum effort and submaximal effort (at 70% of maximal aerobic power - your bodies ability to use oxygen to do work), jerry can transportation at maximal effort, weight load marching for up to 16 km, and ammunition box lift - carry tasks. During the performance of all of these tests my heart rate will be monitored using a Sport Tester heart rate monitor. These tests are designed to measure my physical abilities to perform Army job related physical performance tasks.

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

For maximal effort digging tasks, I will be required to dig gravel from a slit trench simulator. The quantity of the gravel will be approximately 0.5 cubic meter. This quantity represents the approximate volume of a one slit trench which is 1.8 m x 0.6 m x 0.45 m in dimensions.

For marching, I will be required to march 16 km at a pace of 88.9 m per minute with full gear (24.5 kg). This pace is equivalent to marching speed of 5.33 km/h.

For the casualty evacuation task, I will be required to evacuate an individual of my approximate body weight a distance of 100 m at maximum effort.

For maximal effort jerry can task, I will be required to carry three full jerry cans, one at a time, over three shuttles (runs) for distance of 35 m emptying them into a funnel at a height of 1.3 m. Total time to complete the task will be recorded.

In the ammunition box lift task I will be required to lift 48 boxes (one box at a time) from the floor and place them at a height of 1.3 m (height of a truck bed). Each box weighs 20 kg.

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

B (i). INFORMED CONSENT FORM FOR AEROBIC 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.

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 a Sport 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 out will be measured by a 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.

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)

B.(ii) INFORMED CONSENT FORM FOR MUSCULAR STRENGTH AND ENDURANCE LABORATORY TESTS

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

The muscular strength and endurance capacity test battery consists of:

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

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

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

4.Dynamic endurance capacity tests will consist of arm flexions, and trapezius lifts. All of these tests will be conducted utilizing free-weight dynamometer with loads encountered in repeated performance of common army tasks.

DATE:____________________SUBJECT:__________________________

WITNESS:____

B.(iii) INFORMED CONSENT FORM FOR HYDROSTATIC WEIGHING

The body composition determination will involve Hydrostatic Weighing. A rectangular tank six feet in height, four feet in width and 10 feet in length will be used for this purpose. Before entering the tank, I will be weighed, wearing a swimming suit, on a balance scale to the nearest tenth of a kg. Residual lung volume will either be measured directly at the Garneau Pulmonary Center using the helium dilution method or estimated. Hydrostatic weight will then be determined. The procedures for hydrostatic weighing are as follow:

A.Air bubbles will be dislodged from the hair and the body.

B.I will maximally exhale and close the nasal passages.

C.I will maximally lean forward from the waist until I am completely submerged under water.

D.I will remain submerged until I hear a beep- at which time I will lift my head out of the water and blow any remaining air into the autospirometer

This procedure repeats until two similar readings are obtained.

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

Every effort will be made to conduct the tests in such a way as to minimize discomfort and risk. However, I understand that just as with other types of fitness 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.

DATE:_______________________ SUBJECT:_______________________

(SIGNATURE)

WITNESS:_______________________

C. CONSENT FORM FOR BONE DENSITY ASSESSMENT

I..........................authorize Dr. M. Singh and Margaret Oseen of the University of Alberta and Major Wayne Lee of the Canadian Armed Forces and Nigel Gann of the Garneau Bone Density Lab to conduct bone scans of both the lower back and the hip.

I understand that the instrument used to determine bone density will be dual energy radiography. Prior to undergoing the bone scan, I will complete a questionnaire detailing menstrual history, recent dieting history and participation in childhood physical activity. To determine perception of body image, I understand that I will complete a forty item questionnaire on body cathexis.

If during the course of any part of the evaluation I feel unwell, I understand that I or the investigator can and will terminate the test without prejudice to myself.

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

Date..................Signature............................ ....

Witness.. ....

Appendix III. Instructions to Subjects for Maximal Effort Slit Trench Digging

INSTRUCTIONS TO SUBJECTS
MAXIMAL EFFORT SLIT TRENCH DIGGING

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 at a maximal voluntary effort.

