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The validity of using grip strength to represent total body strength and of using a 1Rm bench press to represent upper body strength

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The Validity of Using Grip Strength to Represent Total Body Strength and of Using a 1RM Bench Press to Represent Upper Body Strength

by

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A thesis submitted in partial fulfillment of the requirements for the degree of

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The Thesis of Kristina L. Tucky for the degree of Master of Science in Exercise Physiology is approved.

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Abstract

Thirty-two females, aged 18-30 years, executed 22 isometric strength measurements using strength table procedures similar to Clarke's (1966). A load cell was used in place of the cable tensiometer used by Clarke. Each subject was also administered a grip strength test and a 1RM bench press test. Two criterion measures of strength were identified from the results of the isometric strength tests: 1) total body strength was defined as the sum of the 22 isometric strength measurements and 2) upper body strength was defined as the sum of the 8 upper body isometric strength measurements. The Pearson Correlation Coefficient was used to determine the relationship between: 1)total body strength and grip strength and 2) upper body strength and 1RM bench press test. A statistically significant correlation was found between total body strength and grip strength ($\underline{r}$ = .49422, $\underline{p}$ < .004) and between upper body strength and a 1RM bench press test ($\underline{r}$ = .72483, $\underline{p}$ < .0001). Although a correlation of .49422 was statistically significant the relationship was not strong enough to demonstrate that grip strength was an adequate representation of total body strength. However, a correlation of .72483 was sufficient evidence to suggest that a 1RM bench press test is an adequate representation of upper body strength.

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CHAPTER I

Introduction

Feats of strength have played an extensive role in the evolution of man throughout the course of history. Pictorial history contains murals and cave carvings showing strength training dating back to times before the Christian era. Ancient Indians tried to acquire strength through sacrifices offered to the gods and through the use of a hallucinogenic liquor (Atha 1981). The Athenians and Spartans did not fully believe in the mystic powers of strength although they continued to pay tribute to the gods for the gift of great strength. However, without realizing what they were doing, the Athenians and Spartans made practical sacrifices of work and training (Atha 1981). The Greeks, in the 6th century B.C., became the first to practice progressive resistance training (Atha 1981). However, because the Greeks did not recognize this as weight training the Romans, who emulated the Greeks' theories, were credited with developing weight training.

These Greek and Roman principles of progressive resistance training continued for many centuries. During the time the Greeks and Romans were developing the principles of progressive resistance training their basic idea of training was the same: intensity rather than frequency to develop strength. The

major difference between the Greek and Roman theories and the theories we subscribe to today became apparent with the development of the scientific method and its application to strength topics (Atha 1981). Scientists began to investigate the theory and mechanisms behind strength gain (Atha 1981).

The desire to study and quantify strength led to the development of strength testing methodology. The first strength testing instruments were devised in the late 1700's in Europe (Hunsicker and Donnelly 1955). The use of strength testing instruments began in the United States toward the end of the 19th century (Hunsicker and Donnelly). This ability to determine specific quantities of strength led to the creation of not only strength tests, but also complete physical fitness test batteries.

There are many fitness, skills, motor ability, and general athletic ability tests in use today. Many of these tests have strength testing as a component. Some of these tests include the American Association for Health, Physical Education and Recreation (AAHPER) Physical Fitness Tests, the Youth Physical Fitness Test, and the YMCA Physical Fitness Test Battery (Mathews 1978). The early tests, which stressed strength, included Sargent's Intercollegiate Strength Test and Physical Test of a Man, Rogers' Strength Index (SI) and Physical Fitness Index (PFI), and the Kraus-Weber tests (Mathews 1978).

Strength is measured many ways depending on the objective. Grip strength and one repetition maximum (1RM) tests have both been used as a measure of strength. Grip strength has been used to represent or predict overall

body strength (Golding, Myers, and Sinning 1973) and a 1RM bench press has been used to represent or predict upper body strength. The validity of using these two measurements to represent separate units of strength has not been shown.

Statement of the Problem

The purpose of this study was to determine the validity of using grip strength to accurately represent total body strength and the validity of using a 1RM bench press to accurately represent upper body strength.

Operational Definitions

In order to determine the validity of these two strength measurements there must be a criterion measure to which they can be compared. The criterion measurement of total body strength (SUMALL) was the sum of all 22 strength measurements made on an isometric strength table. The criterion measurement of upper body strength (SUMUB) was defined as the sum of eight of the isometric measurements taken from the upper body only. The strength table procedures were similar to Clarke's (1966) cable tension strength tests.

Assumptions and Limitations

1. It was assumed that the isometric strength table measurements, used as the criterion for total and upper body strength, were actually measuring muscular strength at the various joints.

2. Subjects were given instructions to pull or push maximally for the various measures of isometric strength. It was assumed that the subjects were using their maximum ability on each trial.

3. It was assumed that the weight lifted during the 1RM bench press was the maximum amount that could be lifted.

4. Because college aged women were used only inferences about this group can be made.

CHAPTER II

Review of Literature

Introduction

The subject of strength has an extensive history. The history of strength testing is not as extensive. This chapter briefly summarizes the history of strength training. The balance of the literature search was related to the purpose of this investigation and the methods and procedures of strength testing.

Brief History of Strength Training

Man has always been interested in the development of strength. The history of strength training goes back to times before Christianity. There are murals and cave carvings portraying strength training scenes during these early times (Stafford 1978). Strength training legend continued with the stories of Milo of Croton who is believed to be the first to practice progressive resistance exercise (Davis 1964). Legend has it that Milo began carrying a calf on his shoulders and continued to carry the calf around as they both grew. As the calf matured and got heavier Milo's strength was supposed to increase proportionately. Milo's theories were generally not practiced by the Greeks of that time and it was the Romans who were first to develop concrete ideas about

strength training. Continuing interest in weight training and strength development led to a need to quantify muscle strength. Early research focused on instruments used to measure muscle strength.

History of Strength Testing Instruments

Athletes have opposed their rivals in competitions of strength since the early ages. However, it was not until the 1600's that man began to scientifically measure muscle strength. The purpose of this study is not to describe the history of strength testing but some historical perspective is desirable. The following few paragraphs are taken from the Hunsicker and Donnelly (1955) review with excerpts from other studies.

In 1699 De La Hire made the first scientific attempt to measure muscle strength. He compared the strength of men in lifting weights and carrying burdens with that of horses. The details of this comparison between men and horses is not known. Since De La Hire's time there have been numerous reports of attempts to quantify man's strength, utilizing numerous strength recording instruments.

The dynamometer was the first instrument used to measure human muscular strength. The dynamometer was a scale instrument that recorded the muscular force being applied to it and the force was displayed on a gauge. Graham, an Englishman, was credited with the development of the first dynamometer. Desaguliers, a Frenchman, was the first to use the dynamometer

in a strength testing protocol and publish his results. However, Leroy, another Frenchman, was the first to actually use a spring in his dynamometer. Leroy's dynamometer consisted of a spiral spring within a metallic tube and an attached graduated rod. A globe on top of the rod was grasped and pushed down to compress the spring. The force applied was shown on the graduated rod. Régnier is credited with developing the first metal spring steel dynamometer in 1807 (Figure 1). This was used to measure grip, pulling power, and lifting power and was the forerunner of most spring steel dynamometers.

In 1859 another Frenchman, Burq, invented another modified spring steel dynamometer. Burq's dynamometer had the spring protected by a rectangular ring of metal with the dial inside the spring. Two permanent handles were attached for testing compression and traction or pull could be measured by inserting handles with hooks into the ends of the permanent handles.

In 1863 Duchenne used Burq's dynamometer as a pattern for his own. He placed the dial differently and the handles were modified. Duchenne used the dynamometer in a method which was similar to that developed later by Martin (Davis 1964) as the "break" technique which is described later in this section.

Use of the dynamometer in the United States began toward the end of the 19th century. W.T Brigham, an anthropologist who had done strength testing since 1872 with a case of dynamometers he had acquired in Paris, introduced Dr. Dudley A. Sargent, of Harvard University, to the dynamometer

in 1879 (Davis 1964). Sargent ordered a set of dynamometers, like those Brigham had obtained in Paris, and began strength testing Harvard University students in 1880. Sargent used a dynamometer, similar to Régnier's, to measure back and leg strength. He used another type of dynamometer to test grip strength. This second dynamometer could also be adapted to test arm-pushing and arm-pulling strength.

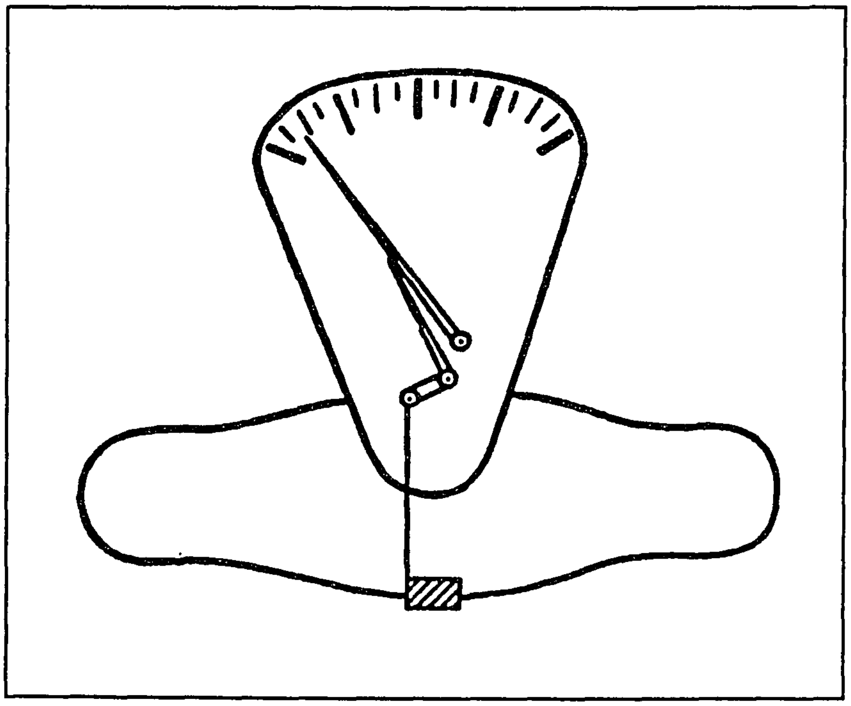

Figure 1. Régnier Spring Steel Dynamometer (from Hunsicker and Donnelly 1955).

One of the next developments of the spring steel dynamometer occurred near the turn of the century. Smedley, another American anthropologist, modified the spring steel dynamometer (Figure 2) by making it adjust to the size of the subject's hand because the previous dynamometer was too large for a child's hand. This became known as the Stoelting Dynamometer after the company who manufactured it. Consequently, spring-type back and leg dynamometers were improved over the years and new developments in grip dynamometers were made including the Collin elliptical spring steel dynamometer and the Narragansett manuometer (Clarke 1966).

Mosso developed an ergograph in 1884 (Figure 3). The ergograph used the principle of lifting a known weight a certain height in a defined time sequence. This was used to study the phases of muscular fatigue because it could record a series of repeated movements. Use of the ergograph showed that there was a difference in types of strength and the terms "strength endurance" and "dynamic strength" came from research using this device.

During the 1890's Dr. John Harvey Kellogg developed a mercurial dynamometer (Figure 4) for measuring the strength of most of the body's muscle groups. It was based on a hydraulic principle. It consisted of a mercury filled cistern mounted on a carriage that could be adjusted to the height of the subject. A cylindrical float was placed on the top of the mercury in the cistern. A system of levers connected grip handles to the float. As the lever system was

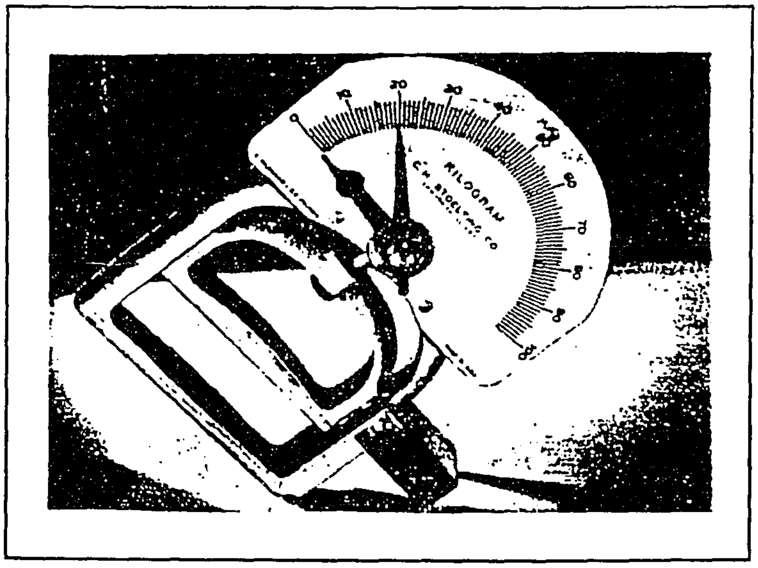

Figure 2. Smedley Adjustable Grip Hand Dynamometer (from Hunsicker and Donnelly 1955).

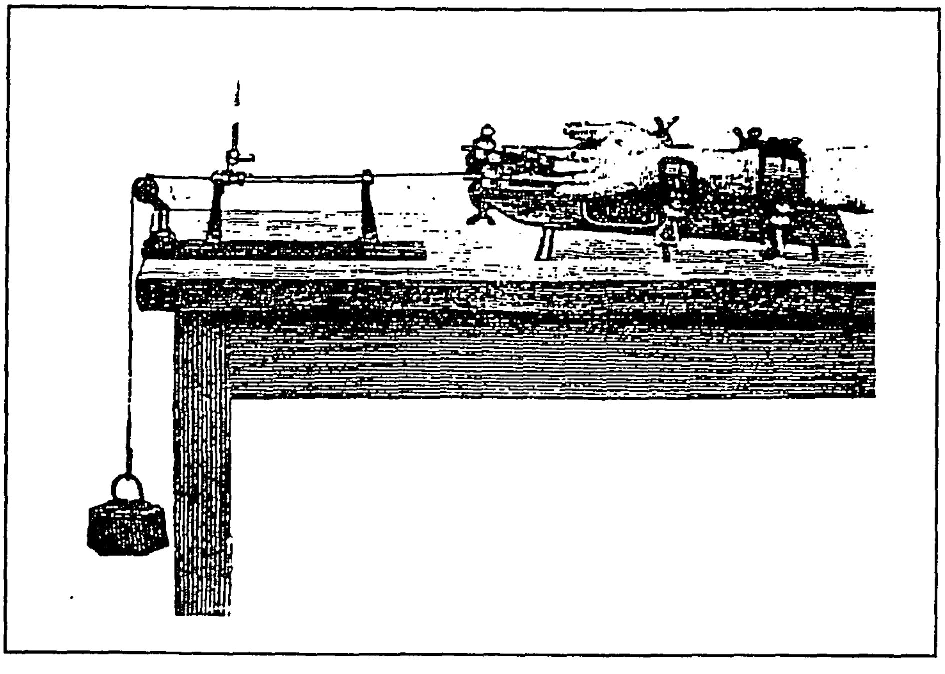

Figure 3. Mosso Ergograph (from Hunsicker and Donnelly 1955).

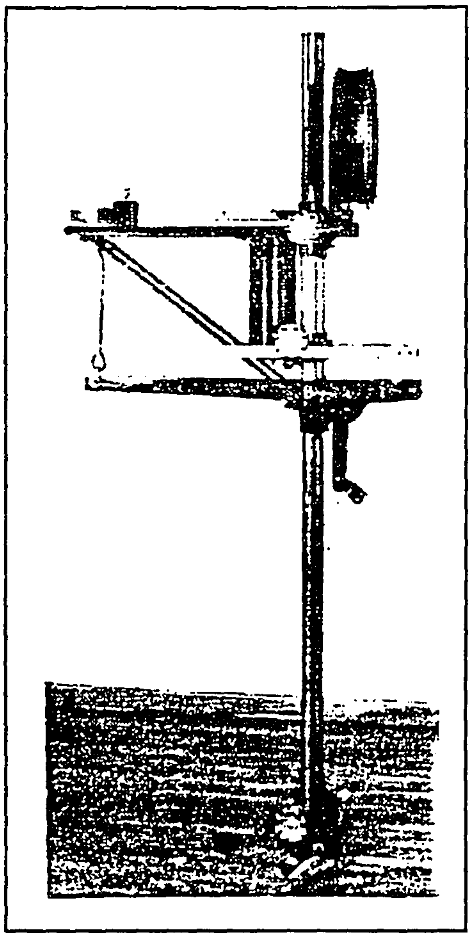

Figure 4. Kellogg Mercurial Dynamometer (from Hunsicker and Donnelly 1955).

circular dial to record how far the float was depressed into the mercury. This was adapted to test nine muscle groups of the upper extremity, eight of the lower extremity, four of the trunk, and four of the neck.

Martin, a physiologist in the Harvard Medical School, was interested in strength testing as a result of the polio epidemic in 1914. He needed an instrument in order to evaluate the effects of his treatment. He used a spring balance scale to measure "breaking strength". The "break" technique was as follows: to test the biceps a strap was fastened to the subject's forearm. The tester held the opposite end of the spring balance scale. The subject was told to flex his/her elbow then to offer maximal resistance to the tester's pull at the opposite end. When the subject's arm began to extend the "breaking strength" was recorded. A.A. Schmier improved the spring balance scale so the operator's role was of less importance which made a more valid test (Davis 1964).

