1994

Muscular endurance in women through adulthood : a predictor of muscular strength?

Anna K. Kuramoto
San Jose State University

Order Number 1358193

Muscular endurance in women through adulthood: A predictor of muscular strength?

Kuramoto, Anna Karpowsky, M.A.

San Jose State University, 1994

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

MUSCULAR ENDURANCE IN WOMEN THROUGH ADULTHOOD: A PREDICTOR OF MUSCULAR STRENGTH?

A Thesis

Presented to

The Faculty of the Department of Human Performance

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

Anna K. Kuramoto

May, 1994

APPROVED FOR THE DEPARTMENT OF HUMAN PERFORMANCE

Dr. V. Gregory Payne

Dr. Carol Christensen

Dr. Emily Wughalter

APPROVED FOR THE UNIVERSITY

ABSTRACT

MUSCULAR ENDURANCE IN WOMEN THROUGH ADULTHOOD:
A PREDICTOR OF MUSCULAR STRENGTH?

by Anna K. Kuramoto

The prediction of midback muscular strength (1-RM) using relative muscular endurance was examined in women. Seventy-three subjects were divided into three age groups of 20-30 yr (Group 1), 40-50 yr (Group 2), and 60-70 yr (Group 3). Testing was performed on a constant resistance lat pulldown machine. One-way ANOVA revealed significant differences between age groups for repetitions. Post hoc comparisons showed Group 3 completed significantly less repetitions than Group 1 and 2. No significant differences were noted between Group 1 and 2. 1-RM prediction equations were developed by combining Group 1 and 2 and treating Group 3 separately.

The best predictors for Group 1 and 2 were repetitions (REPS), muscular endurance weight load (ME WT) and age (AGE). Group 1 and 2 prediction equation: 1-RM = -2.417 + (-0.117 * AGE) + (0.820 * REPS) + (1.295 * ME WT); R = .95, Adjusted R^2 = .89, SEE = 1.85 kg. Group 3 prediction equation: 1-RM = -3.730 + (0.870 * REPS) + (1.092 * ME WT); R = .91, Adjusted R^2 = .81, SEE = 2.05 kg.

ACKNOWLEDGMENTS

I am deeply indebted to my advisor, Dr. Greg Payne who has been a source of infinite support and encouragement. His time, patience and many words of wisdom have allowed me to appreciate the numerous contributions of higher education and research to individuals and society as a whole. I extend my gratitude to the members of my committee, Dr. Carol Christensen and Dr. Emily Wughalter for sharing their personal thoughts, comments and suggestions.

A heartfelt thanks goes out to the many women who were kind enough to give of themselves as subjects. Without them this work would not have been possible. I would also like to express my appreciation to Icarian Fitness Equipment and particularly, Russ Squier for allowing me to use their lat pulldown machine.

One very special thank you goes to my husband, Richard and my sister, Mary who untiringly carried on to help bring life to this project through the magic of video and the wonders of woodwork!

Table of Contents

List of Figures

List of Tables

Table

CHAPTER 1

INTRODUCTION

The scientific and medical community recommend resistance training as an adjunct to adult fitness programs (American College of Sports Medicine, 1990; Fiatarone et al., 1990a; Frontera, Meredith, O'Reilly, Knuttger, & Evans, 1988). For each exercise in a resistance program, an appropriate weight load must be established for safe and effective overload (Anderson & Kearney, 1982; Atha, 1981; Fleck & Kraemer, 1987). The determination of this workload can be based on an assigned repetition maximum (X-RM) or a percent of a one repetition maximum (1-RM) (Kraemer & Fleck, 1988). An inexperienced weight trainer can easily under- or overestimate a specific RM or 1-RM leading to poor training stimulus or injury, respectively.

Proper training intensity is essential to optimizing gains in strength and muscle mass. Utilizing a training intensity of 80% of 1-RM, Frontera et al. (1988) found greater increases in strength and muscular hypertrophy in elderly men than Moritani and de Vries (1980) who used a training regimen at 66% of 1-RM and yielded no significant increase in muscle area. Fiatarone et al. (1990a) studied nonagenarians and found intensity of training to be an important factor in the large strength gains ($\underline{M}$ = 174%, $\underline{SD}$ = 31%) and muscle mass ($\underline{M}$ = 9.0%, $\underline{SD}$ = 4.5%) of the subjects. Thus, proper assessment of training intensity is necessary to avoid wasted effort and less than optimal results.

The measurement of a 1-RM requires a trial and error method of manipulating weight loads until a maximal effort is achieved (Berger, 1962). Maximal lifts can cause severe musculoskeletal injuries such as fractures, spondylolithesis and torn ligaments (Brady, Cahill, & Bodnar, 1982; Brown & Kimball, 1983; Matheson, MacIntyre, Taunton, Clement, & Lloyd-Smith, 1989; Pollock et al., 1991; Risser, 1991; Risser, Risser, & Preston, 1990). Using a submaximal effort to predict muscular strength would be a safe and simple alternative.

Past studies have found a high correlation (r = .75 - .90) between absolute muscular endurance and muscular strength as a static component (Caldwell, 1963; Start & Graham, 1964; Tuttle, Janney, & Salzano, 1955). More recent investigations have focused on dynamic muscular endurance as a predictor of muscular strength (Braith, Graves, Leggett, & Pollock, 1993; Dean, Foster, & Thompson, 1987; Hart, Ward, Mayhew, & Ball, 1990; Invergo, Ball, & Looney, 1991; Mayhew, Ball, Arnold, & Bowen, 1992). A strong correlation was found between the YMCA bench press protocol, an absolute endurance measure and bench press strength using college-aged male (r = .92) (Invergo et al., 1991) and female subjects (r = .85) (Ball & Rose, 1991). Relative muscular endurance (%1-RM) has also been shown to predict bench press strength (r = .98) (Mayhew et al., 1992) and knee extension strength (r = .94) (Braith et al., 1993). The most recent studies have focused on college-aged males while ignoring older adults (Braith et al., 1993; Invergo et al., 1991; Mayhew et al., 1992). The development of accurate strength prediction equations using submaximal weight loads would be valuable in community-based adult fitness programs for establishing and progressing strength training routines.

Declining muscular strength (Häkkinen & Häkkinen, 1991; Heyward, Johannes-Ellis, & Romer, 1986; Hoffman, Stauffer, & Jackson, 1979; Morrow, & Hosler, 1981; Wilmore, 1974) has been shown to contribute to greater musculoskeletal injuries in the later years, particularly in women (Jette & Branch, 1981; Whipple, Wolfson, & Amerman, 1987). With proper strength training women of all ages can benefit physically and mentally (Brown & Harrison, 1986). To encourage women to participate in this form of exercise, safe and effective methods are necessary. One such measure is the use of prediction equations to establish strength training intensity levels.

<u>Statement of the Problem</u>

Overall musculoskeletal strength typically declines with advancing age (Fiatarone et al., 1990b; Frontera et al., 1991; Grimby et al., 1982; Larsson, 1982; McDonagh et al., 1984). Muscular strength appears to deteriorate at a greater rate in the lower body than grip or arm strength (Grimby & Saltin, 1983; McDonagh et al., 1984). For women, weakened lower body musculature and inadequate upper body strength (Heyward et al., 1986; Hoffman et al., 1979; Morrow et al., 1981; Wilmore, 1974) can contribute to an increase in falls, hip fractures, and difficulty in performing daily activities (Jette & Branch, 1981; Whipple, Wolfson, & Amerman, 1987). Strength training modalities have been shown to be beneficial in maintaining musculoskeletal integrity (Brown, McCartney, & Sale, 1990; Charette et al., 1991; Cress et al., 1991; Fiatarone et al., 1990a; Frontera et al., 1988). To provide women direction in their strength training there is a need to clarify and improve methods for establishing safe, simple, and effective intensity levels. To date, investigations have been limited to college-aged subjects focusing on prediction equations for the bench press (Ball & Rose, 1991; Dean, Foster, & Thompson, 1987; Invergo et al., 1991; Mayhew et al., 1992) and knee extension (Braith et al., 1993). No studies have examined older women and strength predictions through relative muscular endurance measures. Furthermore, investigations have neglected the back and more specifically the muscles of the midback. The midback is composed of several important muscles used in many daily tasks, sports, recreation, and the maintenance of good upper body posture. Weakness in this area can have serious health and functional consequences for women.

Purpose of the Study

The purpose of this study was to determine the relationship of relative muscular endurance and muscular strength in predicting the midback strength of women using the lat pulldown machine.

Null Hypotheses

There are no differences in relative muscular endurance across age groups.

There is no relationship between relative muscular endurance and muscular strength in predicting lat pulldown strength.

Delimitations

The sample was delimited to women from three age groups: early adulthood (20 - 30 years), middle adulthood (40 - 50 years) and late adulthood (60 - 70 years) (Payne & Isaacs, 1991). The participants were delimited to non-strength trained females. Dynamic muscular strength and endurance were measured using the Icarian lat pulldown machine (San Fernando, CA).

Limitations

The factors in this study which could not be controlled include:

1. lack of maximal effort as a result of fear, inexperience, or psychological inhibitions;
2. subjects were volunteers and could result in a sample attracting and representing those individuals with an interest in physical or strength activities;
3. honesty of subjects concerning their strength training experience;
4. establishment of 1-RM could lead to a learning effect;
5. day to day variability in strength within subjects;
6. muscular strength and endurance measures were specific to the muscle groups used;
7. lat pulldown machine was not designed exclusively for women;
8. muscular strength and muscular endurance weight loads were measured to .57 kg (1.25 lb).

Definition of Terms

Dynamic tension. The active shortening or lengthening of a muscle or muscle groups with varying tension against a constant load (Kreighbaum & Barthels, 1990a).

Isometric. The static contraction of a muscle where tension is developed without subsequent change in muscle length (Heyward, 1991).

Isokinetic. The maximum tension a muscle develops at a constant speed throughout the full range of motion (Heyward, 1991).

Muscular Strength. The ability of a muscle or muscle group to generate force against a resistance resulting in a maximal effort (Fox et al., 1989).

Repetition. One in a series of consecutive movements of a specific resistance exercise (Sienna, 1989).

One repetition maximum (1-RM). The performance of an exercise at maximal effort against a resistance allowing only one repetition (Heyward, 1991).

Strength Training. "... the use of resistance methods to increase one's ability to exert or resist force. The training may utilize free weights, the individual's own body weight, machines, and/or other devices to attain this goal. In order to be measurably effective, the training sessions ... (require) timely progressions in intensity, ... (to encourage strength gains)" (National Strength & Conditioning Association, 1985, p. 27).

Operational Definitions

Cadence. The beat, time or measure of rhythmical motion followed during the execution of exercise repetitions.

Relative muscular endurance. Under the constraints of a specified cadence, the ability of a muscle group to repeatedly contract against a weight load determined by a percentage of body weight.

Non-strength trained. A subject who has not participated in a weight training program for the past six months and has less than or equal to two years of weight training experience.