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

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

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

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

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

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

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

9.Are there any questions?

Appendix IV. Instructions to Subjects for Weightload March

INSTRUCTIONS TO SUBJECTS 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 120 paces for a maximal distance of 16 km (10 miles) or until you can no longer continue. Each pace is 30 inches in distance. This pace is equivalent to marching speed of 5.33 km/h.

2.Your rate of perceived exertion will be recorded for every 400 m. Upon command "Call Your Perceived Exertion Now" you will read out the exertion score while marching by the recorder. You must maintain the pace until the distance is completed or exhaustion is reached.

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

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

5.Should you not be able to maintain the pace, move to the outside of the track and your test will be stopped.

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

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

8.Are there any questions?

Appendix V. Instructions to Subjects for Casualty Evacuation Task

INSTRUCTIONS TO SUBJECTS
CASUALTY EVACUATION

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 command "Start" you will be required to evacuate a 70 kg mannequin for a distance of 100 m, using the fireman's carry, at a maximum voluntary effort. Once any part of your foot touches or passes the finish line the task is completed. The mannequin is dressed in the army uniform to represent a wounded soldier. The dimensions and weight of different parts of the mannequin has been standardized.

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

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

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

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

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

8.Are there any questions?

Appendix VI. Instructions to Subjects for Maximal Effort Jerry Can Task

INSTRUCTIONS TO SUBJECTS
MAXIMAL EFFORT JERRY CAN TASK

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

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

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

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

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

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

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

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

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

10.Are there any questions?

Appendix VII. Instructions to Subjects for Ammunition Box Lift Task

INSTRUCTIONS TO SUBJECTS
AMMUNITION BOX LIFT - CARRY

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

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

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

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

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

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

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

9. Are there any questions?

Appendix VIII. Instructions to Subjects for the Aerobic Test

INSTRUCTIONS TO SUBJECTS FOR 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 gases that you breathe in and out will be monitored every 30 seconds by special apparatus. You will wear an 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 anaerobic 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?

NOTE:

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).

Appendix IX. (A) Instructions to Subjects for Maximal Strength Tests
(B) Instructions to Subjects for Muscular Endurance Tests

A.INSTRUCTIONS TO SUBJECTS
MUSCULAR STRENGTH TESTS

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

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

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

A.Isometric Arm Flexion Strength Test: *This test will be conducted at elbow flexion angle of 105 degrees. This represents the angle at which soldiers carry ammunition boxes while maintaining the isometric contraction. Special handles have been designed on the weight bar to simulate the distance between hands and the grip used during lifting of an ammunition box.*

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

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

D.Isometric Trunk-Flexion Strength Test: *You will be required to perform a maximal abdominal strength test at a hip angle of 160 degree while standing. The hip angle will be measured with a goniometer during a warm up contraction. Like the trunk extension test, feet position during testing will be shoulder width apart. The heels of each foot shall be placed at the front edge of the white tape attached to the standing surface.*

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

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

B.Concentric-Isokinetic Leg Extension Strength Test: *At the beginning of the test, the dynamometer belt will be secured around your waist. The cable will then be adjusted to your waist height. During the test you shall hold the bar with your hands for greater stability. At the onset of the test you shall pull up on the cable as it is released. Upon reaching the standing height return to the starting position of 90 degrees knee flexion.*

C.Concentric-Isokinetic Knee Extension and Flexion Strength Tests: *These tests will be performed, with the nondominant leg, in a sitting position at a knee flexion range of 90 to 180 degrees. The 180 degree represents full extension of the knee. After a warm-up set, upon the command "start" you extend your knee by exerting maximal voluntary force. Once reaching full extension you shall flex the knee at a maximal effort. Once the knee reaches 90 degree flexion you repeat the procedure. The remainder of the testing protocol is the same as for other isokinetic tests.*