In the late 1940's a new development in strength testing instruments was the result of applying industrial testing units to human subjects. Because of Clarke's interest in testing the strength of disabled soldiers during World War II he adapted an aircraft control cable tensiometer for strength testing. As a force is applied on the cable the riser on the tensiometer is depressed forcing the indicator to shift (Mathews, 1978, Figure 5). Because of its small size the cable tensiometer was extremely useful for testing the strength of many movements.

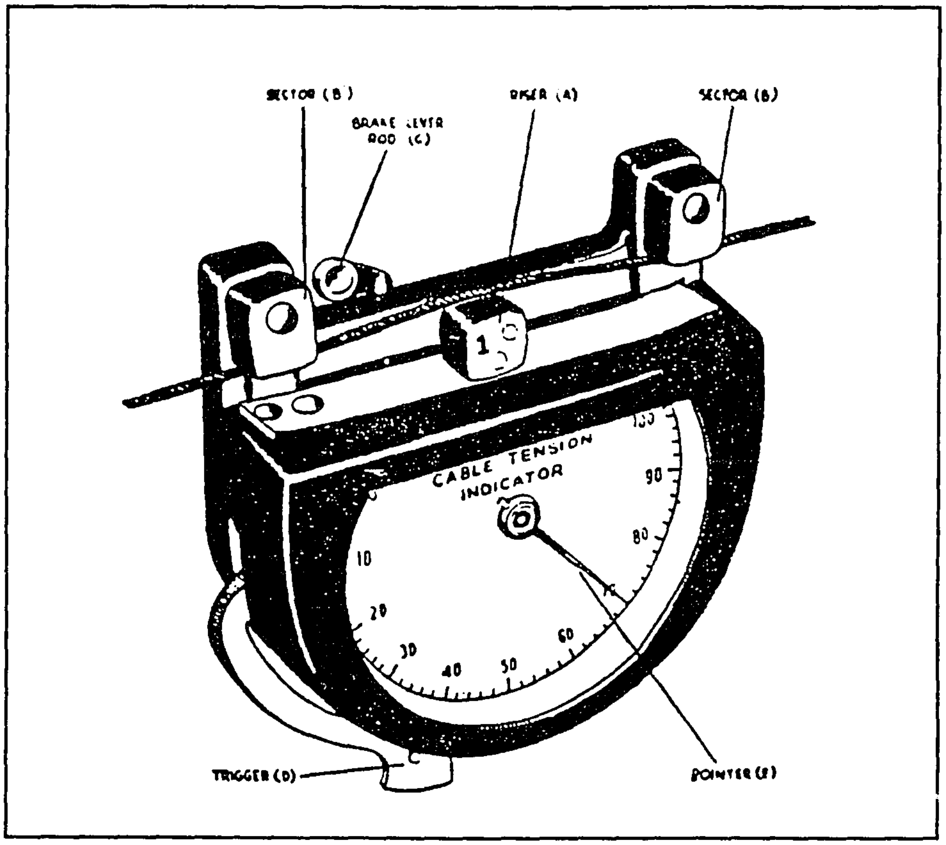

Figure 5. Cable Tensiometer (from Hunsicker and Donnelly 1955).

wrist, elbow, shoulder, trunk, hip, knee, and ankle. Clarke developed a strength table which would facilitate the testing procedure (Clarke & Clarke 1978).

Clarke found that the cable tensiometer had greater precision than a strain gauge or spring scale. Objectivity coefficients, using the tensiometer, strain gauge, and spring scale, were obtained using coefficients of correlation between repeated tests by different testers. The coefficients, using the tensiometer, were all between .90 and .96 for six strength tests (finger flexion, wrist dorsal flexion, shoulder outward rotation, neck extension, knee extension, and ankle plantar flexion). The strain gauge produced objectivity coefficients over .90 with three exceptions: .87 for neck extension, .85 for wrist dorsal flexion, and .81 for knee extension. The spring scale was only used for the weak movements because of capacity limitations. Objectivity coefficients for the spring scale were .91 for neck extension and .97 for wrist dorsal flexion (Clarke 1966). From this, Clarke determined that the tensiometer had the greatest precision of the three instruments for all strength tests.

The initial work by Clarke used joint angles which were empirically selected after a trial of two or more positions. The body positions, for this initial work, were based on kinesiological analyses made by physiatrists at the Mayo Clinic (Clarke 1966). Clarke suggested changes in these body positions, to facilitate maximum strength recordings, and then validated these changes. Further cable-tension strength studies specifically evaluated joint angles to determine which yielded the maximum strength recordings. For this study the

strength of the involved musculature was measured approximately every 20° to 25° throughout the range of motion. Clarke found that there was an optimum position at which each muscle could deliver its maximum strength.

The cable tensiometer used in the Harrison Clarke testing protocols was replaced by a load cell (Transducers Inc., model no. Y363-500-20P1) in the present study.

The strain gauge (known today as a load cell) was the first piece of strength testing equipment to utilize electronics. In 1947 physiologists began to use the strain gauge. Ralston and associates adapted a strain gauge by attaching calibrated aluminum rings to it (Clarke 1966). It initially consisted of a fixed wire in a circular steel ring with the force being applied changing the electrical resistance of the strain gauge (Hunsicker and Donnelly 1955).

History of Strength Tests

Scientists have long been interested in the measurement of muscular strength in man and its relationship to health and athletic ability. In 1873 Sargent, while still a medical student at Yale, used chins and dips as a measure to determine the efficiency of gymnastic students in handling their body weight with their arms (Davis 1964). In 1880, while at Harvard, Sargent began to test his students. In 1897 his "Intercollegiate Strength Test" was adopted by fifteen colleges. He used this test to study other factors which gave an indication of an individual's power and working capacity. This test measured back and leg

strength with a dynamometer (Figure 6); right and left grip with a hand grip dynamometer; lung capacity with a wet spirometer; and arm strength by the number of pull-ups and dips executed. Sargent believed that the primary reason for physical training was to develop overall muscular strength and power for improving the structure and function of the body (Mathews 1978).

Strength testing declined in the early 1900's because it was felt the tests did not take into account measures of endurance and heart and lung development. The theory that athletes became "muscle bound" by strength training was also prevalent during this time (Mathews 1978).

The work of Martin, studying the aftereffects of the Vermont polio epidemic in 1915, revived interest in strength testing (Mathews 1978).

Rogers further revived interest in strength testing in 1925 with the publication of of his dissertation: Physical Capacity Tests in the Administration of Physical Education (Davis 1964). Rogers standardized testing procedures and developed norm tables which showed a significant relationship among physical condition, muscular strength, and athletic performance. Rogers revised Sargent's Intercollegiate Strength Test which became Rogers' Strength Index (SI) for general athletic ability (Mathews 1978). Rogers' Strength Index was composed of the gross score acquired from the following items:

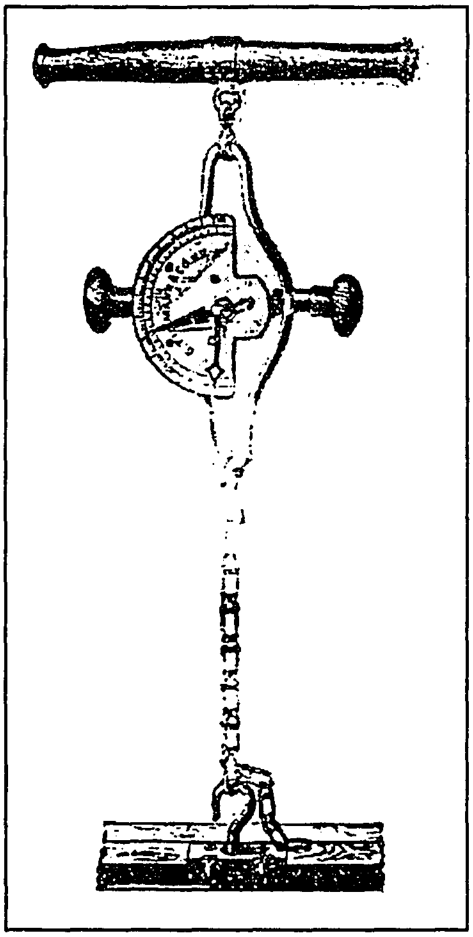

Figure 6. Sargent Back and Leg Dynamometer (from Hunsicker and Donnelly 1955).

1.Lung Capacity - measured with a wet spirometer (in^3)
2.Right and Left Grip Strength - measured with a hand dynamometer (lbs)
3.Back Lift - measured with a back-leg dynamometer (lbs)
4.Leg Lift - measured with a back-leg dynamometer (lbs)
5.Arm Strength -

$$(pull\text{-}ups + push\text{-}ups)\, x \left[\frac{wt}{10} + (ht - 60)\right]$$

The following is an example of Rogers' Strength Index.

-Subject's weight = 150 pounds -Pull-ups = 4

-Subject's height = 65 inches -Push-ups = 6

-Lung capacity = 500 -Right and left grip = 55

-Back lift = 500 -Leg lift = 500

-Arm strength = (4 + 6)(150/10 + 65 - 60) = (10)(20) = 200

-Strength Index = 200 + 500 + 55 + 500 + 500 = 1755

Rogers developed separate tables of Strength Index norms for both girls and boys based on age and weight.

Rogers then developed the Physical Fitness Index (PFI) which was a measure of general physical condition. The PFI is obtained from comparing an individual's SI with a norm based on their gender, weight, and age (Mathews 1978).

McCloy, Van Dalen, and Cureton each stated that lung capacity was not a test of strength and should not be in a battery of strength tests (Davis 1964). The McCloy Strength Test consisted of right and left grip strength, back and leg lift, pull-ups, and parallel-bar dips.

McCurdy modified Rogers' Strength Index, by omitting height, weight, and lung capacity, for a test intended for secondary school boys (Davis 1964).

In 1953 Clarke published a manual of cable tension strength tests (Clarke 1953). Clarke specified instructions for testing 38 muscle groups using a tensiometer. Initially, these tests were constructed for use with orthopedically disabled veterans and hospital patients. The procedures have been used in numerous research studies and it was thought they could be used as an additional test measurement for school children.

Kraus and Hirschland constructed a large battery of fitness tests over a period of eighteen years (Kraus & Hirschland 1954). They examined numerous patients with low back disorders and concluded that most of the disorders could have been prevented by maintaining a certain level of muscular fitness. Kraus and Hirschland selected 6 of the most valid fitness tests and administered them to 4458 American school children (Kraus & Hirschland 1954). These tests, known as the Kraus-Weber tests, were thought to indicate the minimum level of strength and flexibility needed to maintain healthy functioning of the body. They received a great deal of publicity and brought national attention to the low level of muscular fitness of American youth. The first was a test of abdominal and psoas strength, (designated A+, Figure 7). The second was a test of abdominal minus psoas strength, (designated A-, Figure 8). The third was a test of psoas strength,

(designated P, Figure 9). The fourth was a test of upper back strength, (designated UB, Figure 10). The fifth was a test of lower back strength, (designated LB, Figure 11). The sixth was a test of back and hamstring flexibility, (designated BH, Figure 12). The high rate of failure among the American children resulted in Kraus and Hirschland testing European children of the same age. They tested 2870 Austrian, Italian, and Swiss children. The American children were found to be below the Europeans in both strength and flexibility (Kraus & Hirschland 1954).

The publication of these data called national attention to the problem of the low level of physical fitness among American children (Mathews 1978). In 1956 President Eisenhower established a Fitness Commission. A Council on Youth Fitness and a Citizens' Advisory Committee on the Fitness of American Youth were established during the first meeting of the Fitness Commission. The purpose of these two groups was to give top priority to the field of physical fitness; to better coordinate the activities of thirty-five federal agencies; and to examine the facts and alert America on what can and should be done to improve the physical fitness of American youth.

Fox and Atwood tested 575 Iowa children in grades one through six on the Kraus-Weber test (Fox & Atwood 1955). Their findings were similar to those reported by Kraus and Weber.

Phillips and associates administered the Kraus-Weber test to 1456 children from a city in Indiana (Phillips et al. 1955). Of the 1456 children, 215

were tested twice to determine the test/retest reliability of the test items in the Kraus-Weber test and 126 of the children were tested for grip strength to determine the relationship between grip strength and success on the Kraus-Weber test. Phillips found the reliability exceeded .950 but there was no relationship between grip strength and the Kraus-Weber tests. They also found: that the Indiana sample was superior to the Kraus sample in all failure comparisons, that girls were more successful on the flexibility test than boys, that lack of flexibility increased with age for both sexes, and that strength failures decreased with age. Phillips and associates, on the basis of the last two findings, recommended that flexibility and strength scores be separated because as flexibility decreases with age and strength increases with age the combination of these two factors reflect no overall change (Mathews 1978).

Because many physical educators believed the Kraus-Weber test only assessed strength, a more comprehensive test battery was needed to determine physical fitness. The American Association for Health, Physical Education and Recreation (AAHPER) started the Youth Fitness Project in 1957. A test battery, consisting of pull-ups, sit-ups, 40-yard shuttle run, 50-yard dash, 600-yard run-walk, standing broad jump, and a softball throw, was administered to 8500 boys and girls in the fifth through the twelfth grade. This test was given to determine the general fitness level of these students who were considered to be representative of American children. In 1965 Dr. Paul Hunsicker, from the University of Michigan, tested 9200 children from the ages of 10 to 17. He used

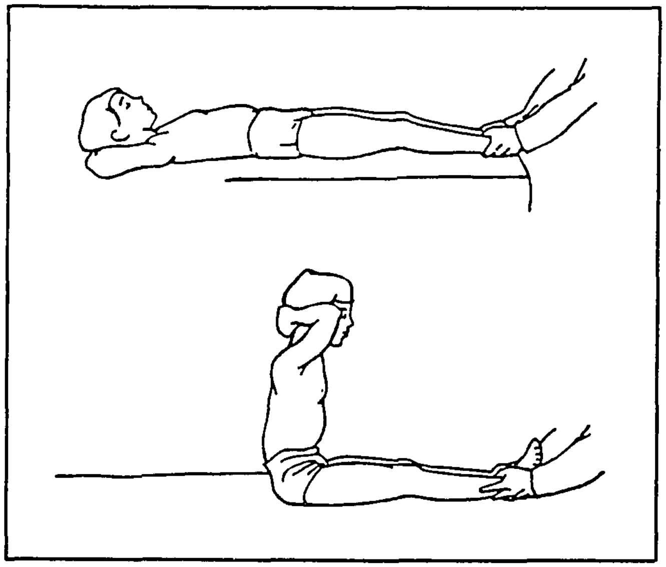

Figure 7. Abdominal Plus Psoas Muscle Test (from Mathews 1978).

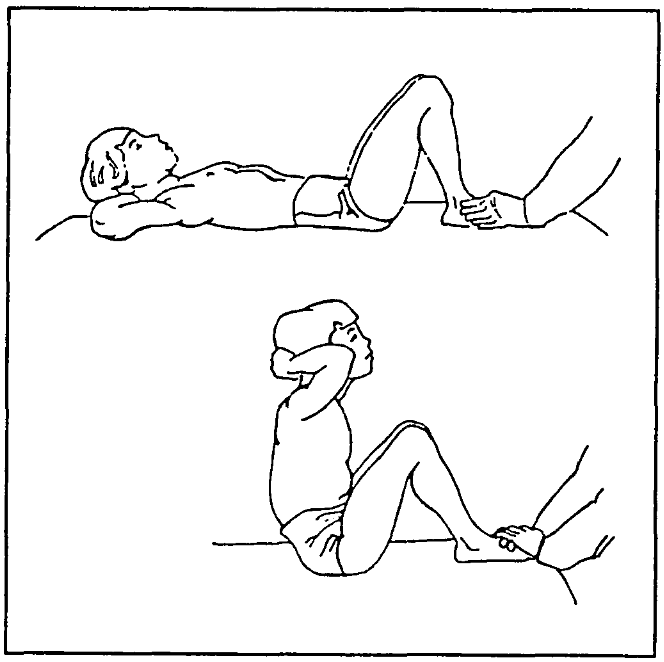

Figure 8. Abdominal Minus Psoas Muscle Test (from Mathews 1978).

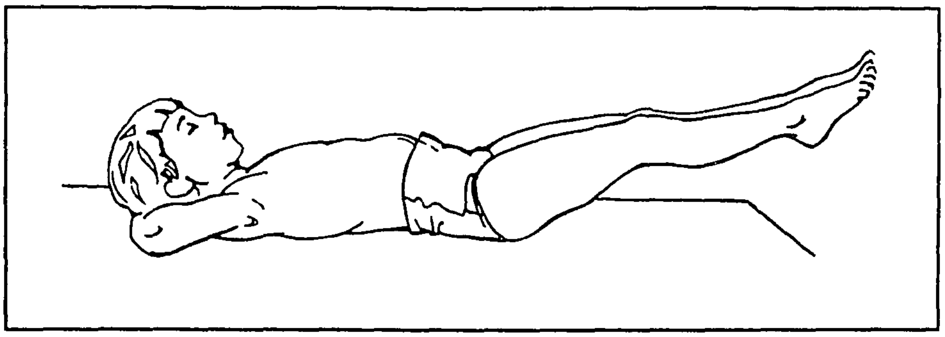

Figure 9. Psoas and Lower Abdominal Muscles Test
(from Mathews 1978).