Summary

In recent years, emphasis has been placed on including strength training as part of an adult exercise routine (ACSM, 1990; Fiatarone at al., 1990a; Frontera et al., 1988). Training intensity is an important factor in strength gains (Berger, 1965). Weight loads can be based on 1-RM or an X-RM method, but these processes require a great deal of time and expertise. The risk of musculoskeletal injury with maximal lifts exists. Studies investigating prediction equations for muscular strength have employed muscular endurance tests as a safe and valid measure for upper and lower body strength on college-aged men and women. Research has shown the importance of maintaining or improving muscular strength throughout life (Fiatarone et al., 1990b; Frontera et al., 1991; Grimby et al., 1982; Larsson, 1982; McDonagh et al., 1984). This is especially true for women where weakened upper and lower body musculature can hamper daily activities (Jette & Branch, 1981; Whipple et al., 1987). By providing safe and sensible means of determining workloads in a resistance program, women can perform their exercise routines more effectively. Therefore, the focus of this study was to investigate the relationship between relative muscular endurance and muscular strength in predicting upper body muscular strength in women throughout adulthood.

CHAPTER 2

REVIEW OF LITERATURE

Introduction

Warriors, athletes and physical laborers have actively sought muscular strength throughout history. Today, people from all aspects of life participate in strength training to maintain a productive lifestyle. In an effort to understand training modalities considerable research on human strength has emerged. This investigation focused on dynamic muscular endurance and its relationship to muscular strength, specifically in three age groups of women. The review of literature is divided into: a) a review of literature on female strength characteristics, b) an overview of muscular strength benefits, c) a description of strength training injuries, d) a discussion on strength testing methods, e) a collection of relevant studies of muscular strength prediction equations, f) functional importance of the midback, and g) a summary.

Female Strength Characteristics

Female strength characteristics have been described in anthropometric and cellular studies comparing gender differences. Unfortunately, many methods have been used to express strength resulting in controversy concerning the differences between genders (McArdle, Katch, & Katch, 1991). Laubach (1976), in a review of two dynamic and seven static strength studies comparing men and women, found the women to be weaker in both the lower (71.9%) and upper (55.8%) body ($\underline{M}$ = 63.5%). However, the author cautioned against referencing these values due to the wide range of mean percentage differences. Wells and Plowman (1983), after compiling several studies, concluded the average man had 30% to 40% greater strength capabilities than the average woman. When comparing strength disparities for various regions of the body, such a generalization was found to be inappropriate. There was less of a gender difference for lower extremity strength values (Laubach, 1976; Wilmore, 1974).

Wilmore (1974) attempted to equalize strength values between genders by creating a body weight and lean body mass ratio strength score. Following a 10 week dynamic strength program the strength of female subjects was equal to or greater than men when absolute strength values were expressed in relative terms. This was not apparent for the upper body where strength values were less than men. One possible explanation for this phenomenon was the limited use of the upper body by females whereas movement of the lower limbs are commonplace for both genders.

Heyward et al. (1986), in her study of male-female strength differences, considered additional structural and physiological variables. Using hydrostatic lean body mass, girths, and skinfold measures of limbs to estimate subcutaneous fat and muscle distribution a distinct gender strength pattern was found. Physically active men were significantly stronger overall than physically active women when tested isokinetically for shoulder flexion and knee extension. Specifically, upper body strength was found to be a more important indicator of differences than lower body strength. When the differences in lean mass, arm and thigh girth, tricep and thigh skinfolds were statistically controlled, no significant differences were found in upper and lower body strength between genders. These controlled factors accounted for 73% of the variance in both shoulder flexion and knee extension strength. From these findings, gender differences in upper and lower body strength appear to be attributed to variations in lean body weight and subcutaneous and muscle mass distribution. The strength variations for women were a result of both limb measures and lean body mass whereas the greater portion of the variances for men were solely from lean body mass.

Muscle composition is another means of characterizing female muscular strength. The cellular make-up of female musculature does not appear to differ from males in strength per unit force production. Using various devices such as computer tomography and ultrasound, muscle appears to have the same ability to generate force per cross-sectional area regardless of sex (Ikai & Fukunaga, 1968; Schantz, Randall-Fox, Hutchison, Tyden, & Astrand, 1983). When these findings are viewed with the results of Heyward et al. (1986), the importance of lean tissue quantity and distribution in the expression of strength becomes evident. At the same time, since tension generated unit for unit is the same for men and women, training methods should be similar (Holloway & Baechle, 1990).

In reviewing differences in male and female muscular strength, Wells and Plowman (1983) acknowledged the distinctions between the genders, but also stressed that differences between any two individuals of the same gender can prove to be of greater variability. Within the female population, studies have shown strength differences to be significant between trained and sedentary subjects as well as across age groups. One such study employed both mature female (M = 44.4 yr) and young female subjects (M = 21.5 yr). The groups were each further divided into control and experimental groups for a strength training and self-concept study (Brown & Harrison, 1986). The mature and young experimental groups exhibited significant strength gains after a 12-week progressive weight training program in comparison to their control counterparts. The experimental groups increased self-esteem scores significantly while the control groups did not. In a study of women over 60 years of age, heavy-resistance training by aerobically active subjects for 6 months revealed a significant gain in muscle strength when compared to sedentary controls (Nichols, Omizo, Peterson, & Nelson, 1993). Another study compared age groups of female masters swimmers in muscular strength and endurance abilities. Swim training resulted in greater strength values for both mature and young active females though strength declined with age. Muscular endurance did not show a decrement across age groups since this form of muscular activity typifies the sport (Dummer et al., 1985). Therefore, the attainment of muscular strength appears to require a regimen geared specifically to muscular strength (Anderson & Kearney, 1982; Häkkinen & Keskinen, 1989).

Most strength training conclusions have been derived from male subjects. Few data have been generated as to the long term effects of heavy resistance training on females. Recent studies have questioned the supposition women are incapable of significant hypertrophic strength gains (Charette et al., 1991; Cureton, Collins, Hill, & McElhannon, 1988; Fiatarone et al., 1990a; Staron et al., 1989; Staron et al., 1991). Early studies used gross indirect anthropometric procedures such as girths, skinfolds and body weight, thereby limiting the ability to accurately detect muscular hypertrophy (Moritani & de Vries, 1979;

Wilmore, 1974). Furthermore, training stimulus may have been too short in duration and/or insufficient in intensity (Holloway & Baechle, 1990). When women subjects completed a heavy-resistance training program (6-8 RM) of 20 weeks duration, significant strength gains were found with muscle biopsies revealing significant hypertrophic changes of myofibers (Staron et al., 1989). Direct measurements of muscle cross-sectional area through the use of computed tomography scans also revealed significant muscle hypertrophy to be a consequence of high intensity strength training in young (M = 25.5 yr) and frail old (M = 90.2 yr) women (Cureton et al., 1988; Fiatarone et al., 1990a).

Another disputed explanation for limited muscle hypertrophy in weight trained females is low circulating androgen levels in comparison to men (Brown & Wilmore, 1974; Mayhew & Gross, 1974; O'Shea & Wegner, 1981; Wilmore, 1974). This viewpoint is not supported given the increase in cross-sectional area of muscle in various heavy-resistance training studies (Charette et al., 1991; Cureton et al., 1988; Fiatarone et al., 1990a; Staron et al., 1989; Staron et al., 1991). Additionally, the degree of influence by testosterone in muscle hypertrophy is questioned given the poor controls on pre-training status, duration and intensity evidenced in past studies (NSCA, 1989). Improperly timed measurements of testosterone blood levels combined with an inappropriate training regimen can also be a source of erroneous findings (Holloway & Baechle, 1990). A clear picture of hormonal influences on heavy-strength training in women has yet to be formed.

Strength Training Benefits

Strength training has contributed greatly to the rehabilitation of individuals with musculoskeletal injuries and neuromuscular disorders (DeLorme, 1945; DeLorme & Watkins, 1951). In 1990, the American College of Sports Medicine published a revision on exercise guidelines for healthy adults. Recommendations for resistance/strength training were included. The basis for incorporating this training modality rests on the importance of improving or sustaining fat free weight (FFW) to guard against deterioration in muscle function.

Elderly subjects have shown dramatic improvement in strength capabilities and muscle composition when placed on a resistance program. Frontera et al., (1988) studied the influence of a strength conditioning program on muscle hypertrophy and function. Male subjects (60 - 72 yr) exhibited significant dynamic strength gains in knee flexors (226.7%) and extensors (107.4%) after a twelve week program utilizing 80% 1-RM. Computerized tomography of the thighs showed a significant increase in the entire upper leg, total muscle area and specifically the quadriceps area. Muscular hypertrophy and myofibrillar protein turnover rate were associated with strength gains in the subjects. A dramatic improvement in muscle strength, muscle mass and a decrease in walking time was observed in frail nonagenarians after an 8 week high-intensity (80% 1-RM) strength training program (Fiatarone et al., 1990a). These findings vary from those of Moritani and de Vries (1980) who found neural adaptation to be the sole contributor to strength gains in the elderly. When lower intensity levels were employed with older adults the strength response was either minimal or nonexistent (Agre et al., 1988; Aniansson & Gustaffson, 1981; Cress et al., 1991; Larsson, 1982; Moritani & de Vries, 1980).

Frontera et al. (1991) studied men and women cross-sectionally from 45 to 78 yrs to determine the relationship between muscle mass (MM) and isokinetic muscle strength. The FFW/MM as well as the muscular strength (elbow and knee extensors & flexors) of the oldest group (65 - 78 yr) of men and women were significantly lower than the youngest group (45 - 54 yr). When adjusting for FFW or MM, the age-related differences were significant only in knee extension. In terms of absolute strength, the women were 42.2% to 62.8% weaker than men. The relative expression of strength to kg of MM, whether in the upper or lower body, discounted or minimized gender differences. The investigators concluded that the loss of muscle mass appeared to be a large contributor to decrements in musculoskeletal strength between genders and age groups.

Decline in strength can result in difficulties with daily life activities and a greater incidence for falls in the elderly (Fiatarone et al., 1990b). Jette & Branch (1981) in the Framingham Study of physical disability found 33% of women from 75 to 84 yr unable to lift weights 10 lbs or under. That increased to 65% when the weight loads were greater than 10 lbs. Subjects 75 yrs and over were evaluated and followed in the community for one year to determine risk factors related to falling (Tinetti, Speechley, & Ginter, 1988). The majority of risk factors identified were considered secondary to neurological and musculoskeletal insufficiencies. Falls in the older population can partly be attributed to muscular weakness in the lower extremities. Nursing home residents with a history of falling were found to have significantly less muscular strength in the ankle and knee joints than controls (Whipple et al., 1987). Subjects identified as "fallers" and their controls were screened to eliminate individuals with terminal illness, orthopedic and neuromuscular limitations, and cerebrovascular dysfunction. Isokinetic dynamometry for flexor/extensor joint action of the knee and ankle revealed significantly reduced peak torque and power for fallers. Muscles involved in ankle dorsiflexion were found to have the lowest values for power production and believed to contribute to balance difficulties in the elderly.