D.Concentric-Isokinetic Trunk Extension Strength Test: *This test will be conducted through a hip angle range of 150 to 175 degrees. The body positioning and handgrip is similar to the trunk extension isometric strength test. While maintaining a straight back and extended legs, you will pull-up on the bar while the cable is released. Once reaching a hip angle of 175 degrees, you will passively allow yourself to be brought back to the starting position.*

E.Concentric-Isokinetic Trunk Flexion Strength Test: *The trunk flexion test will be conducted through a hip angle 175 to 150 degrees. The body positioning is similar to the isometric trunk flexion strength test. From the starting position you shall pull forward and downward while the cable is released from the back. Once reaching 150 degrees of flexion you will return to the starting position.*

F.Concentric-Isokinetic Bench Press Strength Test: *This test will be conducted on the Isokinetic-Isotonic Electric Dynamometer. The cable velocity and the testing protocol is similar to the other concentric-isokinetic tests. It will be performed lying on a bench. The bar height will be preset two inches above the chest, at mid sternum level. At the beginning of the test you will push up until reaching full extension of the elbow joints. Following, you will passively allow your arms to be brought back to the starting position.*

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

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

6.Once the test has ended, you will walk about the test area in order to actively cool-down. Continue to walk until you feel fully recovered. Do not leave until the tester is confident that you are fully recovered.
7.If you feel any of the test is too demanding, you may stop at any time without any explanation.
8.Are there any questions?

B. INSTRUCTIONS TO SUBJECTS MUSCULAR ENDURANCE CAPACITY TESTS

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

1.The Isometric muscular endurance capacity test battery consists of h[illegible] and arm flexion endurance. These tests will be condu[illegible] loads similar to that encountered in the performance [illegible]mon army tasks.

A.Isometric H[illegible] Endurance Capacity Test: *This test represents th[illegible] handgrip endurance requirements while transporting jerry cans. It will be conducted on each hand using the handgrip dynamometer. During the test you will be required to maintain the force output dial at 20 kg force for as long as possible. The tester will provide you feedback when the force starts to deviate. When you are unable to maintain this required force the test will be terminated. This test will be conducted on each hand.*

B.Isometric Arm Flexion Endurance Capacity Test: *This test will be conducted at an elbow angle of 105 degrees. This represents the arm position when a soldier carries an ammunition box while maintaining an isometric contraction. The test will be performed on the free-weight apparatus. A 20.9 kg weight will be loaded on the bar. A goniometer will be used to monitor the angle of your elbow. The handgrip width and body positioning will be the same as for the arm flexion strength tests. Feedback will be given to you by the tester if the angle starts to deviate. You shall hold this position for long as possible. When you are no longer able to maintain this position the test is completed. The total time for which the contraction is sustained will be recorded.*

2.The ***Isotonic Trapezius Lift Endurance Capacity Test*** *will be conducted with a 20.9 kg load representing the weight of an ammunition box. It will be performed utilizing the free-weight dynamometer. You will perform 10 contractions per minute. Each contraction will require about three seconds followed by a three second rest interval. During the test you will only lift upward. During the lowering phase of the bar you will not contract your muscles. The pace will be set with a metronome. It will beep every six seconds. In this time frame you should complete one repetition. You will maintain this pace for as long as possible or until 100 repetitions are achieved. The total number of repetitions will be recorded.*

The test will be conducted while you are standing with knees slightly flexed. At the onset of the test, arms should be in an extended position. Then you lift the bar until your thumbs reach a height parallel to your shoulders. While lifting you *must lead upward with your elbows. The eccentric phase of the test will be performed passively.*

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

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

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

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

7.Are there any questions?

Appendix X. Instructions to Subjects for Hydrostatic Weighing

INSTRUCTIONS TO SUBJECTS HYDROSTATIC WEIGHING

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

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

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

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

4.Residual volume will be measured or estimated while you are in this position.