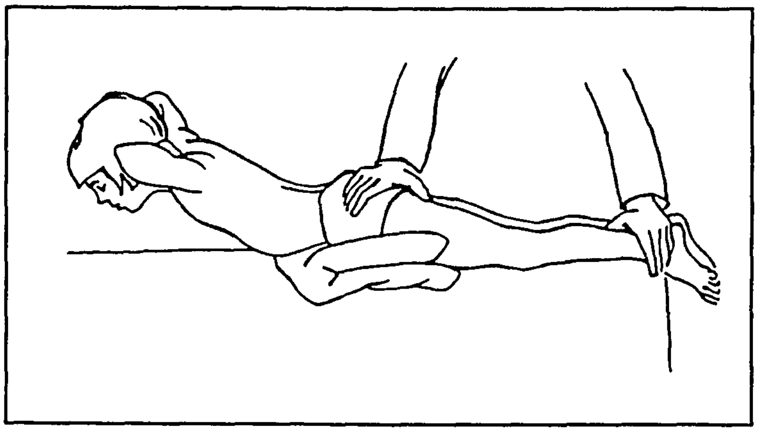

Figure 10. Upper Back Muscle Test
(from Mathews 1978).

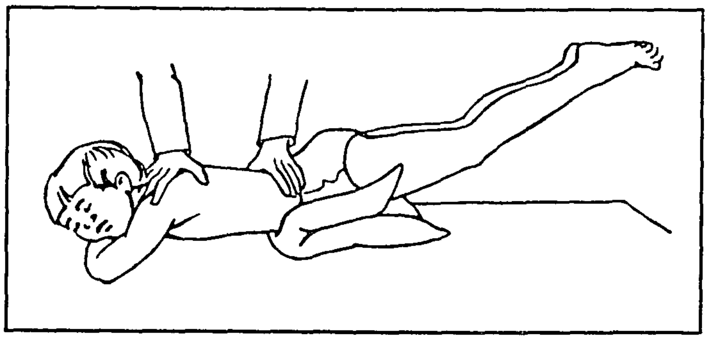

Figure 11. Lower Back Muscle Test (from Mathews 1978).

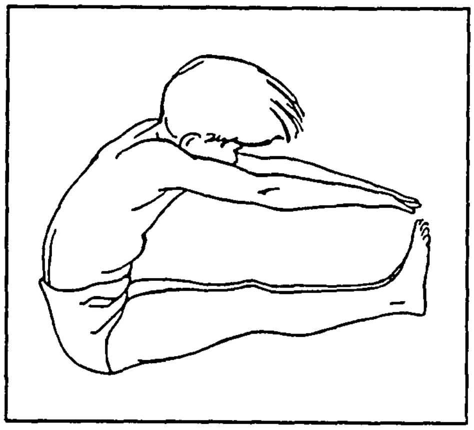

Figure 12. Hamstring Muscles and Length of Back Muscles Test (from Mathews 1978).

the same test battery with the exception of using the flexed arm hang in place of modified pull-ups for girls (Mathews 1978).

Campbell and Pohndorf administered the AAHPER Physical Fitness Tests, including Hunsicker's revision, to over 10,000 British boys and girls (Mathews 1978). The results showed the British children to be superior to the Americans in everything but the softball throw. The difference can be attributed to the fact that British children participated in structured physical education classes which stressed fitness and calisthenics whereas American children participated in physical education classes that were more game oriented.

Knuttgen tested 319 male and 134 female Danish children on the AAHPER test and compared his results with the American average (Knuttgen 1961). Approximately 70% of the boys' scores and 86% of the girls' scores exceeded the American mean scores. Knuttgen attributed the score discrepancy to three lifestyle differences:

1. Danish children have more activity by necessity because the bicycle is their primary means of transportation and television only operates a few hours daily.
2. The physical education program meets at least three times a week with close supervision by the school administration. Soccer is for the boys and handball or longball is played by the girls.
3. Approximately 45% of the Danish population between the ages of 15 and 40 participate in some form of sports.

Strength tests are a valuable tool in public school physical education classes provided the limitations of the various tests are recognized.

Effect of Anthropometric Measurements on Strength

Age

According to Clarke (1973) and Montoye (1977) maximum strength is reached between the ages of 20 to 30 for both males and females. Åstrand and Rodahl (1986) indicate that peak strength for males is reached at 20 years and a few years earlier for females. Hunsicker and Greey (1957) found that the strength of males increased rapidly from 12 to 19 years and more slowly up to 30 years at which time strength began to decrease. Asmussen and Heeboll-Nielsen (1962) also found that strength began to decrease after the age of 30. Hunsicker and Greey (1957) also found that the strength of females increased more uniformly from 9 to 19 years and again more slowly up to 30 years at which time strength began to decrease. A 65 year old individual maintains approximately 75 to 80% of his or her maximal strength (Åstrand and Rodahl 1986). Johnson (1982) found that muscular strength decreased with age but muscular endurance did not decrease.

Height

Johnson (1982) found that for women ages 20-29 there was a significant positive correlation between height and both isometric and dynamic muscle strength. Hunsicker and Greey (1957) report that Martin found that strength and height varied directly. Clarke (1954) found that height and girth of flexed-tensed upper arm were each significantly correlated with arm strength measurements.

Weight

Johnson (1982) found that for women ages 20-29 there was a significant correlation between weight and both isometric strength and endurance. Rasch and Pierson found the correlation between body weight and arm strength to be significantly lower among untrained then trained men (1963).

Gender

Until the age of 10 to 12 years there is no significant strength difference between boys and girls (Åstrand and Rodahl 1986). After this age boys become much stronger than girls. This may be the result of increased amounts of testosterone secretion in boys. The difference in strength between adult males and females varies from one muscle group to another but in general females possess two-thirds the strength of males (Hettinger 1961).

Girth

Humans are capable of generating 3-4 kg of force per cm^2 of skeletal muscle (McArdle, Katch, & Katch 1986). This identical capability for force generating capacity indicates that the difference in strength between males and females is the actual size of the muscle. Hettinger (1961) agreed and determined that muscle strength and muscle cross section increase to the same degree. Åstrand and Rodahl (1986) concurred that muscle mass or girth is the main determination of the potential for strength. However, contradictory to Hettinger, they found that muscle strength and muscle cross section did not increase to the same degree. They determined that during the initial phases of

a strength training program the increase in strength may be due to greater recruitment of motor units rather than changes in cross-sectional area of the muscles.

Isometric vs Isotonic Muscle Strength

Muscular strength, according to Clarke (1966), is the tension muscles can apply in a single maximum contraction. Kroemer (Atha 1981) stated that "strength is the maximal force muscles can exert isometrically in a single voluntary effort." Yet another definition is "the ability of a muscle group to exert maximal force in a single voluntary effort" (Knapik, Wright, Mawdsley, & Braun 1983). An isometric muscle contraction occurs "when both ends of a muscle are fixed and no movement occurs in the involved joint" (Åstrand & Rodahl 1986). An isotonic muscle contraction occurs "when a muscle varies its length when activated to produce a given force" (Åstrand & Rodahl 1986). An isotonic contraction can induce the muscle to either shorten (concentric) or lengthen (eccentric). An isotonic contraction is consider a dynamic contraction because of the movement involved.

According to Bender and Kaplan (1966) dynamic movement can be measured by isometric techniques. Hortobagyi, Katch, and LaChance (1989) stated that "...if there is a general muscular strength component across various contraction modes, then individuals who performed well (or poorly) would achieve the same relative level of performance independent of test mode or type

of strength being evaluated". Carlson (1970) noted a positive relationship between isometric and isotonic strength. Carlson felt it was legitimate to test isotonic strength isometrically as long as the purpose of the test was not to determine the level of muscular strength. Discrimination between strong and weak subjects is the purpose of testing isotonic strength isometrically (Carlson 1970).

Rasch (1963) found that the strength of elbow flexors measured isometrically is highly correlated with the maximum amount of weight lifted isotonically by the elbow flexors. Another study looked at more than elbow flexion and concurred that both isometric and isotonic testing are measuring similar occurrences (Knapik, et al. 1983).

Summary

The literature regarding muscle strength is extensive. Human interest in strength can be traced back to times before Christianity. This interest eventually led to the development of instruments and methods to assess muscular strength and endurance. Increased activity in strength training continued during the development of these instruments and methods and scientists began to have the ability to quantify changes that were occurring due to training.

The first testing equipment, a dynamometer, originated in Europe. It was designed and built by an Englishman but many subsequent modifications were made by Frenchmen. Use of the dynamometer in the United States did not

begin until approximately 150 years later, approximately 1900. Strength testing, using a cable tensiometer, was introduced during World War II by Clarke who was testing the strength of the disabled soldiers. He determined the optimum angle for strength of fourteen different tests. Clarke's procedures using a strength table and a load cell rather than a tensiometer are still in practice today.

The effect of anthropometric measurements on strength has been widely studied. The developmental aspects of strength from childhood through adulthood and old age have been tracked. Studies have also examined the effects of height, weight, gender and girth on muscular strength.

Because the use of muscular strength often involves movement it was necessary to study isotonic or dynamic strength. However, it was determined that as long as absolute strength was not the topic of the study, dynamic strength could be measured isometrically.

Physical fitness batteries used various tests to quantify strength. Two of the most common were grip strength and bench press. The reason, for using grip strength to measure total body strength, was questioned and its use was eliminated from many tests. Bench press is still used in many fitness batteries as a measure of total upper body strength.

CHAPTER III

Methods

Subjects

Thirty-two apparently healthy female subjects, age 18-30, volunteered to participate in the study after the procedure for the study had been explained. Table 1 presents the physical characteristics of the subjects.

Table 1

Physical Characteristics of Subjects (n = 32)

Characteristic	Mean	SD
Age (years)	23.40	3.11
Height (in.)	65.29	2.35
Weight (lbs.)	135.59	16.78
Body Fat %	22.93	4.92

Procedures

-The subjects, age 18-30, completed an informed consent form and the Par-Q (Appendix A).

The following measurements were recorded on a score sheet (Appendix A).

-Body weight was recorded for use as a descriptor. Body Weight was measured with a Toledo scale to the nearest gram. Subjects removed their shoes and excess clothing (sweatshirt, pants, etc.).

-Skinfold measurements were recorded to determine the subject's body fat percentage which was also used as a descriptor. Lange skinfold calipers were used to measure the skinfolds at four sites (abdomen, ilium, triceps, and thigh) according to the procedure described by Golding, Myers, and Sinning (1989). Abdomen is a vertical fold taken approximately one inch to the right of the umbilicus. Ilium is a diagonal fold taken immediately superior to the crest of the ilium on the mid-axillary line. Tricep is a vertical fold taken on the posterior aspect of the upper arm, midway between the shoulder and elbow joints. Thigh is a vertical fold on the anterior aspect of the upper leg, midway between the groin line and the superior aspect of the patella. Percent body fat was calculated using the sum of four site formulae devised by Jackson and Pollock (Golding et al. 1989).

-Girth measurements were taken in the event that there would be a notable result that might be explained by a difference in girth. Girth measurements, using a cloth tape, were measured bilaterally at the following sites: upper arm (mid-biceps), lower arm (3 inches below the medial epicondyle of the humerus), thigh (6 inches above mid-patella), and calf (6 inches below mid-patella). A tape measure was used to measure distance and girth. Measurements were recorded to the nearest one-eighth of an inch. Small pen marks were made on the thigh and calf positions for future landmarks.

-Flexibility measurements were recorded to be used as part of a "fitness profile" used to entice subjects to participate in the study. The subjects warmed up by stretching their hamstrings for approximately one minute then the YMCA (Golding et al. 1989) flexibility test was administered. This procedure uses a commercially available sit and reach device. The subject removed their shoes and sat on the cushion with their knees fully extended. One hand was placed over the other with the fingers extended. Neither hand could extend further than the other. A marker was then pushed, between the legs, as far as possible with the knees remaining extended. The marker was left in place and the subject was allowed to relax. This procedure was repeated 3 times. The score was recorded, in inches, from the end of the marker closest to the subject. This flexibility test was recorded for the subject's small fitness profile (Appendix A).

-The isometric strength tests were administered in the following order using the procedures described by Clarke (1966). A diagram of the strength

table and its accessories may be found in figures 25-27. Each test was repeated 3 times with the subject being instructed to "... pull or push as hard as possible, without jerking, then hold it for three to five seconds." Although 3 trials were recorded, the maximum value was used for statistical evaluation. Where bilateral testing was performed the right side preceded the left side. Joint angles were checked with a goniometer. A load cell (Transducers, Inc., model no. Y363-500-20P1) was used to measure the pull on the cables. The strength readings were taken from a digital display (Toledo, model no. 8140) which read to the nearest .5 kilogram.

1. Elbow Flexion: The subject lay supine with their knees extended and feet against 2x8 board (placed against vertical supports of the table). The elbow was flexed at 90 degrees. The wrist was in neutral position with the testing strap around the wrist at the styloid processes. The opposite arm lay across the chest. Stabilizing straps were placed across the waist and under the axilla (Figure 13).
2. Elbow Extension: The subject lay supine with their knees flexed and their shoulders against the brace. The elbow was flexed to 90 degrees. The wrist was in neutral position with the testing strap around the wrist at the styloid processes. The opposite arm lay across the chest. Stabilizing straps were placed across the waist and under the axilla (Figure 14).

3.Shoulder Extension: The subject lay supine with their knees flexed and their shoulder flexed to 90 degrees. The elbow was also flexed to 90 degrees. The wrist was in neutral position with the testing strap midway between the shoulder and elbow. The opposite arm lay across the chest. Stabilizing straps were placed across the waist and under the axilla (Figure 15).

4.Shoulder Flexion: The subject lay supine with their knees flexed. Their shoulder lay in the anatomical starting position with the elbow flexed to 90 degrees. The wrist was in neutral position with the testing strap midway between the shoulder and elbow. The opposite arm lay across the chest. Stabilizing straps were placed across the waist and under the axilla (Figure 16).

5.Ankle Plantar Flexion: The subject lay supine with the knee of the leg being tested fully extended. The opposite knee was flexed and their shoulders were against the brace to prevent body movement. The ankle to be tested was flexed to 90 degrees. The testing strap was placed around the heads of the metatarsals. The subject's shoes were left on. The arms were folded across the chest and one stabilizing strap was placed above the patella (Figure 17).

6.Ankle Dorsi Flexion: The subject lay supine with the knee of the leg being tested fully extended. The opposite knee was flexed. The heel of the testing leg was placed against a 6" long 2x4 board (placed against one

upright of the table) with the ankle dorsi flexed to 90 degrees. The testing strap was placed around the heads of the metatarsals. The subject's shoes were left on. The arms were folded across the chest and one stabilizing strap was placed above the patella (Figure 18).

7. Knee Extension: The subject sat at the edge of the table with their hands holding the sides of the table. The knee being tested was flexed to 65 degrees. The testing strap was placed at the previously marked point of 6 inches below mid-patella. A stabilizing strap was placed across the upper thigh as close to the body as possible. A knee pad was placed under the testing strap to prevent irritation of the tibia (Figure 19).

8. Knee Flexion: The subject lay prone with their patellas just off the end of the table, the knee not being tested in full extension, and their hands holding the sides of the table. The knee being tested was flexed to 15 degrees with the testing strap placed at the previously marked point of six inches below mid-patella. Stabilizing straps were placed across the scapula and buttocks (Figure 20).

9. Hip Extension: The subject lay prone with their anterior superior iliac spine flexed off the end of the table, the leg not being tested extended to the floor, and their hands holding the sides of the table. The hip being tested was flexed to 50 degrees with the testing strap placed at the previously marked point of 6 inches above mid-patella. A stabilizing strap was placed across the scapula (Figure 21).

10.Hip Flexion: The subject lay supine with knee of testing leg fully extended and the opposite knee flexed. The hands lay across the chest. The leg being tested was at the midline of the body with the testing strap placed at the previously marked point of 6 inches above mid-patella. Stabilizing straps were placed across the anterior superior iliac spine and under the axilla (Figure 22).

11.Trunk Extension: The subject lay prone with their trunk flexed, superior to the anterior superior iliac spine, over the upper end of a 6 inch thick mat (Appendix B). Their knees were fully extended and their arms were placed on the lower back. The testing strap was placed across the chest, immediately inferior to the shoulders. Stabilizing straps were placed across the buttocks and across the belly of the gastrocnemius (Figure 23).

12.Trunk Flexion: The subject lay supine with their legs flexed at 90 degrees. Their knees were also flexed at ninety degrees and resting on a wooden box. The arms lay folded across the chest with the testing strap across the chest, immediately inferior to the shoulders. A stabilizing strap was placed across the anterior superior iliac spine (Figure 24).

-Grip strength was then measured with the dominant hand, using a Smedley type hand grip dynamometer. Grip strength was measured to the nearest kilogram. The instructions were "... hold the dynamometer in any

position except with the elbow braced against the body. Squeeze as hard as possible." Three trials were given with the highest measurement being recorded.