Age-related declines in muscular strength appear to occur more rapidly in the lower extremities than with the upper extremities (Grimby & Saltin, 1983; McDonagh et al., 1984). For women, a weakened upper body coupled with decrements in lower extremity strength can contribute to falls and fractures. Muscle mass and strength has been shown to correlate with several measures of bone integrity. A significant correlation was found between the ash weight of the third lumbar vertebral body from human cadavers and the weight of the psoas muscle (Doyle, Brown, & LaChance, 1970). Greater muscle mass resulted in larger force production upon bony levers and ultimately, higher bone mass. This was considered integral in describing the importance of muscle mass to bone mass stability. Bone mineral density is another variable of skeletal constitution and was studied in postmenopausal women, specifically the lumbar vertebral bodies (Sinaki & Offord, 1988). Back extensor strength and bone mineral density resulted in a significant positive correlation (Sinaki & Offord, 1988). The strength of back extensors was thought to be an important factor in bone mineral density of vertebral bodies. Therefore, strengthening exercises can help to guard against functional deterioration in the later years while retarding the process of diseases like osteoporosis. Females suffering from spinal osteoporosis may be offered protection from greater vertebral fractures with the strengthening of back extensors (Sinaki & Mikkelsen, 1984).

Strengthening of weakened musculature has been shown to enhance the quality of movement and health in later years (Fiatarone et al., 1990b; Frontera et al., 1991). However, a prophylactic approach to reducing age-related strength decrements may provide an additional advantage when begun early in life. One study supporting this contention revealed male subjects (60 - 68 yrs) who had been training before their thirties and forties had significantly higher values in back-lift strength, isometric strength, dynamic strength, and speed of movement of the biceps brachii and quadriceps muscles than untrained subjects or males who had begun training in their fifties (Aoyagi & Katsuta, 1990).

Training Injuries

Weight training injuries occur in all age groups from prepubescents to the elderly. They contribute to minor sprains, strains, and major trauma to spinal columns, bony joints, attachments, and musculature (Brady et al., 1982; Brown & Kimball, 1983; Matheson et al., 1989; Pollock et al., 1991; Reut, Bach & Johnson, 1991; Risser et al., 1990). Precautionary measures are essential for safe and effective programming and should be a primary concern for all participants.

Prepubescent athletes who have not reached Tanner stage V in achieving secondary sex characteristics are at greater chance of injury when participating in maximal lifts (NSCA, 1985). The growth plate is vulnerable to trauma at this time and epiphyseal fractures can result from excess weight loads (Gumbs, 1982; Risser et al., 1990). The NSCA (1985) stresses the importance of proper form and technique during training, but does not recommend the use of a 1-RM with this age group.

Adolescent athletes in junior and senior high school are also prone to injuries. Weight lifting is a source of potential injury when performed without appropriate supervision and safety measures (American Academy of Pediatrics, 1983). Brown and Kimball (1983) sampled 71 teenage powerlifting contestants for injury types and location. A total of 98 powerlifting injuries revealed the back (50%) to be the most frequently affected. The injuries sustained in this region (90.7%) consisted of muscle pulls, tendinitis, sprains, and fractures.

Information on exercise injury rates of the elderly provides valuable insight as to age appropriate exercise prescription. Unfortunately, data on elderly subjects are scarce in the area of strength training. A portion of this can be attributed to the relatively new interest in weight training for the elderly. One recent study evaluated the incidence of injury to older male and female subjects (70 - 79 yr) during 1-RM lifts on 10 variable resistance Nautilus™ machines (Pollock, 1991). Of the 57 subjects tested 11 received injuries to the knee (5/11) from the leg extension, and injuries to the shoulder/arm (5/11) and back (1/11) caused by the bench press. One-RM testing may not be advisable for those who have a history of orthopedic problems since four of the injuries were in subjects with past joint limitations. In a retrospective study on musculoskeletal injuries in older adults, Matheson et al. (1989) noted the prevalence of predisposing limitations to exercise such as osteoarthritis and associated muscle weakness. Such cases warrant muscle rehabilitation, but with a precautionary approach for determining weight loads.

Free weights used in such lifts as the bench press, squat, snatch, and deadlift have been associated with serious injuries like pectoralis major rupture, avulsion fracture of the anterior iliac spine, and rotator cuff tears (Brady et al., 1982; Neviaser, 1991; Reut et al., 1991). However, other resistive devices have also contributed to weight training injuries. Brady et al. (1982) studied the injuries of 43 high school athletes. These injuries were attributed to improper use and poor design of specific pieces of strength training equipment. Athletes using the Leaper (Strength/Fitness Systems, Independence, MO) have sustained lumbosacral complications while attempting to enhance vertical jump distances by leaping against a harness resistance. The overload to the lumbar spine can be detrimental to the bony structures of the vertebral column. The Universal Gym™ (Cedar Rapids, IA) consists of several strength training stations for various muscle groups. Lumbosacral injuries, avulsion of the anterior iliac spine, and knee meniscus tears have occurred on various pieces of the Universal Gym™.

Strength Testing

The 1-RM is a method of testing dynamic muscular strength involving a maximal effort for one repetition as determined by a trial and error method (de Vries, 1986). A progressive protocol is employed whereby weight is increased after each successful attempt up to the maximal lift (Berger, 1962; Heyward, 1991). The subjective nature of assessing weight loads to determine strength is inappropriate for certain areas of research, but is common in weight training studies (Stone & O'Bryant, 1987).

External variables can influence both muscular strength and endurance measures and are important considerations in attempting to achieve optimal performances (de Vries, 1986). Nelson (1978) investigated the influence of various motivational techniques on muscular endurance testing of the forearm flexors. College-aged males were told to give their best effort. Four groups were randomly drawn with the control group receiving no further instruction. The remaining three groups included subjects given realistic norms, a group given high unrealistic norms, and a remaining group provided an obtainable goal of at least 40 repetitions. Analysis of variance resulted in significant differences among the four groups. Post-hoc analysis revealed the three groups given additional instructions significantly outperformed the control group. The greatest number of repetitions was achieved by the fictitious norms group who was given elevated norms of college-aged males and high school boys. This group also had the greatest variability in repetitions achieved (SD = 9.29) as opposed to the control (SD = 4.05), realistic norms (SD = 6.51) and obtainable norms groups (SD = 2.01). The use of ego-damaging false norms appears to induce great efforts as evidenced by the highest number of repetitions. However, increased variability was noted where some subjects may have lacked the drive to continue in the face of perceived failure.

Other psychological factors during testing have been shown to affect strength measures (Ikai & Steinhaus, 1961). Both male and female subjects executed repetitive maximal forearm flexion (one per minute for a total of 30 minutes) under varying circumstances. Groups hypnotized to believe they had greater strength displayed a +26.5% increase in strength followed by shouting of subjects at maximal effort (+12.1%), and a pistol shot just prior to testing (+7.4%). Those hypnotized to believe they had less strength had a decrement of strength (- 31.7%). The capacity to demonstrate maximal efforts can be limited or enhanced by psychological factors and techniques such as improper normative feedback, shouting and hypnosis. Careful consideration of such variables are necessary in developing a standardized protocol for 1-RM testing (McArdle et al., 1991).

The assessment of muscular endurance involves either dynamic muscle action or static tension against a submaximal resistance (Gettman, 1988; Thomas & Nelson, 1990). Dynamic endurance tests can be further subdivided on the basis of workload. An absolute or fixed load requires a specified weight to be moved to a criterion of exhaustion such as a set cadence or time limit (Thomas & Nelson, 1990). In contrast, a relative load is based on a percentage of a subject's 1-RM or body weight to be lifted within a predetermined timeframe or cadence (Heyward, 1991; Fox et al., 1989; Sienna, 1989). The situp and pushup tests are familiar relative endurance tests requiring dynamic contractions and are usually administered over time. The YMCA bench press test is a form of absolute endurance assessment using a fixed weight load of 80 lb for men and 35 lb for women. Repetitions are carried out to a set cadence of 60 beats per minute and are terminated when the cadence is broken (Golding, Myers, & Sinning, 1989). As in muscular strength testing motivation can be a factor in performance of endurance tests and requires consistent instruction and verbal cues (Gettman, 1988).

Relevant Studies Involving Muscular Strength Prediction Equations

Investigations have found high correlations between absolute muscular endurance and isometric strength (Caldwell, 1963; Start & Graham, 1964; Tuttle, Janney, & Salzano, 1955). College-aged male and female subjects pulled back on an isometric dynamometer handle in a mid-prone position to assess isometric strength and endurance. This measure required maximal static force for 7 seconds followed by a relative static force as a percentage of the maximal effort. Absolute static strength was determined with a 40 lb load as measured with a green light signifying adequate tension. Failure to keep the light illuminated terminated the test and the time recorded to fatigue was the measure of muscular endurance. The correlation between static strength and absolute endurance was .86. Other tests using elbow flexor, leg and back dynamometry yielded correlations of .75, .90 and .91, respectively, between isometric strength and absolute muscular endurance (Start & Graham, 1964; Tuttle et al., 1955).

However, when using relative loads sufficient to occlude blood flow an inverse relationship may result between relative muscular endurance and isometric strength (Heyward & McCreary, 1978; Start & Graham, 1964). Tension above this critical level appears to result in anaerobic conditions and muscular fatigue. Heyward (1975) found correlations ranging from -.31 to - .50 ($p < .05$) between continuous static grip squeezing at 4 percentage levels of 1-RM (30%, 45%, 60%, 75%) and maximal effort. The arm, back and legs have also been shown to have a negative relationship between isometric strength and relative endurance (Start & Graham, 1964; Tuttle et al., 1955)

Dynamic endurance has recently been studied for its relationship to muscular strength. Dean et al. (1987) developed a prediction equation for Universal Gym™ bench press strength using a relative measure, the full lever pushup. The pushup to bench press relationship resulted in a moderate correlation of .51, but when corrected for body weight the correlation rose to .86. Crossvalidation of the prediction equation was .95 with a mean absolute error in estimation of 6.3 kg. Invergo et al. (1991) compared both absolute and relative muscular endurance to predict bench press strength. Male subjects performed one minute timed pushups as a relative measure and the YMCA bench press test with 80 lbs as the fixed load for estimating bench press strength. The YMCA bench press test ($r = .93$, SEE = 6.03 kg) did not require controlling for body weight and appeared to predict bench press strength more closely than the pushups with correction for body weight ($r = .75$, SEE = 13.33 kg). The absolute bench press equation was crossvalidated resulting in a correlation of .95 (SEE = 4.49 kg).

Ball and Rose (1991) repeated the YMCA bench press test (15.9 kg) on college-aged women along with a modified weight load of 20.4 kg. Body weight was factored into the equations to improve estimation of the 1-RM. The modified test ($r = .85$, SEE = 2.95 kg) and YMCA bench press test ($r = .81$, SEE = 2.37 kg) were relatively close with the YMCA bench press test having a lower estimated error. Crossvalidation revealed the YMCA bench press test equation (r = .80, SEE = 2.91 kg) was relatively close to the modified prediction formula (r = .81, SEE = 2.99 kg).