5.Following the residual volume determination, hydrostatic weight shall be determined.
The procedure for hydrostatic weighing are as follow:
A.Dislodge all air bubbles from hair and body.
B.When the tester signals, you will hold your nose and and maximally inhale and the exhale through your mouth.
C.Following you will slowly lean forward from the waist until your body is completely submerged in the water.
D.You maintain this position until:
(i) the tester taps on the wall of the tank; or
(ii) you start to feel noticiable discomfort from holding your breath

This procedure is repeated until two similar computer readings are obtained.

6.Verbal encouragement will be given to help motivate you during maximal inhalation and exhalation.

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

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

9.Are there any questions?

Appendix XI.(i) Calculation Procedures for Determination of Body Composition

(ii) Values of actual and estimated residual volumes of 16 subjects

CALCULATION PROCEDURES FOR DETERMINATION OF BODY COMPOSITION

(Mottola, 1980)

(1.) Water Density at Temperature Observed ______

(2.) Dry Body Weight ______

(3.) Corrected Vital Capacity ______

(4.) Residual Volume ______

(5.) Volume Gastro-Intestinal Tract* ______

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

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

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

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

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

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

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

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

(14.) Percent Body Fat (13.) X 100 ______

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

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

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

l = liter, kg = kilogram

Table VII: Values of estimated and measured residual lung volumes of [illegible] subjects

Subject #	Estimated Residual Lung Volume	Measured Residual Lung Volume
7	0.600	1.060
8	0.996	1.170
11	0.768	1.540
20	0.786	1.630
21	0.804	1.180
24	0.912	1.780
30	0.828	1.480
37	0.744	0.970
41	0.792	1.630
43	0.840	1.740
44	0.624	0.750
53	0.624	1.260
54	0.696	1.360
55	0.816	1.210
56	0.864	1.250
66	0.840	1.630

Appendix XII. Questionnaire on Menstrual History and Childhood Physical Activity

A. Questionnaire on Menstrual History

Note:It is essential for the researcher to know if you are normally menstruating because estrogen levels are said to be an important factor when considering bone density. Also the measurement of body fat by the bioelectrical impedance method is based on total body water. Hence a woman's body fat reading will be affected depending on where she is in her cycle at the time of measurement.

Please respond to the following questions:

1.When was your last menstrual period?........................

2.How many days do your periods last?.........................

3.Have you missed any periods?................................

a.If you have missed any periods, over how long a time span?

...

b.Have your periods resumed?.....yes
......no

4.Have you given birth to any children?.....yes
.....no

5.Does your cycle vary from month to month?.....yes
.....no

6.Are you on birth control pills?
If so, specify which type.........................

B. Childhood Physical Activity Questionnaire

Please circle the appropriate response:

1. Did you compete in school athletics during childhood?
a.yes
b.no

2. Did you compete in school athletics during adolescence?
a.yes
b.no

3. Did you engage in physical labour (eg. farm chores) during childhood?
a.yes
b.no

4. Did you engage in physical labour (eg. farm chores) during adolescence?
a.yes
b.no

5. Childhood activity:
a.sometimes active
b. active
c.moderately active
d.very active

Appendix XIII. Questionnaire on Body Weight and Dieting Practices

A.Questionnaire on Body Weight and Dieting Practices

For the following only circle one response.

1. Considering your age and height, do you think you are overweight, underweight, or about right?

1.overweight
2.underweight
3.about right

2. How satisfied or dissatisfied are you with your current physical condition?

1.Very Satisfied
2.Fairly Satisfied
3.Not Too Satisfied
4.Not Satisfied At All

3. Please indicate whether of not you have had a weight loss in the past year?

a. 1.No
2.Yes

b. If you did experience weight loss how may pounds did you lose?

...........pounds

Appendix XIV. Body Cathexis Inventory

A. Body Cathexis Inventory

The following inventory consists of 40 items designed to sample your degree of satisfaction toward various parts of your body. There are no right or wrong answers. What is wanted is your own personal feeling about each given body part. Read each item and decide how you feel about it. Then circle your number provided to the right of the word phrases.