-1RM bench press was the final test to be administered. Subject's were instructed to lie supine on a bench press bench with their eyes aligned under the barbell. The bar was gripped with both hands approximately shoulder width apart. Assistance was given to lift the barbell from its yoke. From the locked-elbow position the subjects were told to lower the barbell, touch their chest, then return to the locked-elbow starting position. No acknowledgment was given if the subject failed to touch the bar to their chest. Each subject was asked to lift the bar, without weight, two times. If this appeared difficult 5 pounds was added. If the lift of the barbell alone appeared easy approximately 10 to 15 pounds was added. Achieving a one repetition maximum took no longer than 4 trials with each subject. A 45 pound barbell was used for each subject. Additional weight consisted of 2x25 lbs, 2x10 lbs, 2x5 lbs, and 4x2.5 lbs.

-The subjects were then given a one page summary of their results with their body composition and flexibility profile (Appendix C). They were also given a table of national averages (Appendix C) which compared their profile to other women their age.

Statistical Methods

-The Pearson Correlation Coefficient was used to statistically compare 27 variables. Descriptive statistics including mean and standard deviation were used to depict the subjects.

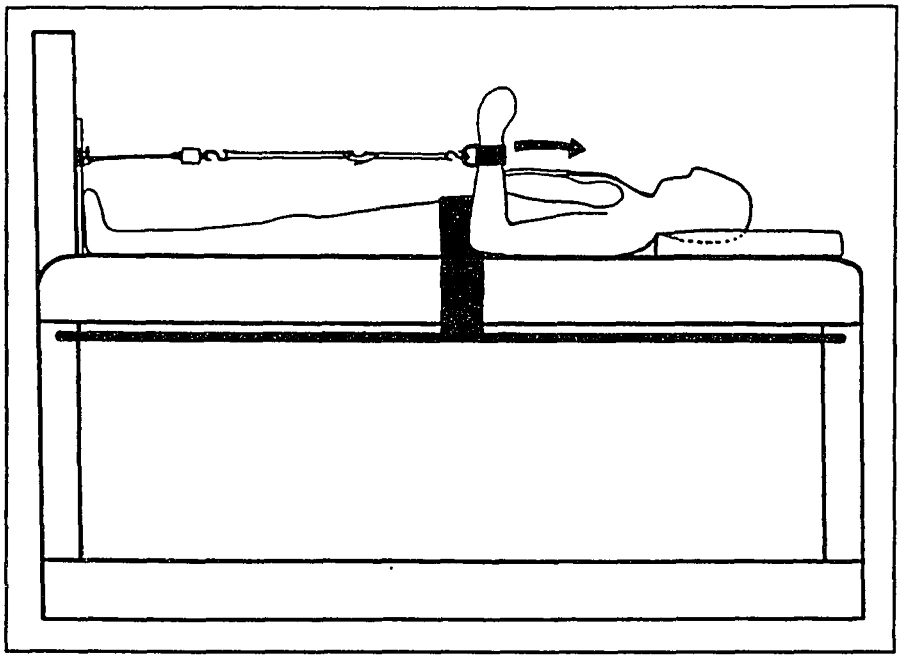

Figure 13. Elbow Flexion

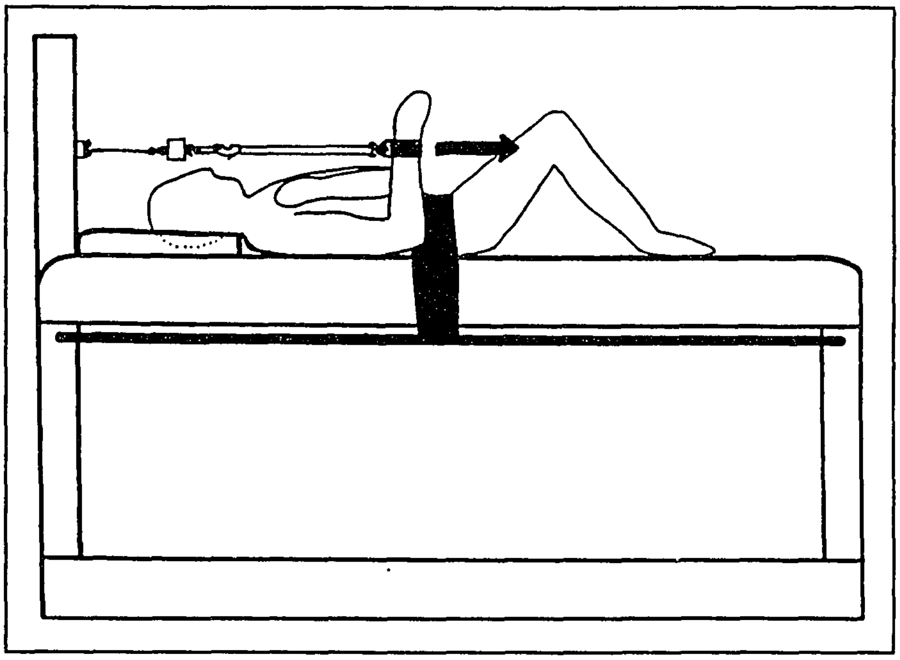