Another bench press strength study utilized randomly assigned relative endurance weight loads (55-95% 1-RM) for a one minute repetition test (Mayhew, Ball, Arnold, & Bowen, 1992). Upon completion of a 14 week free weight and Nautilus™ circuit weight training program (3 sessions/wk, 1 set/exercise, 10-12 RM), 1-RM and % 1-RM testing were performed. Since there were no significant differences between genders values were combined for prediction purposes (r = .98, SEE = 4.8 kg). Cross-validation to a comparable group resulted in high validity (r = .98) and standard error of 5.4 kg. No comparisons were made between pre- and post-training muscular strength and endurance values. However, training status was considered by Braith et al. (1993). A college-aged sample (M = 25 yr) of men and women were randomly assigned to a training or control group. The exercise group trained on a Nautilus™ knee extension machine two or three times per week for 18 weeks with a weight load in the 7-10 RM range. The dynamic strength test for both groups was performed using a predetermined load with the intent to achieve fatigue within 7-10 repetitions. The weight load was standardized to 40% of peak isometric knee extension strength. Pre- and post-testing revealed the training group increased their 1-RM (31.7%) and 7-10 RM (51.4%) strength, whereas the controls showed no significant increase. Prior to training, estimation of strength was not significantly different from controls. The equation (r = .94) was found to have a standard error of 9.3 kg. Post-training values resulted in an overprediction of 21.2 kg and therefore, a second equation was developed (r = .95, SEE = 9.9 kg). Unfortunately, statistical analysis was not completed for differences between genders.

Functional Importance of the Midback

The main muscles of the midback include the rhomboids, trapezius III and IV, latissimus dorsi, teres major with contributing movements from the chest muscles, pectoralis major and minor (Kreighbaum & Barthels, 1990b; Sienna, 1989) (see Figure 1). The broad territory covered by the latissimus dorsi has its furthest points of origin within the lower back, consisting of the sacrum, posterior crest of the ilium, and lumbar spinous processes (Thompson, 1989). Therefore, the term mid-low back has also been used to further differentiate muscular actions of this region of the back (Niederlander & Cibrario, 1992).

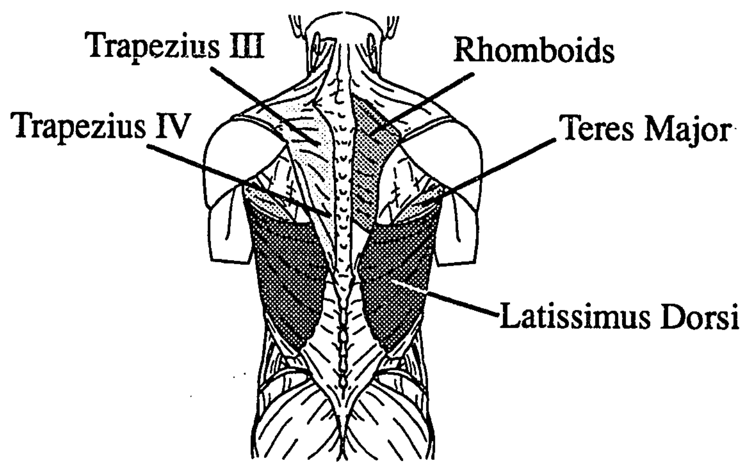


Figure 1. Major muscles of the midback.
From MediClip: The Complete Medical Art Library (Computer Clip Art) by Alpha Media, 1992, Santa Monica, CA: author. Reprinted by permission.

Trapezius IV and pectoralis minor depress the scapulae allowing the shoulders to move out of an elevated position. The rhomboids and trapezius III with assistance by IVwork to retract the scapulae. The humerus is internally rotated and brought into extension by the latissimus dorsi, teres major and pectoralis major (Kreighbaum & Barthels, 1990b; Thompson, 1989). The midback movements of scapular depression and retraction along with internal rotation and extension of the arm have functional importance. First, these actions are used in daily tasks such as bringing down items from a shelf as well as physical labor chores requiring pulling the body up or pulling objects towards the body. Next, a variety of sports depend on midback muscles. Examples include rope or rock climbing, swimming, gymnastics, martial arts, and other sports which use the arms in a pulling down or pulling back motion. Last, the natural curvature of the spine relies on strong midback musculature to maintain proper upper body posture. Excessive atrophy in this region results in kyphosis, characterized by rounding of the shoulders and stooping forward (Janda, 1986).

Summary

Studies on female strength have traditionally focused on gender differences. Controversy exists as to the appropriate expression of strength for gender comparisons (McArdle et al., 1991). Heyward et al. (1986) revealed men were stronger than women in absolute strength with the upper body being the greater contributor in this difference. However, by correcting for lean body mass, limb circumferences, and subcutaneous fat distribution no significant difference in upper or lower body strength was observed. Wells and Plowman (1983) concluded despite the differences between the sexes in muscular strength, a greater variability appears to exist between individuals of the same sex. The training of muscle by either gender should be similar since unit for unit of muscle area little difference between genders has been seen in contractile abilities (Ikai et al., 1968; Schantz et al., 1983). Several heavy training studies have observed significant hypertrophic changes in muscle tissue of females (Charette et al., 1991; Cureton et al., 1988; Fiatarone et al., 1990a; Staron et al., 1989; Staron et al., 1991). These findings question the hypothesis that strength gains are predominantly neurological and/or a result of lower androgen levels (Holloway & Baechle, 1990; NSCA 1989).

The value of strength training has been shown to be beneficial in a variety of settings and has now been accepted in adult exercise programs as necessary for maintaining lean body mass (ACSM, 1990). Elderly strength training has been shown to significantly improve muscle strength, muscle mass, and enhance ambulation with emphasis on heavy-resistance based on 80% 1-RM (Fiatarone et al., 1990a; Frontera et al., 1988; Frontera et al., 1991). Although strength training can be beneficial, it can pose a degree of risk when proper safety precautions are not met. Maximal lifts have been associated with musculoskeletal injuries and has not been advised for prepubescents due to possible damage to growth plates (AAP, 1983; NSCA, 1985). During strength testing (1-RM), joint injuries were incurred by elderly subjects, some of whom had predisposing orthopedic problems (Pollock et al., 1991). Strength testing requires carefully standardized protocols to control for its subjective nature. External variables such as inappropriate feedback, shouting, and sudden noises have a profound impact on the expression of strength (Ikai et al., 1961; Nelson, 1978). Studies have focused on field tests to predict strength of the chest and quadriceps through muscular endurance maneuvers (Ball & Rose, 1991; Braith et al., 1993; Dean, Foster, & Thompson, 1987; Invergo et al., 1991; Mayhew et al., 1992). None has focused on the strength of the back. The musculature of the midback is one region of the upper body with practical importance in daily tasks, physical labor, recreational pursuits, and the maintenance of the natural curve of the spine. Further investigation into this area would help to clarify the value of prediction equations for midback muscular strength when maximal efforts are not feasible.

CHAPTER 3

METHODOLOGY

Introduction

This investigation focused on the relationship between relative muscular endurance and muscular strength measures in predicting midback muscular strength. The methods for this study are described with respect to subjects, instrumentation, procedures, and statistical analysis.

Subjects

A total of 73 females were tested for muscular endurance and strength measures of the midback. Volunteers responding to local advertisements (see Appendix A) were employed as subjects. Recruitment of subjects was through local advertisement at community centers, places of employment, local newspapers (San Jose Mercury News, Senior Spectrum, The Villager, Senior Times, Willow Glen Resident), local community colleges (San Jose City College, DeAnza College, West Valley College), the campus of San Jose State University, local organizations (Older Women's League, Silver Streaks, YWCA, Fifty Plus Fitness Association, South Bay Striders, LEADS, hospital volunteers), electronic mail (Internet) and by word-of-mouth. Three age groups of women were formed: a) early adulthood (20 - 30 years, n = 23), b) middle adulthood (40 - 50 years, n = 27), c) late adulthood (60 - 70 years, n = 23) (Payne & Isaacs, 1991). Adult women were studied since previous investigations have focused on college-aged men. Further, inquiry into strength characteristics of women in their later years is lacking.

Subjects completed an informed consent (see Appendix B) explaining the purpose of the study, associated risks and benefits, timeframe for participating, and their rights as participating volunteers. The use of a medical/training history questionnaire (see Appendix C) screened for musculoskeletal problems and limitations, previous weight training experience, past and present exercise habits, medications, and chronic and current illnesses.

Inclusionary criteria consisted of subjects who were: non-strength trained females within the aforementioned age groups. The exclusionary criteria were: hypertension (≥ 140/90), hypotension (< 90/60), cerebrovascular disease, cardiovascular disease, orthopedic or musculoskcletal limitations to neck, shoulder and back.

Instrumentation

To statistically describe the three groups of subjects, age and anthropometric measures for height and weight were used.

Anthropometric Instruments

Anthropometric data were collected using the following instruments according to the procedures (see Appendix D) of Lohman, Roche, and Martorell (1991).

1. Weight was measured by a Health-o-meter balance beam floor scale (Bridgeview, IL) to the nearest 0.1 kg. The scale was calibrated prior to conducting the study using 5, 10 and 25 lb free weight plates.
2. A movable sliding height rod attached to the scale measured standing height to the nearest 0.25 cm.
3. Body mass index was calculated using the Quetelet Index of weight relative to height (kg/m^2) (Revicki & Israel, 1986).

Muscular Strength and Endurance Testing Equipment

1. The Icarian lat pulldown machine (San Fernando, CA), a constant resistance device, was used for muscular strength and endurance measures (see Figure 2).
2. The type of cadence device employed was an audiotape recording.
3. A curtain concealed the subject's view of weight stacks and tester when the weight load was manipulated.
4. Adapter weights were used for small incremental changes, .57 - 2.27 kg (1.25 - 5 lb).
5. Constructed wooden platforms aligned the subject's hips and knees.
6. The lat pulldown bar was padded at the midpoint to avoid injury from direct contact of the bar to the base of the neck.