BE SURE TO RESPOND TO EVERY ITEM

Mark 1 2 3 4 5 if you have a strongly negative feeling

1 2 3 4 5 if you have a moderately negative feeling

1 2 3 4 5 if you have no feelings one way or the other

1 2 3 4 5 if you have a moderately positive feeling

1 2 3 4 5 if you have a strongly positive feeling

ITEMS	**Strong Positive Feeling**	**Moderately Positive Feeling**	**No Feeling**	**Moderately Negative Feeling**	**Strong Negative Feeling**
1.hair...............	5	4	3	2	1
2.facial complexion..	5	4	3	2	1
3.appetite..........	5	4	3	2	1
4.hands............	5	4	3	2	1
5.distribution of ... hair (over body)	5	4	3	2	1

6.nose...............	5	4	3	2	1
7.physical stamina...	5	4	3	2	1
8.elimination........	5	4	3	2	1

	Strong Positive Feeling	Moderately Positive Feeling	No Feeling	Moderately Negative Feeling	Strong Negative Feeling
9.muscular strength..	5	4	3	2	1
10.waist............	5	4	3	2	1
11.energy level....	5	4	3	2	1
12.back.............	5	4	3	2	1
13.ears.............	5	4	3	2	1
14.age..............	5	4	3	2	1
15.chin.............	5	4	3	2	1
16.body build.......	5	4	3	2	1
17.profile..........	5	4	3	2	1
18.height...........	5	4	3	2	1
19.keeness of senses.	5	4	3	2	1
20.tolerance of pain.	5	4	3	2	1
21.width of shoulders	5	4	3	2	1
22.arms.............	5	4	3	2	1
23.chest............	5	4	3	2	1
24.appearance of eyes	5	4	3	2	1
25.digestion.........	5	4	3	2	1

	Strong Positive Feeling	**Moderately** Positive Feeling	No Feeling	**Moderately** Negative Feeling	**Strong** Negative Feeling
26.hips..............	5	4	3	2	1
27.resistance to illness...........	5	4	3	2	1
28.legs..............	5	4	3	2	1
29.appearance of teeth.............	5	4	3	2	1
30.sex drive.........	5	4	3	2	1
31.feet.............	5	4	3	2	1
32.sleep............	5	4	3	2	1
33.voice............	5	4	3	2	1
34.health...........	5	4	3	2	1
35.sex activities...	5	4	3	2	1
36.knees.............	5	4	3	2	1
37.posture...........	5	4	3	2	1
38.face..............	5	4	3	2	1
39.weight............	5	4	3	2	1
40.sex organs........	5	4	3	2	1

Appendix XV. Forces Faulted as Women Fail in Combat Training

FORCES FAULTED AS WOMEN FAIL IN COMBAT TRAINING

OTTAWA (CP) - Failure of Canada's first women in an infantry training course shows the Armed Forces have a lot to learn about recruiting mixed platoons, says the officer in charge.

Cmdr. J.E. Harper, director of combat-related employment of women, said the movement to introduce women in combat roles will not suffer a setback due to the failures. All eight women in the four-month training course at Camp Wainwright in Alberta failed the comprehensive final exam for the course.

And Cmdr. Harper said seven of the 13 women who began training in the second mixed-gender platoon in September have left the program to join other courses.

Fourteen of 21 men in the first platoon passed and all 20 of the men who started out in the second platoon are still in the group.

"We never put women through this before," Cmdr.Harper said. "We knew what to look for in men, and we thought we should look for the same things in women."

She noted, however, that five women passed the artillery training course in October and 12 passed the signalling course this month.

Most of the women didn't make it because they couldn't meet the physical strength standards, which are the same for men and women, said spokesman Captain Dave Niles in Edmonton. Some withdrew for health reasons.

"The whole idea of this is to find out if they can do it or not," said Niles. "The military standards are set. War is not going to change."

The women had to participate in unarmed hand-to-hand combat, marksmanship and field craft, which includes patrolling, camouflage and finding your way through the woods.

Niles said some did well in individual tests but failed the exam.(The Edmonton Journal, 1989)