Figure 14. Elbow Extension

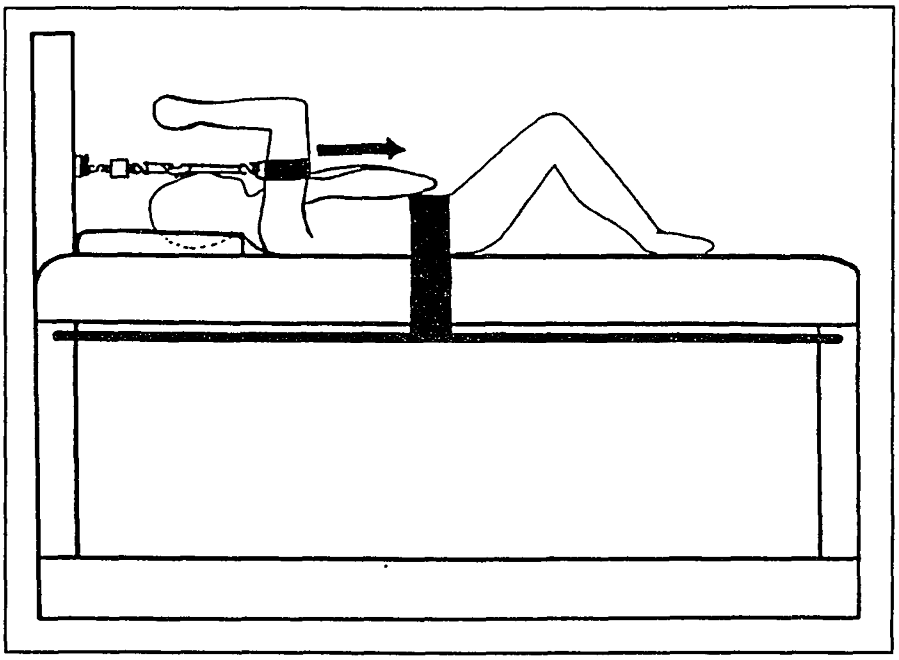

Figure 15. Shoulder Extension

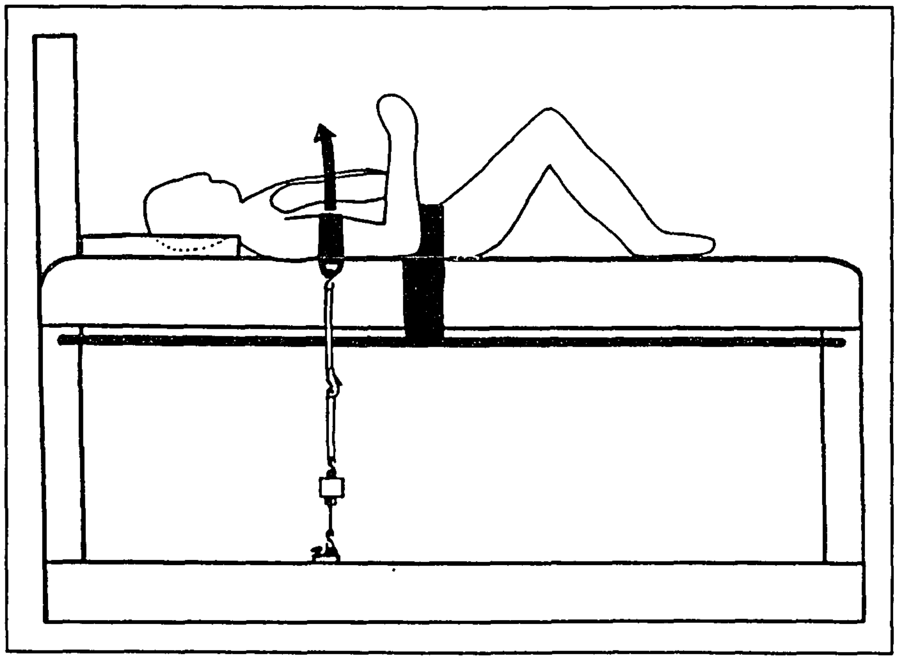

Figure 16. Shoulder Flexion

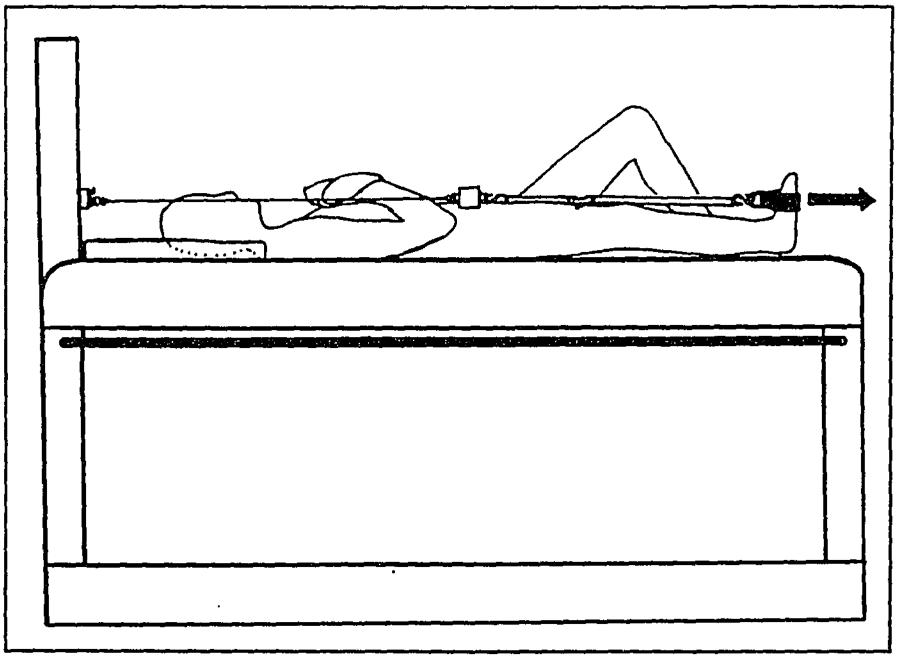

Figure 17. Ankle Plantar Flexion

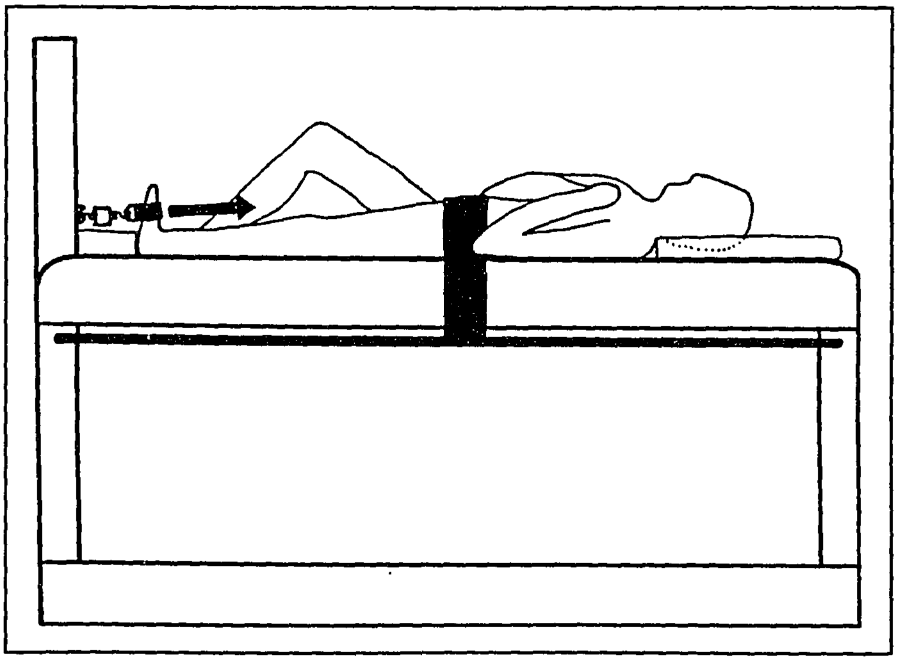

Figure 18. Ankle Dorsi Flexion

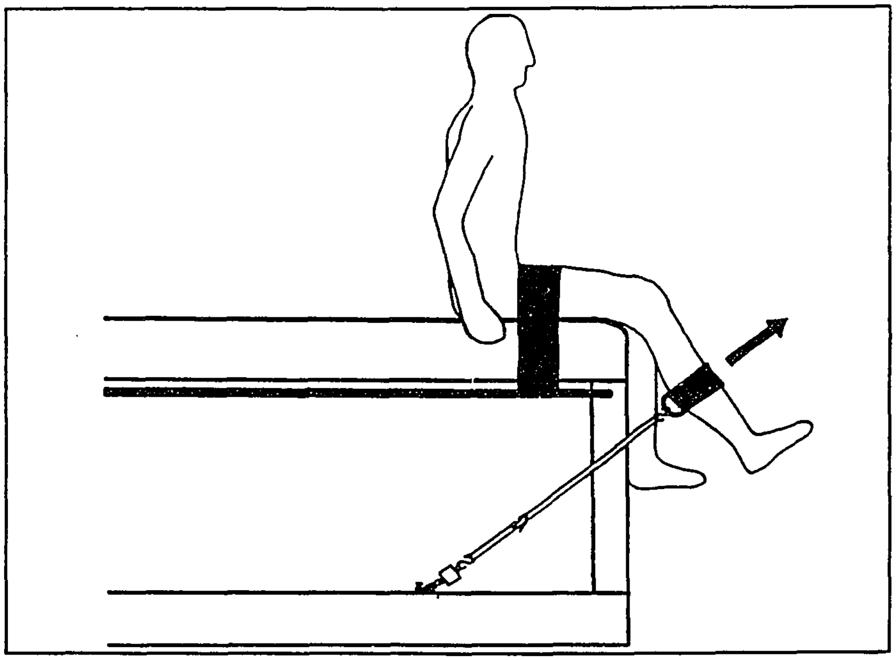

Figure 19. Knee Extension

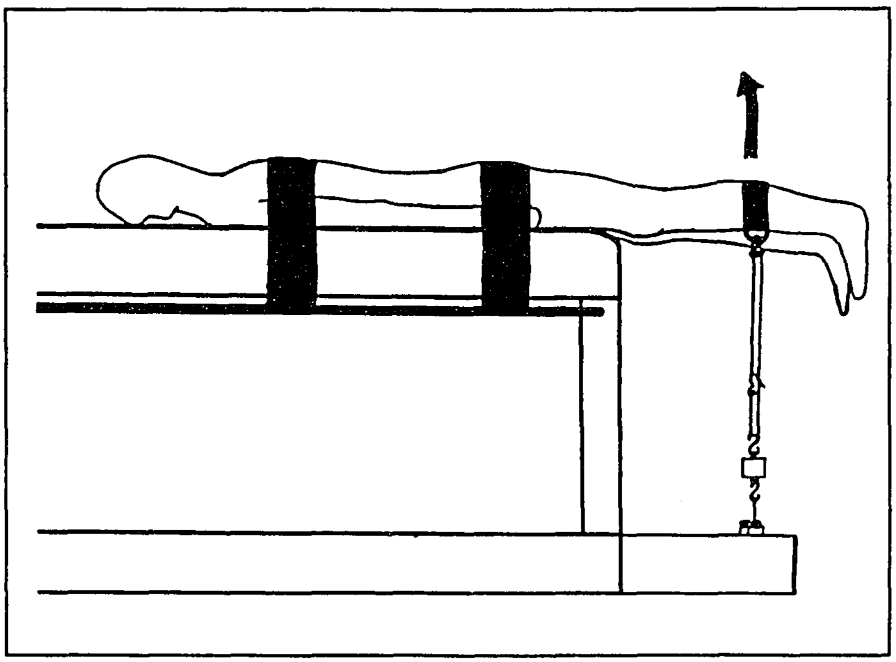

Figure 20. Knee Flexion

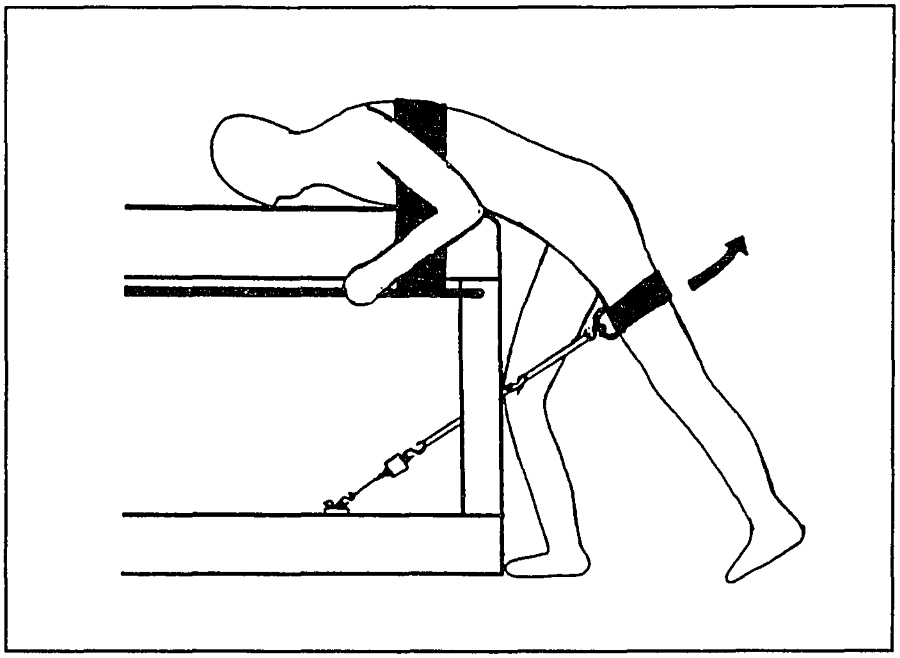

Figure 21. Hip Extension

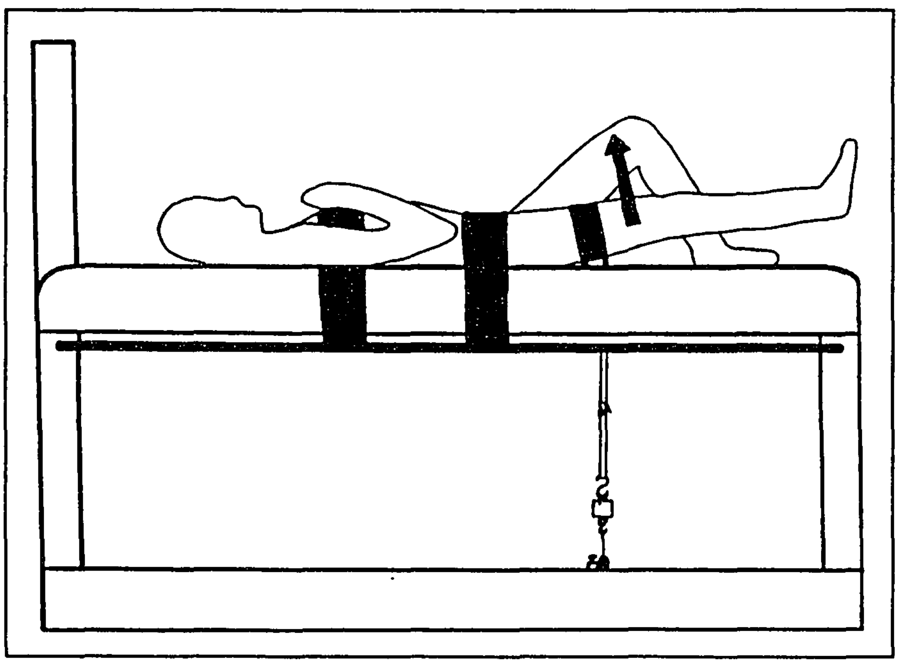

Figure 22. Hip Flexion

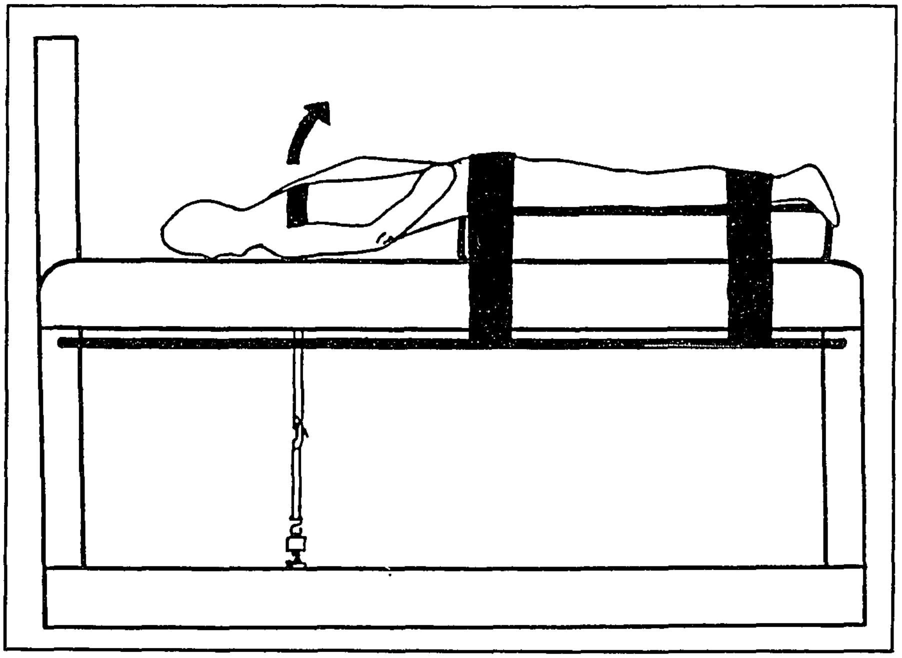

Figure 23. Trunk Extension

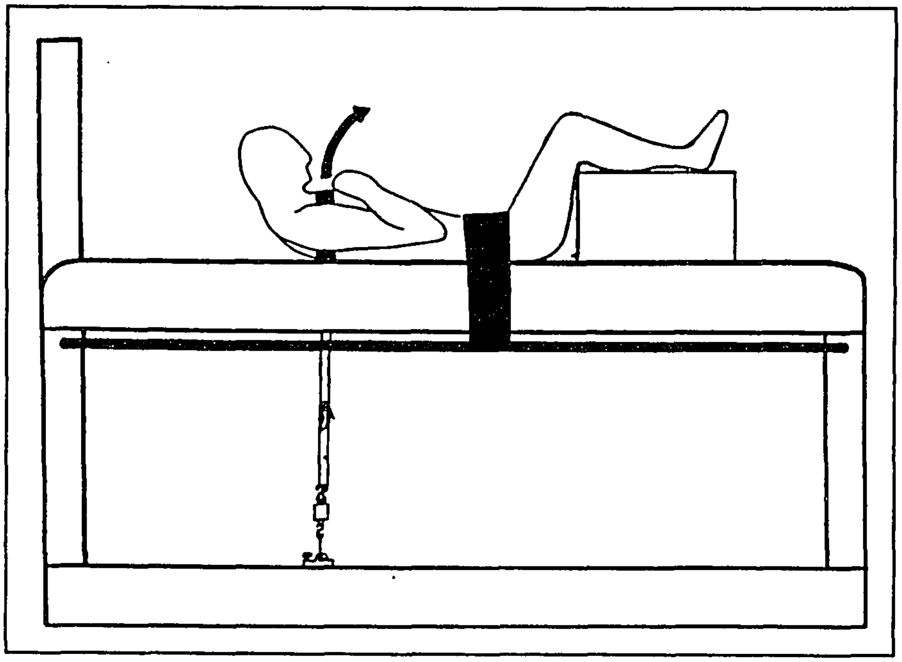

Figure 24. Trunk Flexion

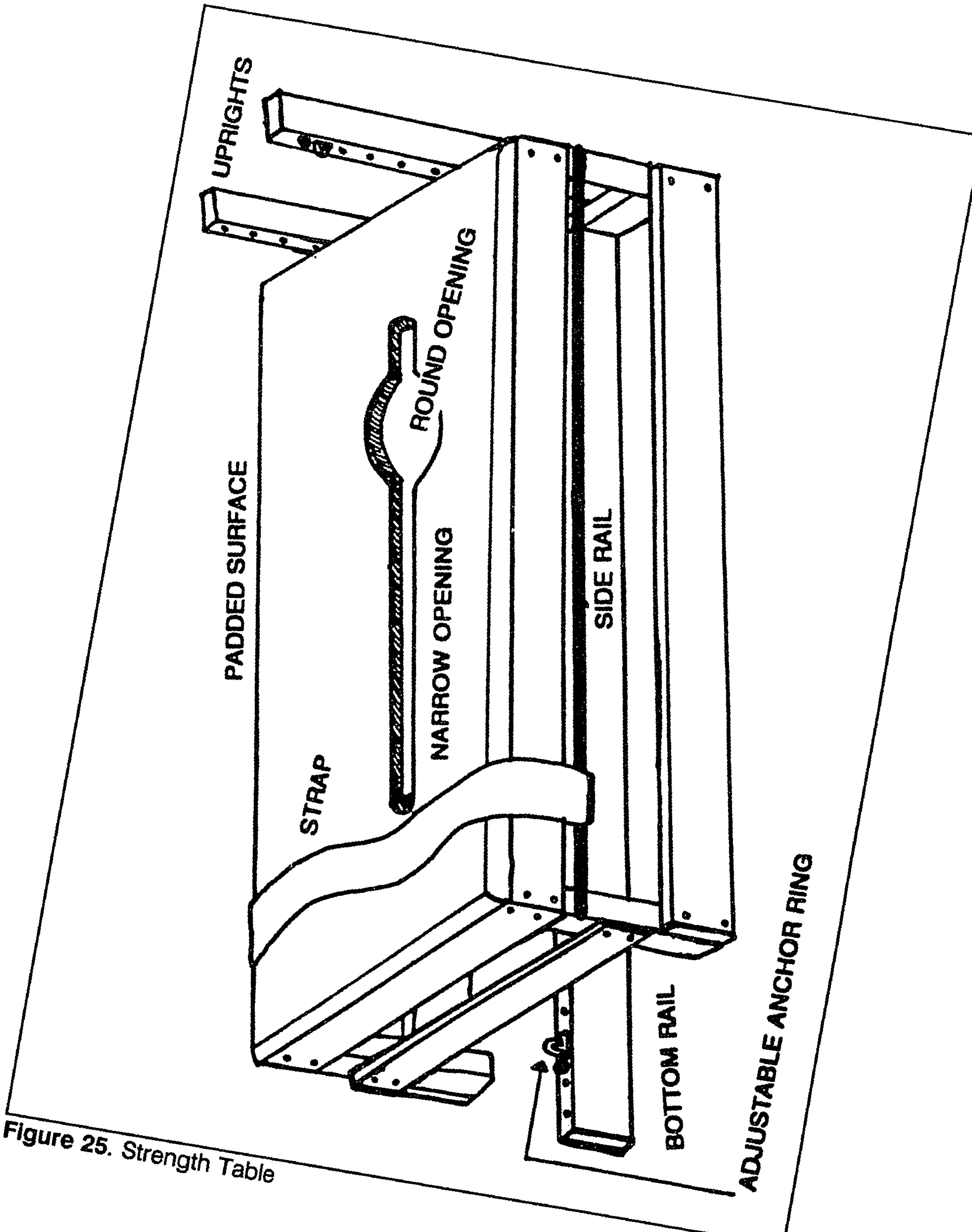

Figure 25. Strength Table

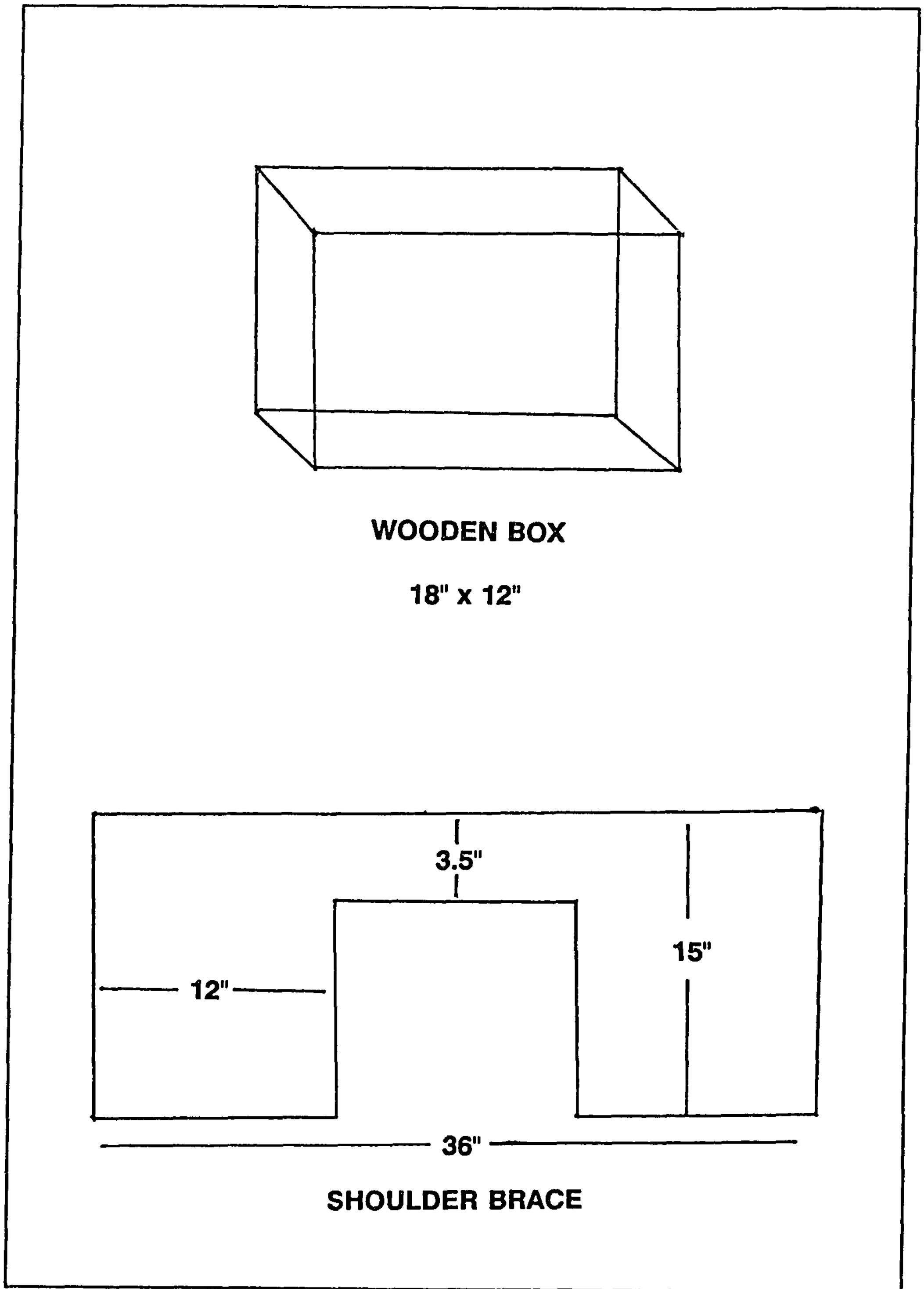

Figure 26. Strength Table Accessories

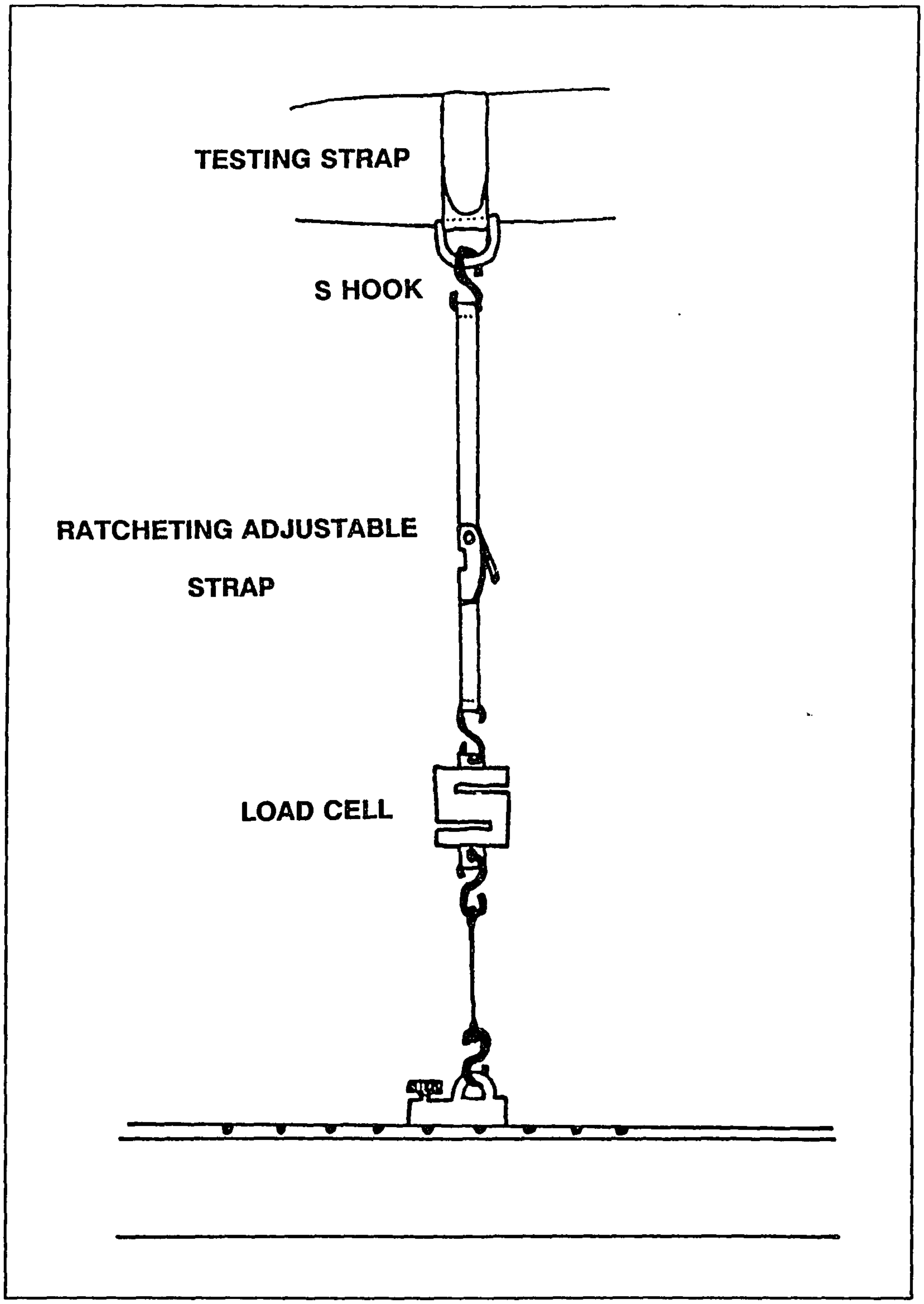

Figure 27. Load Cell Attachment

CHAPTER IV

Results and Discussion

Muscular strength and/or muscular endurance is part of every physical fitness test battery. Muscle strength is considered by all authorities to be an essential component of any definition of physical fitness or any physical fitness assessment. Tests used to evaluate muscle strength include grip strength, a calisthenic exercise such as push ups or pull ups, and a 1RM test for a major muscle group. Of these, grip strength and bench press (1RM) are two commonly used tests.