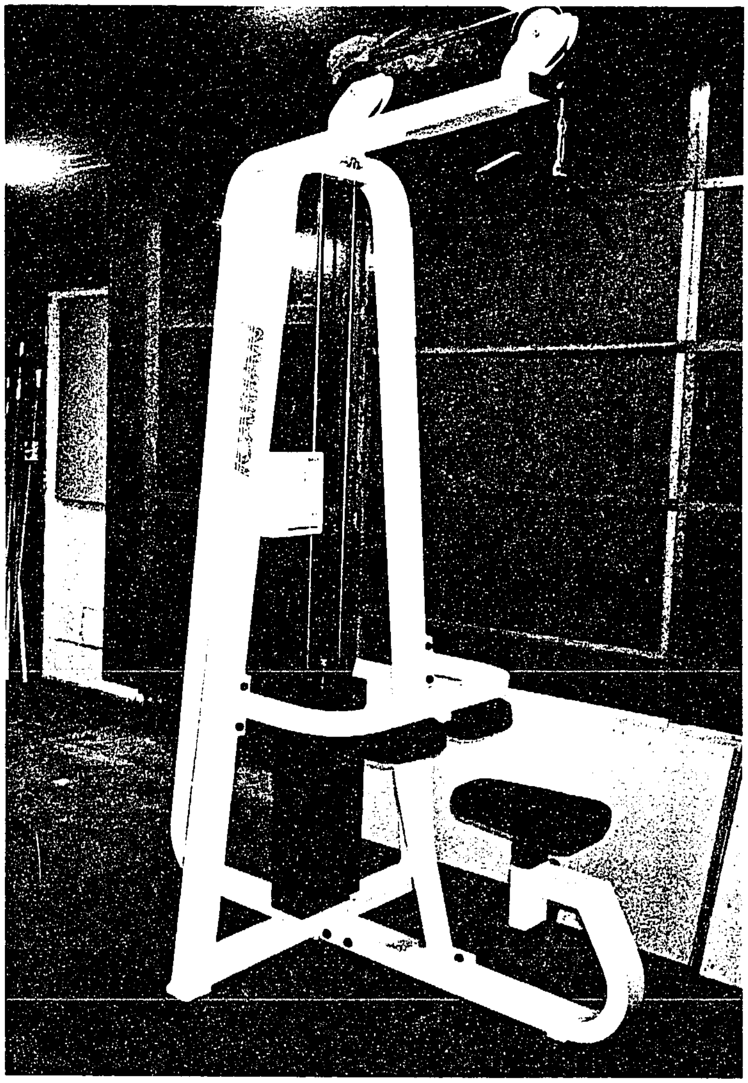


Figure 2. Lat pulldown machine without modifications.

Procedures

Introduction

Subjects were briefed on the 1-RM and muscular endurance tests for the lat pulldown using a computerized slideshow introduction created on Persuasion (Aldus Corporation, Seattle, WA) as well as videotaped instructions on testing procedures (see Appendices E, F, G, I). Anthropometric measurements were also taken at this time for descriptive and statistical analysis. Subjects participated in one testing session for all values. The first measure tested was the 1-RM followed by the muscular endurance test (see Appendices H, J). A 15 minute rest period was placed between the two tests to reduce the impact of fatigue. Subjects were identified by an assigned code number upon completion of the medical/history training questionnaire (see Appendix C). Confidentiality was maintained by placing the medical/history training questionnaire and subject's assigned code number within a locked file cabinet.

A pilot study was conducted with 26 subjects to evaluate the feasibility of the protocol, the appropriate cadence parameters, hand placement, body positioning on equipment, amount of relative weight load, and amount of warm-up weight load and repetitions.

Pre-Testing

Anthropometric measurements were obtained while the subject was barefoot, in shorts and a t-shirt. Appendix D describes the techniques used and the recording form is included as Appendix K. Weight and standing height were assessed. The subjects were given standardized instruction on performing the 1-RM and the muscular endurance test for the lat pulldown (see Appendices G, I).

Testing Session

Subjects reported for testing after abstaining from new or unusual physical activity for at least 48 hours. They warmed-up for both tests with the specified weight load and repetitions. Weight training gloves were worn for comfort and support.

One-Repetition Maximum Standards

The 1-RM as a measure of muscular strength has logical validity since what is tested is what is measured (Thomas & Nelson, 1990). This method has been employed in various studies to determine muscular strength for the bench press and the leg press using the Universal Gym™ and free weights (Anderson & Kearney, 1982; Berger, 1962; Jackson, Watkins, & Patton, 1980; Wilmore et al., 1978). Content validity has also been established for this procedure using factor analysis of 1-RM performances on the Universal Gym™ for lat pulldown strength (Jackson et al., 1980). Reliability of the 1-RM has been demonstrated by Berger (1962) using test-retest on the bench press (r = .97) and by Jackson et al. (1980) with pilot study comparisons for 12 selected Universal Gym™ performances (lat pulldown = .84).

The 1-RM lat pulldown procedures (see Appendix H) were derived from pilot findings and Beckett (1983). Each subject was seated and situated with the shoulders and hips below and perpendicular to the midpoint of the lat pulldown bar. A hand placement of 29 in (73.7 cm), approximately a two hands width grip on the pulldown bar was derived from evaluating the biacromial width (M = 14.5 in, SD = .67 in) of pilot subjects, their feedback on various grip positions and the constraints of the bar itself (see Figure 3). The actual grip sites for each subject was marked with tape for consistent hand placement (see Figure 4). A tape marker was applied to the subject's seventh cervical spinous process. The subject was secured into the seat by raising the seat to allow the stabilizing pads to meet the thighs with hip and knee joint in horizontal alignment. Wooden platforms were also placed below the feet of the subject to maintain this placement (see Figure 5). The subject's hips were positioned in a slight forward flexion and the head was maintained in a natural upright position with a slight forward flexion (see Figure 5). The tester assisted the subject in grasping the bar in a palms-down manner with the arms fully extended. A start signal was given to initiate the movement down. The subject's marker on the base of the neck was tapped by the tester to provide tactile orientation and a verbal cue to begin was provided. A proper lift occurred when the bar contacted the vertebral marker in one continuous pull (see Figure 5). Appendix G describes standardized instructions given to the subject prior to and during testing.

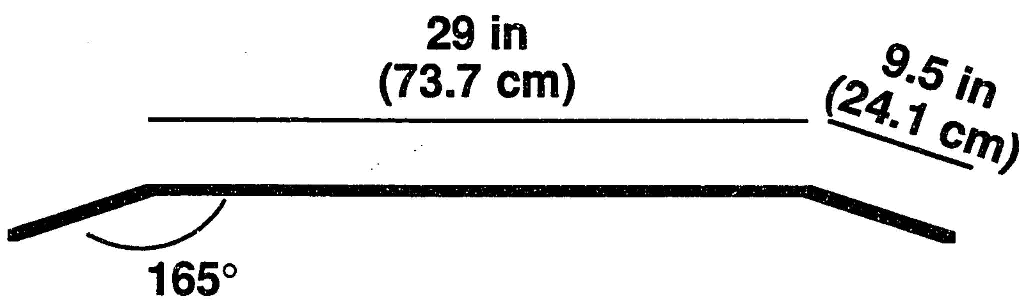


Figure 3. Dimensions of the lat pulldown bar.

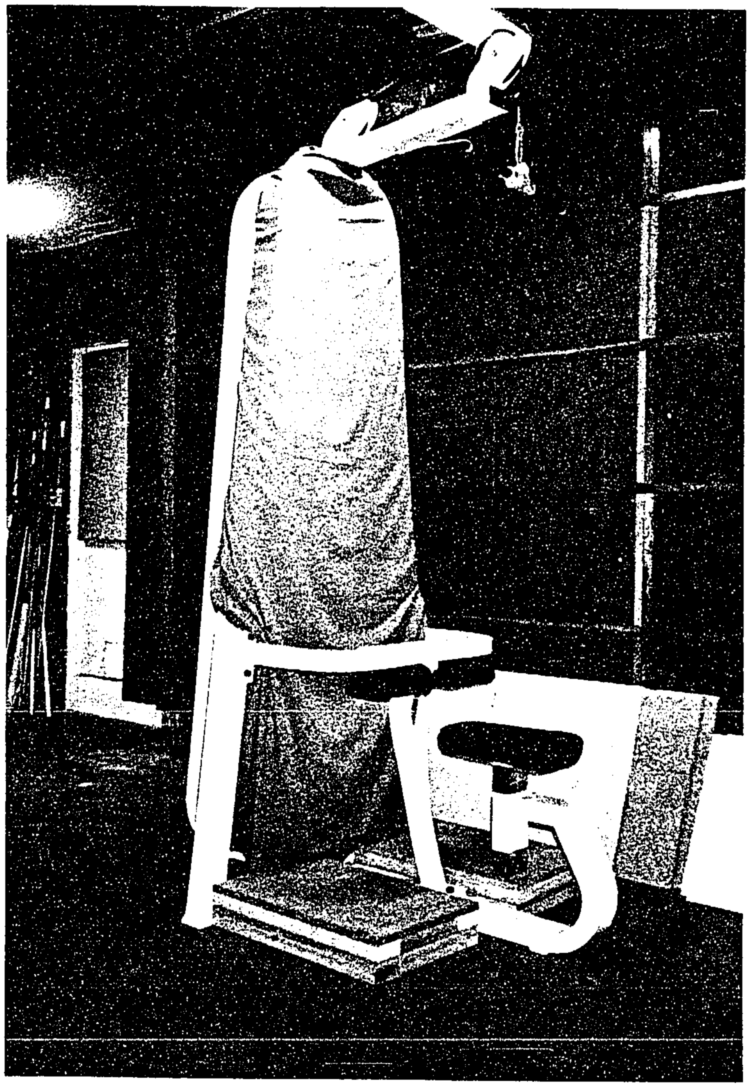


Figure 4. Lat pulldown machine with wooden platforms, taped markers and padding to bar, curtain, and incremental adapter weights.

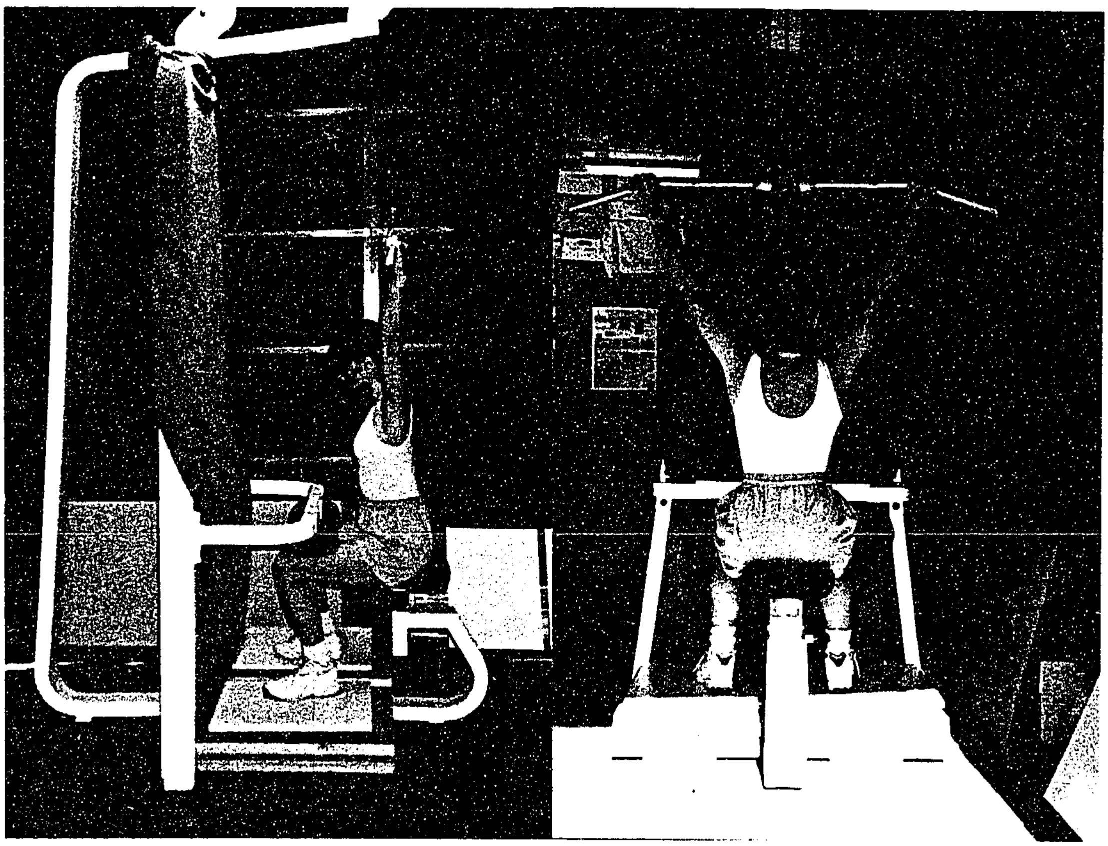


Figure 5. Start position for 1-RM and muscular endurance testing.

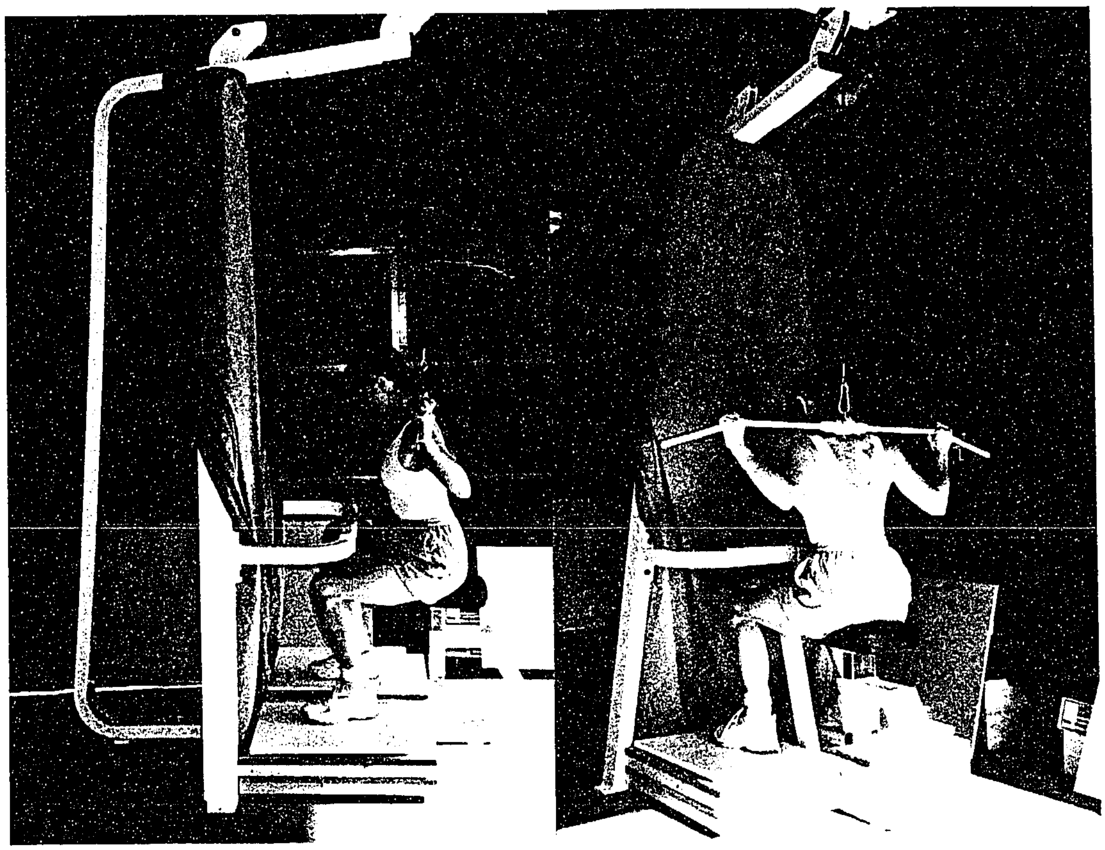


Figure 6. End position for 1-RM and muscular endurance testing.

A warm-up set was performed with a submaximal weight of 13.64 kg (30 lb) and designated repetitions of 8. A three minute rest period was placed between trials. The resistance was increased by .57 - 2.27 kg (1.25 - 5 lb) increments as determined by the difficulty of the previous lift. The 1-RM was recorded as the largest amount of weight pulled from full elbow extension overhead to the end point of elbow flexion with the bar touching the vertebral marker.

Muscular Endurance Standards

Muscular endurance testing is logically valid because the test is the ability directly measured (Thomas & Nelson, 1990). Anderson and Kearney (1982) conducted training and testing studies on relative muscular endurance with the bench press. Female masters swimmers were tested for muscular endurance of the shoulder and knee joints (Dummer et al., 1985).

Heyward (1991) utilized a relative weight load of 50% of body weight for muscular endurance testing in college-aged subjects. However, a reduced load of 45% was established to preserve age group comparisons especially with the potential for decreased performance from older subjects. The cadence ratio was established at a 2 to 4 count (finish to start position) equaling approximately 12 repetitions per minute. The warm-up set was 9.09 kg (20 lb) and was performed to the taped cadence for 10 to 12 repetitions. Appendix I provides detailed instructions for the subjects before and during the testing. Lat pulldown placement procedures followed those in the 1-RM testing. The testing was based on the coordination of extension and flexion movements in time with the established cadence. The repetitions were counted until the subject could no longer keep pace with the cadence, exhibited poor form and technique or chose to discontinue. Poor form and technique were deviations potentially injurious to the subject such as hyperextension/flexion of the neck and lower back or torquing of the vertebral column. Slight variation in form and technique easily corrected with a verbal cue or remark were considered acceptable. The breaking of the cadence was the criterion of muscular endurance indicating fatigue (Gettman, 1988).

Statistical Analysis

A one-way analysis of variance was used to determine if differences existed between the three age groups for relative muscular endurance performances. The level of significance was .05. Scheffé post hoc analysis was employed to determine which means were significantly different from one another. Significant differences would require separate multiple regression analyses to derive the appropriate prediction equation of strength. The predictor variables considered for regression were age, repetitions, muscular endurance weight load, weight, height, and body mass index.

The multiple correlation coefficient for the relative endurance equations was used to determine the best predictor of strength as well as the standard errors of estimates. The adjusted coefficient of multiple determination (Adjusted R^2) in conjunction with theoretical considerations for variable selection indicated goodness of prediction (Berry & Feldman, 1985; Lewis-Beck, 1980; Neter, Wasserman, & Kutner, 1989).

Summary

A sample of 73 female subjects were categorized into three age groups of early, middle and late adulthood. All participants read and signed a consent form and completed a health/training history questionnaire for screening purposes. Anthropometric indices were obtained at this time. The subjects completed all aspects of testing in one session. The first test consisted of a measurement for 1-RM followed by a relative muscular endurance measure. The lat pulldown strength test required a 1-RM as the criterion for strength and the endurance criterion was the breaking of the 2:4 cadence while repetitions were performed against a muscular endurance weight load equal to 45% of total body weight. The tests were performed on the Icarian lat pulldown machine using a standardized protocol of instruction and procedure. Proper positioning on the lat pulldown required alignment of shoulder and hips, hips and knees, hand placement on the bar, and bar alignment to the base of the neck.

The study consisted of the predictor variables of age, repetitions and muscular endurance weight load. The criterion variable was the 1-RM. A one-way analysis of variance was conducted to determine significant age group differences for relative muscular endurance. A post hoc test was conducted on age group muscular endurance performances to determine if significant main effects were found from the analysis of variance. Significant differences would require separate multiple regression analyses. The relative prediction equations were compared viewing the multiple correlation coefficient, adjusted coefficient of multiple determination and standard error of estimate.

CHAPTER 4

RESULTS and DISCUSSION

The purpose of this study was to determine the relationship of relative muscular endurance and muscular strength in predicting lat pulldown strength in women. The results and discussion of findings are addressed within this chapter.

Results

A total of 73 women participated in this study. The subjects were divided into early, middle and late adulthood groups as: Group 1 (20.7 - 30.2 years), Group 2 (40.3 - 50.0 years) and Group 3 (60.1 - 70.7 years). The means and standard deviations for various physical characteristics are summarized in Table 1. Height and weight values were greatest for Group 2. Muscular endurance and muscular strength of the midback were represented by repetitions to fatigue and 1-RM efforts, respectively. A general decline in muscular performance was observed with increasing age (see Table 2).

One-way analysis of variance ($\alpha = .05$) was employed to determine if significant differences for repetitions existed between the means of the three age groups. A significant difference was noted for repetitions, F (2, 70) = 3.13, $p < .001$ (see Table 3). A Scheffé post hoc analysis was performed to determine which age group differed significantly from the others in muscular endurance (see Table 4). Group 3 was found to differ significantly from the two younger groups. Group 1 and Group 2 were not significantly different from each other. The proportion of total variance in muscular endurance attributed to age was 39.7%. As a result of the post hoc findings, Group 1 and Group 2 were combined for regression statistics to predict 1-RM strength and Group 3 was analyzed separately. The number of predictor variables was conservatively maintained below a 10 to 1 ratio since the ratio between the number of subjects and variables has a direct relationship to the correlation (Thomas & Nelson, 1990). A subject-to-variable ratio of 16.7 to 1 for Group 1 and 2 and 11.5 to 1 for Group 3 was employed to avoid a spuriously high correlation. The multiple

Table 1

Means and Standard Deviations of Physical Characteristics by Age Group

Group	n		Physical Characteristics			
			Age (yr)	Weight (kg)	Height (cm)	BMI (kg/m²)
			Early Adulthood			
1	23	M	26.8	57.7	162.0	21.9
		SD	2.9	5.2	4.4	2.3
			Middle Adulthood			
2	27	M	45.2	64.2	164.8	23.6
		SD	3.1	12.4	8.2	4.3
			Late Adulthood			
3	23	M	64.0	63.4	162.3	24.0
		SD	3.3	8.8	5.0	3.0

BMI = Body Mass Index

Table 2

Means and Standard Deviations of Performance Characteristics by Age Group

Group		Repetitions	ME WT (kg)	1-RM (kg)	1-RM/BMI
		Early Adulthood			
1	M	10.7	25.9	35.8	1.63
	SD	3.8	2.5	4.8	0.17
		Middle Adulthood			
2	M	8.8	28.9	36.0	1.54
	SD	4.0	5.6	6.4	0.20
		Late Adulthood			
3	M	4.6	28.5	31.4	1.31
	SD	4.3	3.9	4.7	0.18