The purpose of this study was to assess the validity of using grip strength to represent total body strength and the validity of using a 1RM bench press test to represent upper body strength. The Pearson Correlation Coefficient was used to analyze the data.

A problem of determining validity is the mechanism or tests against which grip strength and 1RM bench press can be compared.

Cable tension strength tests have been used, in various forms, to measure strength since the 1950's (Clarke 1966). Clarke and Schopf (1961) generated an intercorrelational study of cable-tension strength tests using data obtained from the Medford, Oregon, Boys' Growth Project (Clarke & Esslinger

1958). They established a criterion measure for total strength consisting of the average of the 18 cable-tension strength tests administered to the boys. For the purpose of the present study the following bilateral measurements were assessed, summed, and designated as the criterion measure of total strength (SUMALL): elbow flexion and extension, shoulder flexion and extension, ankle dorsiflexion and plantar flexion, knee flexion and extension, hip flexion and extension, and trunk flexion and extension. Upper body strength (SUMUB) was designated as the sum of the elbow and shoulder flexion and extension measurements. In addition, because of their frequent use in test batteries, grip strength and a 1RM bench press were also assessed. A correlation matrix including all the measures of strength allowed comparison and analysis of related tests. The correlations are presented in Table 2.

The correlation between grip strength and the sum of all measurements (SUMALL) was small but statistically significant (r = .49422, p < .004). R^2 for this correlation was .24 which indicates the proportion of variability shared by grip strength and SUMALL. This low correlation did not represent a predictive or causal value, however, it did indicate (based on r = .49422 being a low to moderate correlation) that a high score on one variable did not necessarily result in a high score on the other variable. Therefore, a high grip strength score did not indicate a high level of overall body strength, conversely a low grip strength score did not indicate a low level of overall body strength.

No other research could be found supporting or refuting the use of grip strength as a sole indicator of total body strength. However, it has been used, in combination with other measures of strength, as an estimate of total strength. Sargent (Davis 1964), Rogers (Mathews 1978), McCloy (Davis 1964), and McCurdy (Davis 1964) have all used grip strength as a part of their tests of strength.

Golding, et. al. (1989) initially used grip strength as a strength test in the National YMCA Fitness Test Battery, stating that "... dominant hand grip strength is fairly representative of total body strength". However, they eliminated grip strength from later versions of the National YMCA Fitness Test Battery. Early fitness batteries commonly used a combination of strength tests to represent total body strength. Sargent's (Davis 1964) initial Strength Index used right and left grip strength and back and leg strength to represent a total strength. Because elbow extension and elbow flexion strength (measured by push-ups and pull-ups) were commonly used in most test batteries, Golding, et al. used bench press (elbow extension) in the latest edition of the National YMCA Fitness Test Battery. The bench press was substituted for push-ups because of the strenuous nature of push-ups for middle to old-aged subjects and a sit-ups test was also used to test muscular strength and endurance of the abdominal musculature.

The correlation between the 1RM bench press test and the sum of the upper extremity isometric strength table measurements (SUMUB) was strong

and statistically significant, (r = .72483, p < .0001). R^2 for this correlation was .53 which indicates that greater than 50% of the subjects shared the variability between 1RM bench press and SUMUB. This would support the use of a 1RM bench press to represent upper body strength. However, since the 1RM represents a maximum effort and is relatively time consuming, the 1RM is not appropriate for unfit or older populations.

The most practical use of a 1RM as a measurement of upper body strength may be by athletes or trained individuals. Many athletic teams, both male and female, participate in vigorous strength training programs, and use changes in the 1RM as an indicator of strength gains. The results of this study support the use of the 1RM as a test of upper body strength.

The correlation between grip strength and the sum of the upper body (SUMUB) measurements (r = .57846) is slightly higher than that between grip strength and the sum of all (SUMALL) the strength measurements (r = .49422). Although r = .57846 is not considered a strong correlation, it may be higher than the SUMALL correlation because it excludes leg strength. For example, an individual is capable of having a very strong upper body yet very little, if any, leg strength. An exaggerated case would be a paraplegic.

The correlation between grip strength and 1RM bench press, (r = .42427, p < .0155), is poor. An R^2 of .18 indicates that only 18% of the subjects shared the variablity between grip strength and 1RM bench press. Grip strength did not correlate significantly with any of the individual isometric strength

measurements, SUMUB, or SUMALL. This suggests that grip strength should not be used to predict or represent either total strength or 1RM bench press ability. However, the use of grip strength is a valuable tool in the strength assessment of the shoulder, elbow, wrist, and hand. Stratford, Norman, and McIntosh (1989) have demonstrated that grip strength used for comparing the involved to noninvolved limb, within a subject, is reliable. But comparing different subjects or estimating total strength is a severe limitation.

The measurement SUMALL has a correlation above .7 with every individual isometric strength measurement except those of the elbow and ankle. Because the elbow and the ankle were the smallest joints tested, and strength of joints were not weighted, the larger joints of the body may exert a greater effect on the measurement of SUMALL. Based on data in this study and because the joints in the hand are small, it appears that grip strength should not be used to predict or represent total body strength. This relationship may also be an indication that field tests of strength should use large joints and muscle groups to represent total body strength. This is supported by the fairly high correlation between 1RM bench press and SUMALL ($r = .71854$, $p < .0001$). This correlation is greater than that between grip strength and SUMALL and may be evidence to support the 1RM bench press to estimate total body strength. However, no other research could be found supporting or refuting this possibility.

The intercorrelations reveal that two of the components of the squat, hip extension and knee extension, have the highest correlations with SUMALL. This may support the use of the 1RM squat test as a predictor of total body strength.

Table 2

Correlation Matrix

	REF	LEF	REE	LEE	RSF	LSF	RSE	LSE	RAD
REF	1.00000								
	0.0000								
LEF	0.90951	1.00000							
	0.0001	0.0000							
REE	0.63850	0.76792	1.00000						
	0.0001	0.0001	0.0000						
LEE	0.60894	0.72671	0.85583	1.00000					
	0.0002	0.0001	0.0001	0.0000					
RSF	0.50862	0.47040	0.29621	0.29562	1.00000				
	0.0030	0.0066	0.0997	0.1004	0.0000				
LSF	0.48265	0.45753	0.35885	0.39728	0.90985	1.00000			
	0.0051	0.0085	0.0437	0.0244	0.0001	0.0000			
RSE	0.56406	0.49122	0.37692	0.29304	0.74352	0.68720	1.00000		
	0.0008	0.0043	0.0335	0.1036	0.0001	0.0001	0.0000		
LSE	0.52423	0.47897	0.38948	0.32070	0.79624	0.76739	0.86428	1.00000	
	0.0021	0.0055	0.0276	0.0735	0.0001	0.0001	0.0001	0.0000	
RAD	0.42611	0.31918	0.12646	0.13377	0.36485	0.23070	0.43506	0.37592	1.00000
	0.0150	0.0750	0.4904	0.4655	0.0401	0.2040	0.0128	0.0340	0.0000

Legend: REF & LEF - Right & Left Elbow Flexion
REE & LEE - Right & Left Elbow Extension
RSF & LSF - Right & Left Shoulder Flexion
RSE & LSE - Right & Left Shoulder Extension
RAD - Right Ankle Dorsiflexion

	REF	LEF	REE	LEE	RSF	LSF	RSE	LSE	RAD
LAD	0.43806	0.37790	0.21451	0.18556	0.33140	0.29558	0.48818	0.39715	0.85376
	0.0122	0.0330	0.2384	0.3093	0.0639	0.1005	0.0046	0.0244	0.0001
RAP	0.57324	0.49816	0.21747	0.22847	0.70027	0.63098	0.68789	0.54774	0.51853
	0.0006	0.0037	0.2318	0.2085	0.0001	0.0001	0.0001	0.0012	0.0024
LAP	0.53605	0.41321	0.17576	0.08677	0.74209	0.64382	0.67890	0.60432	0.45850
	0.0016	0.0187	0.3359	0.6368	0.0001	0.0001	0.0001	0.0002	0.0083
RKE	0.63347	0.60785	0.36877	0.39044	0.72905	0.70479	0.71440	0.77195	0.55091
	0.0001	0.0002	0.0378	0.0272	0.0001	0.0001	0.0001	0.0001	0.0011
LKE	0.57956	0.57406	0.48050	0.47015	0.67098	0.61069	0.66282	0.74861	0.50262
	0.0005	0.0006	0.0054	0.0066	0.0001	0.0002	0.0001	0.0001	0.0034
RKF	0.41244	0.38560	0.22714	0.25689	0.62716	0.60534	0.51858	0.58862	0.43058
	0.0190	0.0293	0.2112	0.1558	0.0001	0.0002	0.0024	0.0004	0.0139
LKF	0.57411	0.52043	0.37840	0.32275	0.68242	0.62426	0.56154	0.64940	0.48466
	0.0060	0.0023	0.0327	0.0716	0.0001	0.0001	0.0008	0.0001	0.0049
RHE	0.52449	0.43620	0.17109	0.25923	0.80603	0.68920	0.70412	0.65337	0.63926
	0.0021	0.0126	0.3491	0.1519	0.0001	0.0001	0.0001	0.0001	0.0001
LHE	0.58758	0.50745	0.28942	0.34546	0.83741	0.76193	0.73879	0.71604	0.48842
	0.0004	0.0030	0.1081	0.0053	0.0001	0.0001	0.0001	0.0001	0.0046

Legend: LAD - Left Ankle Dorsiflexion
RAP & LAP - Right & Left Ankle Plantarflexion
RKE & LKE - Right & Left Knee Extension
RKF & LKF - Right & Left Knee Flexion
RHE & LHE - Right & Left Hip Extension

	REF	LEF	REE	LEE	RSF	LSF	RSE	LSE	RAD
TRE	0.38765	0.34736	0.20636	0.23750	0.75995	0.79505	0.54025	0.66416	0.28341
	0.0284	0.0514	0.2571	0.1906	0.0001	0.0001	0.0014	0.0001	0.1160
TRF	0.29105	0.29411	0.10510	0.17288	0.64339	0.58410	0.46776	0.48281	0.41265
	0.1061	0.1023	0.5670	0.3440	0.0001	0.0004	0.0069	0.0051	0.0189
RHF	0.43399	0.34763	0.25601	0.37296	0.66154	0.67197	0.47181	0.62237	0.32755
	0.0131	0.0512	0.1573	0.0355	0.0001	0.0001	0.0064	0.0001	0.0672
LHF	0.42708	0.33632	0.28623	0.41289	0.71723	0.73127	0.55571	0.63798	0.50827
	0.0148	0.0598	0.1122	0.0188	0.0001	0.0001	0.0010	0.0001	0.0030
SUMUB	0.74340	0.72057	0.59376	0.55775	0.87962	0.86718	0.88207	0.90201	0.40648
	0.0001	0.0001	0.0003	0.0009	0.0001	0.0001	0.0001	0.0001	0.0210
SUMALL	0.66736	0.57728	0.36439	0.38599	0.76718	0.73450	0.77145	0.82953	0.58044
	0.0001	0.0005	0.0403	0.0291	0.0001	0.0001	0.0001	0.0001	0.0005
GRIP	0.57956	0.59184	0.47586	0.39781	0.44079	0.45060	0.50861	0.40855	0.14936
	0.0005	0.0004	0.0059	0.0241	0.0116	0.0097	0.0030	0.0203	0.4146
1RM	0.62276	0.60983	0.55371	0.35317	0.57068	0.56604	0.62552	0.67754	0.50409
	0.0001	0.0002	0.0010	0.0474	0.0006	0.0007	0.0001	0.0001	0.0033

Legend: TRE - Trunk Extension
TRF - Trunk Flexion
RHF & LHF - Right & Left Hip Flexion
SUMUB - Sum of The Upper Body Isometric Measurements
SUMALL - Sum of All The Isometric Measurements
GRIP - Grip Strength
1RM - One Repetition Maximum/Bench Press

	LAD	RAP	LAP	RKE	LKE	RKF	LKF	RHE	LHE
LAD	1.00000								
	0.0000								
RAP	0.63085	1.00000							
	0.0001	0.0000							
LAP	0.54038	0.84959	1.00000						
	0.0014	0.0001	0.0000						
RKE	0.57032	0.63949	0.63544	1.00000					
	0.0007	0.0001	0.0001	0.0000					
LKE	0.62234	0.53529	0.55000	0.78393	1.00000				
	0.0001	0.0016	0.0011	0.0001	0.0000				
RKF	0.40976	0.32280	0.42157	0.65346	0.68703	1.00000			
	0.0199	0.0715	0.0163	0.0001	0.0001	0.0000			
LKF	0.50289	0.41784	0.58301	0.71623	0.76682	0.87347	1.00000		
	0.0034	0.0173	0.0005	0.0001	0.0001	0.0001	0.0000		
RHE	0.57689	0.67728	0.69206	0.71745	0.65159	0.78817	0.78058	1.00000	
	0.0005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	
LHE	0.50617	0.61614	0.69444	0.70752	0.67193	0.72474	0.80916	0.90259	1.00000
	0.0031	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000

	LAD	RAP	LAP	RKE	LKE	RKF	LKF	RHE	LHE
TRE	0.38631	0.45701	0.56599	0.67858	0.64671	0.69296	0.79377	0.72924	0.84182
	0.0290	0.0086	0.0007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
TRF	0.26952	0.38830	0.43816	0.58904	0.49440	0.72885	0.66367	0.75366	0.58432
	0.1358	0.0281	0.0121	0.0004	0.0040	0.0001	0.0001	0.0001	0.0004
RHF	0.36446	0.41490	0.51166	0.66934	0.68153	0.64212	0.68437	0.61253	0.65800
	0.0403	0.0182	0.0028	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001
LHF	0.50957	0.47402	0.53946	0.73352	0.67738	0.67802	0.72390	0.71733	0.76257
	0.0029	0.0061	0.0014	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
SUMUB	0.44822	0.69722	0.69170	0.81599	0.77384	0.61962	0.70548	0.74442	0.81654
	0.0101	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001
SUMALL	0.62919	0.66239	0.69696	0.84460	0.82244	0.75189	0.81030	0.83623	0.82340
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
GRIP	0.29450	0.36882	0.33546	0.53684	0.54782	0.56409	0.57552	0.48152	0.52181
	0.1018	0.0378	0.0605	0.0015	0.0012	0.0008	0.0006	0.0053	0.0022
1RM	0.54533	0.55325	0.59902	0.59552	0.55319	0.52792	0.63209	0.54801	0.53375
	0.0012	0.0010	0.0003	0.0003	0.0010	0.0019	0.0001	0.0012	0.0017

	TRE	TRF	RHF	LHF	SUMUB	SUMALL	GRIP	1RM
TRE	1.00000							
	0.0000							
TRF	0.57142	1.00000						
	0.0006	0.0000						
RHF	0.63072	0.48675	1.00000					
	0.0001	0.0047	0.0000					
LHF	0.70817	0.55649	0.87053	1.00000				
	0.0001	0.0009	0.0001	0.0000				
SUMUB	0.69424	0.54400	0.64456	0.69453	1.00000			
	0.0001	0.0013	0.0001	0.0001	0.0000			
SUMALL	0.72365	0.63000	0.77645	0.79548	0.85636	1.00000		
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000		
GRIP	0.43841	0.30678	0.46078	0.37085	0.57846	0.49422	1.00000	
	0.0121	0.0877	0.0080	0.0367	0.0005	0.0040	0.0000	
1RM	0.40487	0.44517	0.48868	0.48979	0.72483	0.71852	0.42427	1.00000
	0.0215	0.0107	0.0045	0.0044	0.0001	0.0001	0.0155	0.0000

CHAPTER V

Summary, Conclusion, and Recommendations

Summary

This study was designed to assess the validity of using grip strength to represent overall body strength and the validity of using a 1RM bench press to represent upper body strength.

Thirty-two female subjects between the ages of 18-30 volunteered. Each subject's height, weight, percent body fat, and a combination of trunk and hamstring flexibility were measured and recorded. A fitness profile of the tests, which explained the subject's results, was given to each subject.

The subjects then completed a series of 22 isometric strength tests. The tests comprised movements of the elbow, shoulder, hip, knee, ankle, and trunk. Each test was administered bilaterally using a table constructed for isometric strength testing. Three repetitions were recorded for each measurement with the highest score being used for statistics. Subjects initially given instructions to push or pull the apparatus as hard as possible without jerking. The measurements were assessed by a load cell and read to the nearest .5 gram on a digital readout.

The subjects were then given a grip strength test using their dominant hand. Three trials were given with the highest measurement being recorded.

The final testing procedure required a one repetition maximum bench press test. The barbell, weighing 45lbs, was handed to the subjects with their elbows fully extended and their shoulders flexed to 90°. One repetition consisted of the subject touching the barbell to their chest and returning their hands to the starting position. Weight was increased in five pound increments. The most weight the subject could successfully lower to the chest and raise to the starting position one time was recorded as the 1RM.

Each of the isometric strength measurements (all 22 tests) was summed to determine the criterion measurement of total body strength. Each of the upper body isometric strength measurements (8 tests) was summed to determine the criterion measurement of total upper body strength. The relationships of total body strength compared to grip strength and total upper body strength compared to 1RM bench press were determined using the Pearson Correlation Coefficient.

Both comparisons showed statistically significant correlations ($r = .49422$, $p < .004$ and $r = .72483$, $p < .0001$). These statistics indicate that grip strength does not give an accurate representation of total body strength but 1RM bench press does give an accurate representation of total upper body strength.

Conclusions

The following conclusions can be suggested, based on the results of this study.

1. Grip strength, although significantly correlated, does not give an accurate representation of total body strength.
2. A 1RM bench press does give an accurate representation of upper body strength.

Recommendations

The use of grip strength should be limited to the comparison of one limb to another for the purpose of medical evaluation. Grip strength should not be used to compare the strength between individuals.

The identification of the lack of an accurate predictor of total body strength indicates a need for further research. Current fitness batteries employ strength tests which combine the components of strength and endurance. It is important to find practical and current field tests which can differentiate between muscular strength and muscular endurance and give an accurate prediction of total body strength.

The invention of a retraction system involving the use of only one cable for each of the isometric strength tests would greatly reduce the amount of time

necessary to test one subject. The cable would pull from the housing to the exact length necessary for the joint angle of each isometric test. A lock could be enabled to prevent the cable from retracting or lengthening.

Appendix A

Forms

Informed Consent

Par-Q

COLLEGE OF HUMAN PERFORMANCE AND DEVELOPMENT
EXERCISE PHYSIOLOGY LABORATORY

CONSENT FOR RESEARCH PARTICIPATION
UNIVERSITY OF NEVADA LAS VEGAS

Title of Study: Validity of Using Grip Strength and a 1RM Bench Test to Represent, Respectively, Overall Body Strength and Lower Body Strength, measured isometrically.

You have volunteered to participate in a study which involves isometric testing of the major muscle groups of the body and isotonic testing of the upper extremity. You will be asked to participate in one session only, lasting approximately 90 minutes.

During the session you will be tested for upper body, lower body, and trunk strength, isometrically. You will also be given a grip strength test and a 1RM bench press test. The exact procedures and form will be described to you in more detail when you arrive for participation.

Your age and height will be requested and your weight, percent body fat, and various girths will be recorded. Your identity will in no way be associated with either the demographic information or the strength data generated from the study.

Your participation is voluntary and you are free to withdraw your consent and discontinue participation at any time. If at any time during the study you are unsure about the procedures, feel free to ask the experimenter for clarification. If at any time you experience discomfort which prevents you from continuing you may request that the experiment be terminated immediately.

YOUR SIGNATURE BELOW INDICATES THAT YOU HAVE DECIDED TO PARTICIPATE IN THE STUDY, THAT YOU HAVE READ THE INFORMATION PROVIDED ABOVE, AND THAT IF YOU HAVE ANY QUESTIONS, THEY HAVE BEEN ANSWERED TO YOUR SATISFACTION.

__________	____________________	______________
Date	Signature of Participant	Print Name
__________	____________________	______________
Date	Signature of Witness	Print Name

UNIVERSITY OF NEVADA, LAS VEGAS/4505 MARYLAND PARKWAY/LAS VEGAS, NEVADA 89154-3016
(702) 739-3766/FAX (702) 597-4191

Physical Activity Readiness Questionnaire (PAR-Q)*

PARTICIPANT IDENTIFICATION

PAR Q & YOU

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check (✓) the ☐ YES or ☐ NO opposite the question if it applies to you.

YES	NO	
☐	☐	1. Has your doctor ever said you have heart trouble?
☐	☐	2. Do you frequently have pains in your heart and chest?
☐	☐	3. Do you often feel faint or have spells of severe dizziness?
☐	☐	4. Has a doctor ever said your blood pressure was too high?
☐	☐	5. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?
☐	☐	6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?
☐	☐	7. Are you over age 65 and not accustomed to vigorous exercise?

If You Answered

YES to one or more questions

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness test. Tell him what questions you answered YES on PAR-Q, or show him your copy.

programs

After medical evaluation, seek advice from your physician as to your suitability for

- unrestricted physical activity probably on a gradually increasing basis
- restricted or supervised activity to meet your specific needs, at least on an initial basis. Check in your community for special programs or services

NO to all questions

If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:

- A GRADUATED EXERCISE PROGRAM - A gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort
- AN EXERCISE TEST - Simple tests of fitness (such as the Canadian Home Fitness Test) or more complex types may be undertaken if you so desire

postpone

If you have a temporary minor illness, such as a common cold

* Developed by the British Columbia Ministry of Health. Conceptualized and critiqued by the Multidisciplinary Advisory Board on Exercise (MABE). Translation, reproduction and use in its entirety is encouraged. Modifications by written permission only. Not to be used for commercial advertising in order to solicit business from the public.
Reference: PAR-Q Validation Report, British Columbia Ministry of Health, 1978.
* Produced by the British Columbia Ministry of Health and the Department of National Health & Welfare.

Appendix B

Score Sheets

	AGE	HT	WT	ABD	IL	TRI	THI	%	Rt Gr	Lt Gr	1RM	RA	LA	RFA	LFA	RT	LT	RC	LC	FLEX	DOM
1	25	67	153	23	24	14	31	25.4	40	44	80	11.25	11	9.5	9.5	20	19.5	14.75	15.25	19	L
2	28	62	125	15	12	17	25	21	47		70	11.25	11.13	10	9.5	18.75	19	14.25	14.5	20	R
3	30	61.5	122.5	19	21	21	31	26.6	32		75	12	11.75	9.5	9	19.5	19.5	13.75	13.75	15.5	R
4	22	63	167.5	29	24	22	39	30.6	37		80	11.5	11	10.25	9.75	23	22.5	16.25	16	23	R
5	23	67	158					24.5	35		85	10.5	11	9.25	9	20	20.25	16	15	21.5	R
6	19	64	125.5	17	17	16	21	20.1	35		85	10.38	10	9	8.75	18.75	18.75	13.63	13.75	9	R
7	22	65.5	137	14	14	19		21.2	36		65	11	10.75	9.25	9.25	20.25	19	15	15	17	R
8	19	63	168	30	34	23	44	34.6	34		80	11.5	11	10.75	10.25	22.25	22.75	16.5	15.5	20	R
9	20	66	110.5	18	21	16	23	22.5	27		50	9.13	9	8	8	16	16.25	12.25	12	20	R
10	22	65	129	32	26	15	28	26.8	19		55	10.25	10.5	8.75	8.75	17	17.25	12.25	12.75	9	R
11	20	65	164	22	25	22	31	26.8	36		100	12	12.25	10.5	10.25	21	21.25	16.25	16	22	R
12	21	62	107.5	18	21	9	14	17.7	23		65	8.75	8.75	8.25	8	17	17	12.5	12.5	19	R
13	23	66	126	20	14	14	21	20.8	34		70	10	10	9.25	9	16.75	16.75	12.75	13	20	R
14	25	82 5	118	14	13	15	28	20.8	31		100	10	10	9.5	9	18.5	19	13.5	13.5	21	R
15	29	66	137	25	12	14	32	24.4	23		60	10.25	10	9.25	8.5	19.25	19.5	14.5	14.88	19.5	R
16	18	63	149.5	35	37	28	45	35.5	24		65	11.5	11.5	9.5	9.25	19.25	20.13	14.25	14.25	8	R
17	23	64	145.5	9	15	16	21	18.4	31		80	11	11	10.5	10	20.5	20.5	15.75	16	18	R
18	21	66	132.5	21	22	20	32	25.8	18	17	60	10	10.25	9.25	9.75	17.75	18.5	13.88	14	20	L
19	23	67	142.5	15	12	17	21	19.6	27	20	90	11	10.88	9.5	9.25	19	18.5	14.5	14.38	22	R
20	24	64	113	21	17	17	27	23.1	25	20	55	9	9	8.5	8.25	16.25	16.5	13	12.5	22	R
21	21	67	129.5	10	12	10	17	15.2	30	29	95	10	9.5	9.25	9	17.5	16.75	14	14	17	R
22	22	64	149.5	14	30	20	41	27.9	30*	41	100	11	10.75	9.5	9.25	21.5	21	15	14.5	19	R
23	28	65.5	120	10	12	8	19	16.1	34	36	75	9	8.75	8.5	8.5	17	17	13.5	13.5	18	R
24	22	64	128	9	10	9	25	16.5	38	45	105	10	10	9.75	9.25	19	18.75	14.25	14.25	26	R
25	24	67.5	127	8	13	12	20	17.2	38	42	100	10.5	9.5	9.5	9.25	18	17.75	13.75	13.25	12	R
26	29	64.75	126	15	15	19		23.1	33	33	70	9.75	10	8.75	9	17.75	17.75	14.75	14.25	9.5	L
27	28	67	124	15	15	14	25	21	30	28	60	9.5	9	9	8.75	17.5	17.25	13.75	13.75	22	R
28	23	65.5	150	22	20	20	37	27.5	31	32	75	11.5	11.75	10	9.75	19.75	20	14.75	14.5	19	R
29	23	67	134	14	14	14	24	'9.6	37	29	80	11	10.5	10.5	9.75	18	17.75	14.5	14.25	7	R
30	24	64.5	120	22	20	12	20	22	32	25	75	9.5	9.25	8.5	8	16.75	17.25	13.5	13.5	14	R
31	22	72	161	18	16	16	26	21.3	34	24	60	10.5	10	9.5	9	18.75	19	14.75	14.5	21	R
32	25	71	138.5	17	16	17	20	20.1	38	35	65	10	10	9	9	17.5	17.5	13.5	13.5	22	L
AVG	23.4	65.29	135.59	18.4	18.5	16.3	27.2	22.93	30.91	31.25	75.938	10.453	10.305	9.375	9.1094	18.742	18.754	14.235	14.133	17.875	
SD	3.11	2.35	16.783	6.79	6.75	4.5	8.05	4.922	8.426	8.836	15.157	0.888	0.9226	0.678	0.5988						

	R ELB F			L ELB F			R ELB E			L ELB E			R SH F			L SH F			R SH E			L SH E		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	29	28	30	31	30	28	19.5	19.5	20.5	23.5	19.5	22	23	21.5	22.5	23.5	25	25	19	24.5	22	23	26.5	26
2	19.5	19.5	20	20	19.5	18.5	11	10.5	10.5	10.5	10	10.5	21	21.5	14.5	26	25.5	23	28.5	32.5	36	30.5	30	28
3	17.5	17	17	18.5	17.5	17.5	12	12.5	12.5	12.5	12.5	12	17	22.5	21.5	16.5	20	21.5	17.5	20	18.5	17.5	20	20
4	15	17.5	15.5	15.5	16	16.5	11	10.5	10	10.5	11.5	9.5	16.5	16.5	15.5	12.5	14.5	15.5	16.5	16	18	13.5	15.5	16
5	20	19.5	20	18	19	16.5	9	8.5	9	10	9.5	8.5	28	30.5	29.5	23.5	28	24.5	35	38.5	37	30.5	30	30
6	18	18	17	17	17	16.5	11	10.5	8.5	10	9.5	10	14.5	10.5	13	14	16.5	15	16.5	21	19.5	18.5	18.5	20
7	19	19	18.5	17	16	16.5	10	10	9.5	11.5	10.5	10.5	27.5	26.5	25	23	21	21.5	39.5	37	35	43.5	31.5	32
8	17.5	19	18	19	19	19.5	12.5	11.5	11	11.5	11	11.5	17.5	17	16	18	20	23.5	16	21.5	24.5	16.5	25.5	28.5
9	13	12	13	10	11	12.5	9.5	9	9	9	9.5	9	10.5	12.5	12.5	13.5	14	14.5	11.5	10.5	11.5	10	14	13
10	15	14.5	14	14.5	14.5	14.5	10	9.5	9.5	10.5	10	10	15	14	15	16	14	13	14	18.5	22.5	18	18	18

	R ANK D			L ANK D			R ANK P			L ANK P			R KN E			L KN E			R KN F			L KN F		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	15.5	15.5	15.5	16	15	15.5	22	26.5	30	24.5	22	22	63.5	55	58	64.5	59.5	58.5	30	31	29.5	36	35.5	32
2	8	8	8	12.5	12	12	23	24	24	21	23.5	27	54.5	53	54	48	49	52.5	35	35.5	34.5	28	29.5	30.5
3	11.5	11	11.5	10	11.5	11	14.5	15.5	15.5	14	14	17.5	31	31	29.5	25.5	28.5	29	24	26.5	29	21	21	21
4	22.5	21	20	22	20	19.5	16	25	26	24	26	29	44	44	48	48	50	54	31.5	31.5	32	30	31	33
5	23	23	21.5	19.5	20	19	35	41	44	30	35	31	60	55.5	65	59	59	55	48	40	41	32.5	31.5	31.5
6	15.5	14	13.5	14.5	14	13.5	14.5	15	17.5	12	18	24	31.5	30.5	33.5	26.5	25.5	29	26	28.5	27	28.5	31	27
7	19	17.5	17	15.5	15.5	15	18	16.5	25	19.5	21.5	23	71.5	71.5	65.5	54	57	60	40	38.5	36.5	36.5	33	33.5
8	13	13	16.5	13.5	15.5	17.5	13.5	21.5	26	15.5	19.5	18.5	54.5	55.5	59	44.5	45.5	45	26.5	34	32.5	26	24.5	30
9	11.5	12	12	12.5	13.5	11.5	9	9	10	9	11.5	12	16.5	22	23.5	20	29.5	31	20.5	19.5	20	17.5	20.5	19
10	11.5	11.5	11	12.5	13	13	17	23	24	19	19.5	20	29	32	31.5	34.5	35	36	15	13	13	13.5	14.5	15.5

	R HIP E			L HIP E			TR E			TR F			R HIP F			L HIP F		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	36	32.5	39	47	41	43	25	24	31.5	19.5	18.5	18.5	30	31	36	35	36.5	33
2	23.5	28.5	30.5	41.5	34.5	29.5	29.5	34.5	33	17	16.5	16	32.5	31	31.5	23.5	24.5	23.5
3	30.5	34	36	35.5	32.5	31.5	18	22.5	21.5	14.5	15	12.5	24.5	30.5	26.5	14.5	23.5	27
4	41	27	37.5	36.5	36	37	10	14	17.5	18	20	18	33.5	42	45	34	40	39
5	65	66	65	50	49.5	50	21	21	28	40	40	47	29.5	28.5	29	34.5	29	32.5
6	33.5	35	32.5	25.5	29	26.5	22.5	23	22.5	20.5	17.5	17	20	20.5	18.5	17.5	14.5	16
7	55.5	53.5	52.5	50	58.5	57.5	36.5	36.5	35	26.5	26	25.5	39.5	39.5	38.5	43	39	39.5
8	28.5	34	35.5	21.5	25	21.5	21.5	24.5	29	26.5	24	23	17.5	21.5	21.5	20	23.5	21
9	17.5	22	22	22	24.5	24	13.5	17	18	7.5	7	7	19.5	21.5	21	20	21.5	21.5
10	23.5	25.5	23	25.5	19.5	19.5	16	15.5	17	725	8.5	10	16	18.5	18	15	17.5	18