ME WT = Muscular Endurance Weight Load

1-RM = One Repetition Maximum

1-RM/BMI = One Repetition Maximum over Body Mass Index

Table 3

One-way Analysis of Variance for Repetitions by Age Group

Source of Variation	Sum of Squares	df	Mean Square	F	p
Between Groups	454.342	2	227.171	13.900**	< .001
Within Groups	1143.987	70	16.343		
Total	1598.329	72			

** $p < .01$

Practical Significance (ω^2) = 39.7%

Table 4

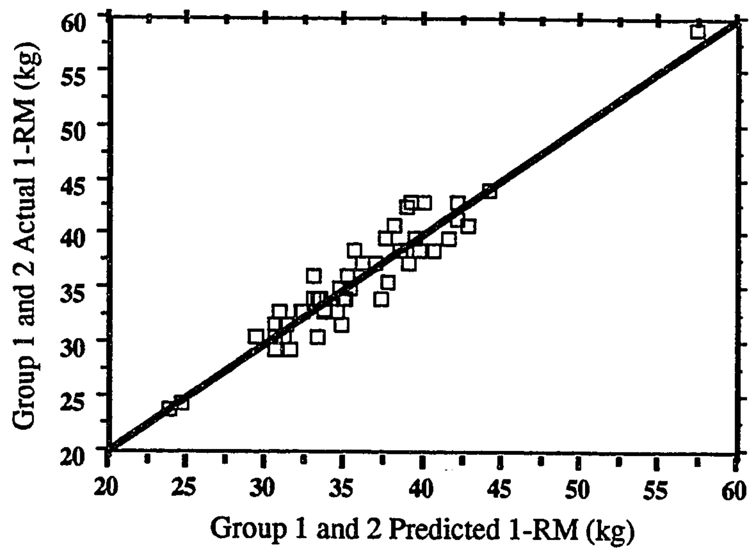
Scheffé Analysis for Repetitions by Age Group

Mean	Group	3	2	1
4.6087	3	--	--	--
8.8141	2	**	--	--
10.7391	1	**	--	--

** $p < .01$

regression equation for Group 1 and 2 employed three predictor variables consisting of repetitions, muscular endurance weight load and age (see Figure 7). Because the number of repetitions performed was dependent on the weight load employed both variables were used in the multiple regression equation. Additionally, since Group 1 and 2 were analyzed together, age was also incorporated. The standard error of the estimate was 1.85 kg. The prediction of muscular strength for Group 3 resulted in a multiple regression equation with repetitions and muscular endurance weight load as the two variables of choice at an accuracy of ± 2.05 kg (see Figure 8).

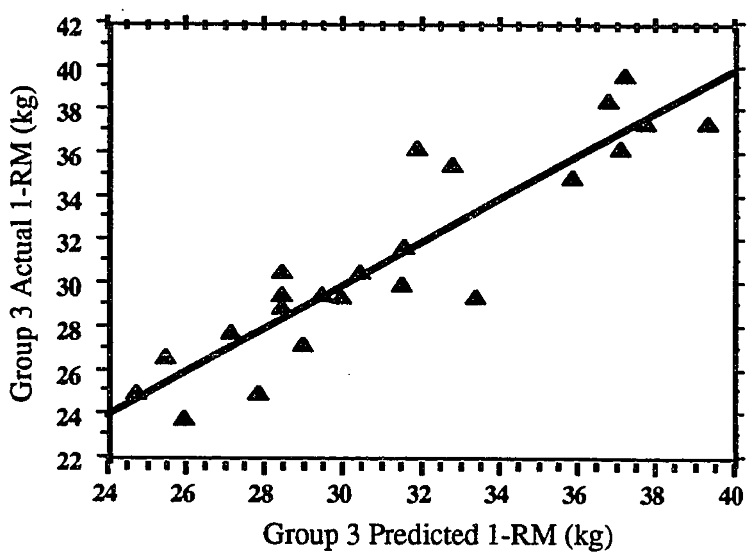
Residuals were analyzed for the appropriateness of the regression model. The residuals of the combined Group 1 and 2 as well as Group 3 were normally distributed. Linearity and homoscedasticity were observed for residuals against fitted values for the combined Group 1 and 2 and for Group 3 (Cohen & Cohen, 1983; Neter, Wasserman, & Kutner, 1989).



$$\hat{Y} = -2.417 + (-0.117 * \text{AGE}) + (0.820 * \text{REPS}) + (1.295 * \text{ME WT})$$

$R = .95$ $R^2 = .90$ Adjusted $R^2 = .89$ SEE = 1.85 kg

Figure 7. Relationship between predicted and actual strength of Group 1 and 2. Strength prediction equation of Group 1 and 2.



$$\hat{Y} = -3.730 + (0.870 * \text{REPS}) + (1.092 * \text{ME WT})$$

$R = .91$ $R^2 = .83$ Adjusted $R^2 = .81$ SEE = 2.05 kg

Figure 8. Relationship between predicted and actual strength of Group 3. Strength prediction equation of Group 3.

Discussion

The first null hypothesis of no age group differences in relative muscular endurance was statistically rejected ($p < .001$). Scheffé post hoc comparisons of the three age groups revealed Group 3 had the least ability to complete repetitions to fatigue. This finding follows the general age-related decline in musculoskeletal strength and endurance observed regardless of activity level (Clark, Hunt, & Dotson, 1992; Fiatarone et al., 1990b; Frontera et al., 1991; Grimby et al., 1982; Larsson, 1982; McDonagh et al., 1984).

The second null hypothesis was also statistically rejected ($p < .001$). A relationship existed between muscular endurance and muscular strength in predicting lat pulldown strength. For Group 1 and 2, the muscular endurance measures of repetitions and muscular endurance weight load resulted in a strong relationship to strength ($R = .93$, $R^2 = .86$, Adjusted $R^2 = .86$). This relationship was further enhanced by the inclusion of age ($R = .95$, $R^2 = .90$, Adjusted $R^2 = .89$; $p < .001$).

Muscular strength can be developed with any level of overload, but more so with intensive efforts closest to maximal (Sale, 1987). The use of a predetermined ME WT at 45% of total body weight represented intensities of 73% 1-RM and 80% 1-RM for Group 1 and 2, respectively (see Figure 9). Repetitions averaged 9.8 for Group 1 and 2 and fell within the range of repetitions commonly prescribed for resistance/strength training (American College of Sports Medicine, 1990). Therefore, the high R value is in part explained by this variable. Additionally, since muscular endurance performance is dependent upon the designated weight load, this was considered another important component. Age was included in the prediction equation since Group 1 and 2 were separated by a decade.

The second null hypothesis was also rejected for the oldest group, Group 3 ($p < .001$). The muscular endurance measures related strongly to strength ($r = .91$) with 81% of the variance explained by repetitions and muscular endurance weight load.

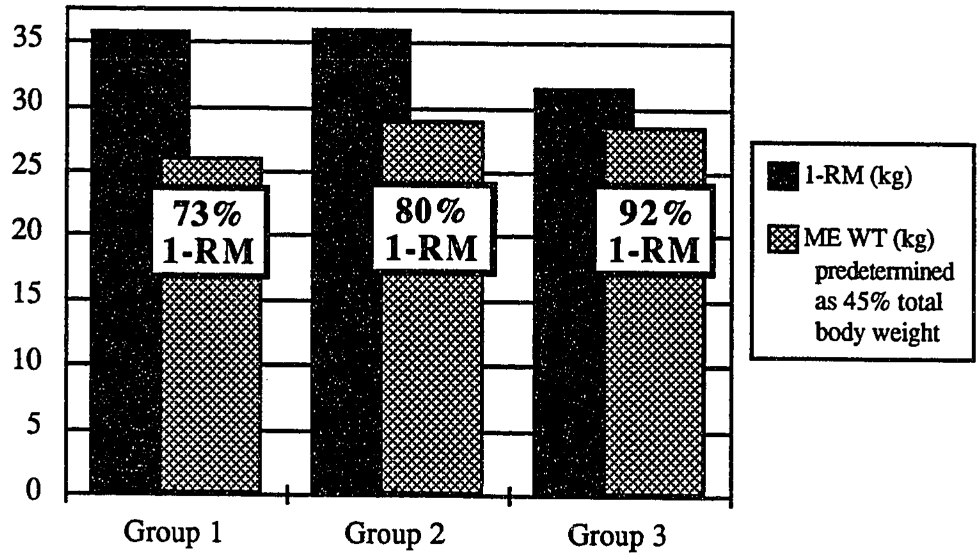


Figure 9. Muscular endurance weight load as % 1-RM by age group.

A floor effect was a potential problem for Group 3. Eight of the 23 subjects could not complete a single repetition during the muscular endurance test (see Table 5). Body composition differences appears to have contributed to this performance disparity. No significant height differences were observed between Group 3 subjects (nonperformers) unable to execute the muscular endurance test and those subjects successful in carrying out repetitions to fatigue (t (21) = .67, $p > .05$). The body weight (t (21) = 2.21, $p < .05$) and body mass index (t (21) = 2.08, $p < .05$) of Group 3 nonperformers were significantly greater than the performers of the muscular endurance test. Had the higher body weight and body mass index of Group 3 nonperformers been attributed to greater muscle mass the expectation would be to observe at least comparable and possibly enhanced test performance from Group 3 performers. However, the nonperformers responded with a reduction in 1-RM effort in comparison to performers and an inability to execute the muscular endurance test with the designated weight load (see Figure 10).

Greater body fat and a decline in muscle tissue within the nonperformer subgroup appears to be a major factor in this performance decrement as evidenced by significantly lower muscular strength relative to body mass index (t (21) = 4.48, $p < .001$). Although the corelation of body mass index ($r = .70$) to hydrostatic weighing is not as great as skinfolds ($r = .84$) it is commonly used in epidemiological investigations as an estimate of body fat and was employed within this study as a practical field test measure of body composition (ACSM, 1991; Revicki & Israel, 1986). When Heyward et al. (1986) examined lean mass, limb girths and skinfolds in describing strength characteristics of females, a large percentage of the variance was accounted for by these measures. Therefore, the contribution of body composition and anthropometric parameters to the expression of strength and muscular endurance are important considerations.