	R ELB F			L ELB F			R ELB E			L ELB E			R SH F			L SH F			R SH E			L SH E		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
11	24	24	24	24.5	24	23.5	12	12.5	12	12.5	12	11	38	33	32.5	30	31.5	29.5	25.5	38	31.5	34.5	35.5	
12	14.5	14.5	14	14.5	14.5	13.5	8	7.5	8	9	10	8	10.5	10.5	9.5	11	8	11.5	12.5	13	15	13	15.5	14
13	11.5	12.5	14.5	17	19	19	9.5	11	10.5	9	8.5	9	14	13.5	14.5	14.5	13.5	14	16	18.5	17	14.5	17	20
14	20.5	19.5	19.5	19.5	19.5	19.5	11.5	11	11	12	12	12	30.5	28.5	32.5	30	33	33	24.5	30.5	32	35.5	40	40
15	17.5	17.5	18	16.5	17.5	17.5	9.5	9	9	7.5	7.5	7	11.5	14	12.5	7	7	11	16.5	17.5	18	15.5	19	18.5
16	16	15.5	16	16.5	15.5	15.5	10.5	9	9	8	8	9	19	15	15.5	18	15.5	15.5	14	19.5	16.5	23	22.5	17
17	18.5	16.5	18.5	19.5	18	18	14	14	13.5	13	12	13	13.5	14.5	13	13.5	16.5	15.5	17.5	23	25.5	21.5	20	24.5
18	13.5	14.5	13.5	14	14.5	15	6	6.5	6	8	8.5	8	11	10.5	10	10	14.5	13.5	9	12.5	12.5	15.5	11	11
19	19.5	19	18.5	20	19	20.5	12.5	13	13	12.5	11	12.5	15	15.5	16	15.5	15.5	15.5	18	23.5	26.5	15	24	27
20	14.5	14.5	14.5	13.5	13	13.5	8	7.5	8	7.5	7.5	7.5	12.5	17.5	18	10	15	15	14	18	21	18	16	18.5

	R ANK D			L ANK D			R ANK P			L ANK P			R KN E			L KN E			R KN F			L KN F		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
11	20.5	21	21.5		18	18.5	27.5	40	33	38.5	46	40	72	69.5	64.5	60	62.5	62	53.5	55	54	52	54.5	51
12	16	14.5	13.5	15	14.5	14	13.5	14	16.5	11	15	15	32.5	32	35.5	20.5	22.5	24.5	23	23	23	21	22	22
13	13	13.5	14.5	14.5	15.5	17.5	13	19.5	20.5	18.5	23	23	46.5	53.5	51	41	39	41.5	30	27	31	23	26.5	26
14	17.5	16	17.5	18.5	17.5	15.5	42	50	54	44	47	51	57.5	54.5	53	48	59	55	34.5	35.5	36	32.5	32	31
15	18.5	18	16.5	14	12.5	15	12	13.5	12.5	15	13	16	25.5	28	24.5	29	29.5	33	11.5	11.5	11	16	16	12.5
16	12	12	11	10.5	9.5	8.5	10	15	14	13	16	15	22.5	22	25.5	26	28.5	25.5	17.5	15	15.5	18.5	17	19
17	20	19.5	18.5	19.5	19.5	18.5	15	17	16.5	15	20	22	45.5	51	51	48.5	46	47.5	24	24.5	23.5	20.5	21	20
18	12	12	12.5	13.5	13.5	14	10.5	8	10	8.5	15.5	16.5	22	22	27	18	23.5	22.5	14.5	15.5	16.5	15	13	14.5
19	20.5	21	20.5	18	19	19.5	18.5	19.5	17	15	13	12.5	52	58	53.5	50.5	49.5	50.5	33	35.5	33	28	28	33.5
20	14.5	15	14.5	12	13	13.5	17	19.5	23.5	22.5	31	38	34	43.5	40.5	28	33.5	35	26	27.5	28	27	29	28

	R HIP E			L HIP E			TR E			TR F			R HIP F			L HIP F		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
11	76.5	61	57.5	67	70.5	66	40	48.5	44.5	34	35.5	35.5	42.5	40.5	40	41	44.5	39.5
12	28	33	27.5	24.5	25.5	25.5	16.5	20.5	20	23.5	19.5	19	29.5	31	26.5	29	24.5	24.5
13	27	28	28.5	26	26	28.5	17.5	24	23	17	15	18	25	26	25.5	24	24.5	24.5
14	48.5	51.5	51	50	49.5	50	36	38	38.5	23	23	22	41.5	46	44.5	37	36	34.5
15	15.5	14.5	17	16	17	17.5	8.5	11.5	11.5	7	10	10.5	12.5	17.5	18.5	12.5	13.5	12.5
16	16.5	18.5	23.5	22	28	28	13.5	12	17.5	6	7.5	8	20.5	22.5	17	20	20.5	19.5
17	31	34.5	32	30.5	31	31.5	21.5	23.5	24	18.5	13.5	10.5	0	22	21.5	22.5	24	22.5
18	13.5	20.5	20.5	23	23	26.5	16.5	18	16.5	10.5	15	17	11.5	17	15.5	19	19	19.5
19	29	30.5	27	34.5	34.5	34	14	19	21.5	10.5	11	12	21	27	26	21.5	28	29.5
20	38	38.5	40	38.5	40	37.5	27	30.5	31.5	12	13.5	19.5	24.5	21.5	21.5	24.5	20.5	26

	R ELB F			L ELB F			R ELB E			L ELB E			R SH F			L SH F			R SH E			L SH E		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
21	22.5	22.5	22.5	22.5	22	20	12.5	12	12	10	10	10	24	24.5	24	16	19	19.5	21	31	35	24.5	31	35
22	19	23.5	22	20	21	20.5	11	11.5	11.5	11.5	11.5	11.5	14	16.5	15.5		17.5	17.5	23.5	32.5	28.5	30	36	35
23	25	21.5	22.5	20	20.5	20.5	9.5	9.5	9	8.5	8.5	8.5	16	14.5	13	17	14.5	13.5	16	17	17	17.5	16	18
24	25.5	26	22.5	22.5	22.5	23	12.5	13.5	13.5	12	12	12	25	34	35	36.5	34	36.5	47	44	45	39.5	39	40
25	18.5	19	19	18	20	19.5	11	13	13	10	9.5	10	16.5	19	20.5	13	16	18.5	19.5	23	24	24.5	24	27
26	17.5	16.5	16	18.5	18.5	17.5	10.5	10.5	10	10.5	10.5	10	22	20.5	19.5	19	18.5	18	25	26	24.5	26	24.5	23.5
27	17.5	17.5	17.5	18.5	17	18	8	7.5	7.5	9.5	9.5	9.5	14	13	14.5	11.5	12	12	13	14	14.5		14.5	15
28	18	17	17.5	18	17	17.5	9	10.5	10.5	11.5	11	11	25.5	25	25	28.5	24.5	27.5	31.5	29.5	31.5	25.5	28.5	28.5
29	22.5	23	22	17	21.5	22	13	12.5	11.5	10	11	12	13.5	10.5	10	9	9	10	20	38	16	21	18.5	17
30	16.5	16	16.5	16	15.5	13.5	12.5	11.5	11.5	10.5	10	9.5	15.5	16.5	15.5	15.5	14	13.5	25.5	25.5	22.5	23	24.5	24.5

	R ANK D			L ANK D			R ANK P			L ANK P			R KN E			L KN E			R KN F			L KN F		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
21	18.5	17.5	17	20	19.5	20	21.5	36	36.5	41.5	51	31	49	58	49.5	60	58.5	59	23.5	27.5	22.5	26	29.5	35
22	20.5	20	19	21.5	19	20	16	24	28	21	28	28	55	60	54	54	55	60	29.5	33	36.5	31.5	33	34.5
23	19	18	17.5	16	17	17.5	12	18	21	26.5	30	27	40	45	44	36.5	35.5	35	34.5	36	40	31.5	37	34.5
24	22	20.5	19.5	24	22.5	24	45	60	64	57	57.5	57.5	84	78	79	61.5	58	54.5	28	29.5	29.5	39.5	38	36
25	14	13.5	12.5	14.5	13.5	13	13.5	17	17	19	18.5	20.5	37	41.5	38.5	39.5	41.5	42.5	25	27.5	29.5	30.5	28.5	32.5
26	19.5	19.5	19	21.5	20	20.5	30.5	26	24.5	16	21	23.5	47.5	47.5	45	57	55	53.5	32	31	30	35.5	34.5	31.5
27	17	18	17.5	18	17	17	22.5	34	37	16.5	21	20.5	35.5	40	40.5	39	36	32.5	16.5	21	21	17.5	16.5	18
28	20.5	20.5	18.5	22	21.5	20	33	34.5	30	33	34	33	45	50	51.5	37.5	40	46	33.5	31.5	31	32.5	32.5	30
29	19	18	17	19.5	19	18	36	43	38	32	28	27	30	30	32.5	24.5	30	28.5	16	18	19.5	17	19	19
30	15.5	15.5	16	19	19	18	13	16.5	17	22	24	23	59.5	59	53.5	59.5	62	62	39.5	38.5	36.5	36.5	37.5	36

	R HIP E			L HIP E			TR E			TR F			R HIP F			L HIP F		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
21	40.5	42	40	40	43.5	40	22	25	25.5	11.5	12.5	13	20.5	26	24	18	19.5	22.5
22	37	42.5	45	34.5	31.5	41	23	23.5	26	17	14.5	19.5	36	39.5	41.5	35.5	28.5	30
23	44.5	38.5	40.5	45	49.5	41	35	33.5	34	12	13	13.5	23.5	27	22	20	26.5	23
24	50.5	58	56.5	57	64	63	51	50	50	31	31	27	38	41.5	39	50	48	45
25	35	34	41	36.5	36.5	40.5	26	26	27.5	11	15.5	11.5	19	24	22.5	22	23	21.5
26	40	52.5	53	54.5	49	45	46	43	37	22.5	23.5	21.5	23.5	28	22	22.5	22.5	20.5
27	25	32	30	22	26.5	21	7	12	18	8	10.5	9	13.5	16	16.5	10.5	13	17
28	40.5	48	50.5	54.5	57	50.5	37	38.5	41	7	8.5	7.5	29.5	32.5	33	43	43.5	43
29	30	24.5	42.5	34.5	35	39.5	5.5	5	5	5	8.5	5.5	13	10	13.5	14.5	10.5	12
30	34.5	33	32.5	27.5	29.5	35.5	26.5	28	31	21	20.5	19.5	27	26.5	27	32	30	28.5

	R ELB F			L ELB F			R ELB E			L ELB E			R SH F			L SH F			R SH E			L SH E		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
31	18	20.5	19	17	18.5	18	8	7.5	7.5	7.5	7.5	7.5	14	17	18	11.5	11	12.5	14.5	16	17.5	13	15	17
32	18	20.5	19.5	20.5	20.5	21	10	10	10	12	12	11.5	19.5	20	20	18.5	21	21	21	26	26	16	24	24.5
33																								
34																								
35																								
36																								
37																								
38																								
39																								
40																								

	R ANK D			L ANK D			R ANK P			L ANK P			R KN E			L KN E			R KN F			L KN F		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
31	16	15.5	15	16.5	15.5	16	22	27	30	27.5	29	22	43.5	46.5	53	35.5	44	45	20.5	22.5	22	21.5	24	25.5
32	15.5	16.5	15	16.5	16.5	18.5	25	28	28	24.5	21.5	26	43	47	47	51	55	45.5	31	36.5	34	33	33	34
33																								
34																								
35																								
36																								
37																								
38																								
39																								
40																								

	R HIP E			L HIP E			TR E			TR F			R HIP F			L HIP F		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
31	28.5	34	33	26.5	27	26.5	20	18	15.5	9.5	11.5	10	22.5	28	25	22	22.5	24
32	43	50	51	43.5	48.5	49.5	28.5	35.5	28	16.5	18.5	19	30	34	29.5	29.5	30.5	27
33																		
34																		
35																		
36																		
37																		
38																		
39																		
40																		

Appendix C

Norm Tables (18-25 yrs and 26-35 yrs)

Body Composition and Flexibility Profile

Y's Way to Physical Fitness

Physical Fitness Evaluation Profile

Norms—Women 18-25

Name ____________________ Dates: T1 ________ T2 ________ T3 ________

Rating	% ranking	Resting HR	% fat	3-min step test	PWC max (kgm)	$\dot{V}O_2max$ (mL/kg)	Flexibility	Bench press	Sit-ups
Excellent	100 95 90	54 56 60	13 15 17	72 79 83	1830 1640 1440	71 67 58	27 25 24	50 42 36	55 48 44
Good	85 80 75	61 64 65	18 19 20	88 93 97	1320 1235 1175	54 50 48	23 22 21	32 29 28	41 38 37
Above average	70 65 60	66 68 69	21 22 23	100 103 106	1120 1075 1030	46 43 42	21 20 20	25 24 22	36 34 33
Average	55 50 45	70 72 73	24 25 25	110 112 116	990 950 915	41 40 39	19 19 18	21 20 18	32 30 29
Below average	40 35 30	74 76 78	26 27 28	118 122 124	880 845 810	37 35 34	18 17 17	16 14 13	28 26 25
Poor	25 20 15	80 82 84	29 30 31	128 133 137	775 740 705	32 31 29	16 15 14	12 9 8	24 22 20
Very poor	10 5 0	86 90 100	33 37 43	142 149 155	640 555 500	26 22 18	13 12 8	5 2 1	17 10 4
Actual Scores	T1	____	____	____	____	____	____	____	____
	T2	____	____	____	____	____	____	____	____
	T3	____	____	____	____	____	____	____	____

	T1	T2	T3
Actual Weight	________	________	________
Target Weight	________	________	________
Blood Pressure	____/____	____/____	____/____

Your actual weight should be within 10% of your target weight. If your blood pressure exceeds 150/90 it is considered high. Your YMCA Medical Advisory Committee should have guidelines for when blood pressure is too high to continue fitness testing.

Y's Way to Physical Fitness

Physical Fitness Evaluation Profile

Norms—Women 26-35

Name ______________________ Dates: T1 ________ T2 ________ T3 ________

Rating	% ranking	Resting HR	% fat	3-min step test	PWC max (kgm)	$\dot{V}O_2$max (mL/kg)	Flexibility	Bench press	Sit-ups
Excellent	100	54	13	72	1600	69	26	48	54
	95	55	15	80	1440	59	24	40	42
	90	59	18	86	1330	54	23	33	40
Good	85	60	19	91	1245	51	22	29	37
	80	63	20	93	1180	48	21	26	34
	75	64	21	97	1115	46	20	25	33
Above average	70	66	22	103	1065	43	20	22	32
	65	67	23	106	1020	42	19	21	30
	60	68	23	110	985	40	19	20	29
Average	55	69	24	112	955	38	18	18	28
	50	70	25	116	925	37	18	17	26
	45	71	26	118	885	35	18	16	25
Below average	40	72	27	121	840	34	17	14	24
	35	74	29	124	805	33	16	13	23
	30	76	30	127	765	31	16	12	21
Poor	25	78	31	129	730	30	15	9	20
	20	80	33	131	695	28	14	8	18
	15	82	35	135	655	26	14	5	16
Very poor	10	84	36	141	600	25	13	2	12
	5	88	39	148	530	22	11	1	2
	0	94	49	154	490	20	8	0	1
Actual Scores	T1	____	____	____	____	____	____	____	____
	T2	____	____	____	____	____	____	____	____
	T3	____	____	____	____	____	____	____	____

	T1	T2	T3
Actual Weight	________	________	________
Target Weight	________	________	________
Blood Pressure	____/____	____/____	____/____

Your actual weight should be within 10% of your target weight. If your blood pressure exceeds 150/90 it is considered high. Your YMCA Medical Advisory Committee should have guidelines for when blood pressure is too high to continue fitness testing.

COLLEGE OF HUMAN PERFORMANCE AND DEVELOPMENT
EXERCISE PHYSIOLOGY LABORATORY

THANK YOU FOR PARTICIPATING IN THIS STUDY!!

BODY COMPOSITION

A body composition profile is an important part of most physical fitness test batteries. Most people agree that a lean body performs better and is not as much of a health risk as an overweight body.

Two components, lean body weight and fat weight, combine to account for your total body weight. Lean body weight includes bones, muscles, and organs while fat weight includes structural and storage fat. Storage fat is accumulated when excess calories are eaten and it is deposited beneath the skin and above the muscle. Storage fat is what will be measured by skinfold calipers.

Average % body fat for females as well as desirable % body fa is shown below. Your recommended weight is a weight that will put you within the desirable range. Remember, average does not mean good!

Average Female......25% fat Desirable......19-23% fat

Your Body Weight _______ Your Percent Body Fat ________
Your Recommended Weight _______ Pounds To Lose ________

Increasing the amount of regular exercise is the best recommendation to affect a positive change in your body composition. If you are trying to lose weight the combination of reduced fat in your diet and increased regular exercise is the best recommendation.

FLEXIBILITY

Flexibility is the ability to move a limb or body part through a range of motion. Flexibility throughout the body is important as it has been related to reduced injuries, good posture, decreased low back pain, and good physical performance.

Your Score __________

Flexibility can be easily increased and maintained with consistent stretching. Pain is never a sign of a good stretch although you should feel a gentle pull. NEVER bounce or move rapidly from one stretch to another.

If you have any questions regarding your performance on these tests or any exercise related topics, please contact me at 597-4102. Thank you again for your participation.

Kristina L. Tucky

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(702) 739-3766/FAX (702) 597-4191

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