Table 5

Means and Standard Deviations of Group 3 Performer and Nonperformer Physical Characteristics

Group 3 Subgroups	n		Physical Characteristics		
			Weight (kg)	Height (cm)	BMI (kg/m^2)
Performers	15	M	57.7	162.0	21.9
		SD	5.2	4.4	2.3
Nonperformers	8	M	64.2	164.8	23.6
		SD	12.4	8.2	4.3

BMI = Body Mass Index

Table 6

Means and Standard Deviations of Group 3 Performer and Nonperformer Performance Characteristics

Group 3 Subgroups		Performance Characteristics			
		Repetitions	ME WT (kg)	1-RM	1-RM/BMI
Performers	M	0	27.2	32.5	1.4
	SD	--	4.3	4.7	.2
Nonperformers	M	7.1	30.8	29.2	1.1
	SD	3.2	4.3	4.1	.1

ME WT = Muscular Endurance Weight Load

1-RM = One Repetition Maximum

1-RM/BMI = One Repetition Maximum over Body Mass Index

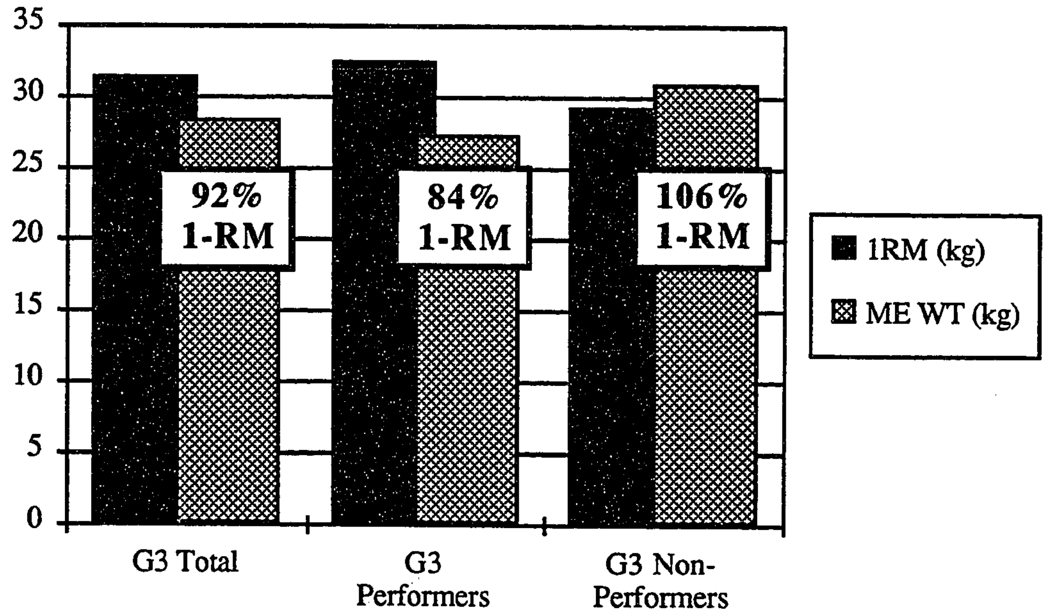


Figure 10. Group 3 weight load comparisons for muscular strength and muscular endurance performances.

Age disparity was another limiting factor considered within the nonperformer subgroup with a possible preponderance of subjects greater than 65.5 years of age. Age differences were not found between Group 3 performers (M = 63.6 yr, SD = 3.4 yr) and non performers (M = 64.9 yr, SD = 3.1 yr) (t (21) = -0.94, $p > .05$).

Additionally, psychological inhibitions can influence muscular strength and endurance performances (Brown & Harrison, 1986; Ikai & Steinhaus, 1961; Nelson, 1978). An older woman's motivation to fully exhibit her strength capabilities can be hindered by age-role expectations and perceived physical limitations (Berger & Hecht, 1989; Ostrow, Jones, & Spiker, 1981; Ostrow & Dzewaltowski, 1986; Prohaska, Leventhal, Leventhal, & Keller, 1985). Sports-related activities classified according to gender can create sex-role conflicts for female participants engaging in physical pursuits labeled masculine such as strength training (Metheny, 1965; Ostrow, Jones, & Spiker, 1981; Ostrow & Dzewaltowski, 1986). Therefore, despite strict adherence to protocol conducive to a genuine maximal effort, mental barriers may have contributed to the disparity between muscular endurance performers and nonperformers.

The nonperforming muscular endurance subgroup may also have incurred greater physical strength declines due in part to a higher degree of inactivity of the upper body. Table 7 depicts the level of physical activity of all three age groups for screening and descriptive purposes. The majority of subjects within each age group were involved in either cardiovascular exercise or leisure/sport pursuits. Subjects who denied participation in these areas or did not specify other physical activities were considered sedentary. Three of the eight nonperformers were identified as sedentary and as a result could have had reduced exposure to upper body movements necessary for the maintenance of muscular integrity in this region. The muscles of the midback fix the scapula and are involved in maintaining upright posture. Disuse of these muscles is highly likely as the nature of most daily activities is oriented in a forward flexed position. The resulting muscular atrophy can result in rounded shoulders and reduced shoulder joint flexibility thereby hampering efforts to achieve proper biomechanical alignment for upper body exercises and optimal performance (Israel, 1992 ; Janda, 1986).

Comparatively, the high predictive values for midback strength support findings of previous muscular strength studies of the chest and anterior thigh. However, the independent variables chosen for prediction purposes have varied from study to study (Ball & Rose, 1991; Braith et al., 1993; Dean, Foster, & Thompson, 1987; Invergo et al., 1991; Mayhew et al., 1992). The characteristics of body weight, weight load and repetitions to fatigue have been employed singularly in the past while this investigation has made use of weight load, repetitions and age in an integrated fashion (Ball & Rose, 1991; Braith et al., 1993; Dean, Foster, & Thompson, 1987; Invergo et al., 1991; Mayhew et al., 1992). Earlier studies consisted of college-aged men and women whereas this study utilized female subjects across three age groups.

Table 7

Participation in Physical Activity by Age Group

Type of Physical Activity	Group 1	Group 2	Group 3
LIA Dance Class	1	6	4
Aerobic Step Class	7	3	5
Swimming	3	1	1
Tennis	4	0	1
Running	3	1	2
Gymnastics	0	0	0
Walking	11	14	11
Sedentary	7	5	5

LIA = Low Impact Aerobic

CHAPTER 5

SUMMARY, CONCLUSIONS and RECOMMENDATIONS

Summary

The purpose of this study was to examine the relationship between muscular endurance and muscular strength for the prediction of midback muscular strength in three age groups of women. Seventy-three female subjects were divided into three age groups of early ($n = 23$), middle ($n = 27$) and late ($n = 23$) adulthood. Tests of muscular strength and endurance were performed on a constant resistance lat pulldown machine. The muscular endurance test required repetitions to fatigue in concert with a taped cadence to maintain proper form and technique. The designated muscular endurance weight load represented 45% of total body weight. Data analysis was completed with StatView and Excel software. One-way analysis of variance resulted in significant differences between age groups for repetitions ($p < .001$). Post hoc comparisons revealed the oldest group completed significantly less repetitions than both the early and middle adulthood subjects while no significant differences were noted between the early and middle adulthood groups. Therefore, multiple regression for muscular strength prediction was performed separately on the later adulthood group while the two younger groups were combined. For the early and middle adulthood groups, the best predictors of muscular strength were muscular endurance weight load, repetitions and age while muscular endurance weight load and repetitions were the chosen predictors for the oldest age group.

The late adulthood group was scrutinized for a possible floor effect since 8 subjects were not capable of any repetitions during the muscular endurance test. The muscular endurance weight load of the nonperforming subgroup represented 96 to 115% of their 1-RM efforts resulting in an inability to initiate and complete repetitions to fatigue. Several factors were considered contributory to this phenomenon. The body mass index of the nonperformers was significantly higher than for subjects able to complete the muscular endurance test ($p < .05$). Had this greater body mass index been attributed to a larger portion of muscle mass muscular strength and endurance performances would be expected to at least match or surpass the nonperformers. However, the muscular strength of nonperformers expressed relative to body mass index was significantly less than the performers ($p < .001$). Subsequently, this subgroup was not able to execute the muscular endurance test with the designated weight loads. Greater body fat and reduced fat free mass appears to have contributed to this disparity in performance. Another possible factor was age discrepancy, but nonperformers did not have a significantly larger proportion of subjects greater than 65.5 years ($p > .05$). Additionally, inhibitory factors related to upper body physical inactivity and psychosocial issues could have played a role in less than optimal values.

Conclusions

On the basis of the results yielded in this research, the following conclusions are offered:

1. The outcome of muscular endurance testing is dependent on and specific to the parameters used to define and conduct the test. The designated weight load and cadence for movement are critical features of consideration.

2. Assessment of strength using maximal efforts is not always safe or practical in the field setting. With the reduced risk of injury and the high predictive values for strength, this testing method offers a safe and accurate alternative for health and fitness professionals working with non-strength trained women. Exercise prescriptions can then be readily established with appropriate weight loads.

3. Muscular strength is thought to decline beginning in middle age and progressively thereafter. However, the comparable midback strength values of the young and middle aged subjects contradict this age-related decrement in performance.

4. A general strength decline did not typify the oldest subjects. The disparity in performance observed within this group was in part attributed to compositional changes in lean body mass and adiposity. Opportunity exists for preserving and enhancing musculoskeletal integrity as evidenced by the diversity of results.

Recommendations

The following recommendations are presented based on the findings of this study.

1. Predictive testing for strength requires strict adherence to protocol standards and control of external variables deleterious to optimal performance.

2. Many women have not fully utilized the strength of their upper body. Progressive weakness of midback musculature can contribute to a forward curvature of the spine, loss of postural stability and reduced bone integrity. Therefore, health and fitness professionals should include midback exercises when designing strength programs for women.

3. Further research is needed to determine causes for disparity in muscular strength and endurance performance of older adult women. Screening tools to assist in this task can include:

(a) A psychological survey to ascertain the effects of pre- and posttesting attitudes and feelings about muscular strength and endurance testing.

(b) A survey of daily life activities to control for upper body movements contributory to midback muscular strength and endurance.

4. The study prediction equations should be cross-validated with representative samplings of women to determine validity and generalizability to a greater population.

5. A similar study should be conducted comparing strength trained and non-strength trained subjects, aerobically sedentary and aerobically active groups or the age groups of 30, 50 and 70 year olds. In addition, research should be conducted to compare genders, compare performance of various muscular endurance weight load percentages, 30 - 45% of total body weight for older subjects, incorporate other anthropometric measures such as girths and skinfolds and utilize other major muscle groups of the body.

REFERENCE

Agre, J. C., Pierce, L. E., Raab, D. M., McAdams, M., & Smith, E. L. (1988). Light resistance and stretching exercise in elderly women: Effect upon strength. Archives of Physical Medicine and Rehabilitation, 69, 273-276.

American Academy of Pediatrics. (1983). Weight training and weight lifting: Information for the pediatrician. The Physician and Sportsmedicine, 11, 157-161.

American College of Sports Medicine. (1990). ACSM position stand: The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. Medicine and Science in Sports and Exercise, 22, 265-274.

Anderson, T., & Kearney, J. T. (1982). Effects of three resistance training programs on muscular strength and absolute and relative endurance. Research Quarterly, 53, 1-7.

Aniansson, A., & Gustafsson, E. (1981). Physical training in elderly men with special reference to quadriceps muscle strength and morphology. Clinical Physiology, 1, 87-98.

Aoyagi, Y., & Katsuta, S. (1990). Relationship between the starting age of training and physical fitness in old age. Canadian Journal of Sport Science, 15, 65-71.

Atha, J. (1981). Strengthening muscle. Exercise and Sports Sciences Reviews, 9, 1-73.

Ball, T. E., & Rose, K. S. (1991). A field test for predicting maximum bench press lift of college women. Journal of Applied Sports Science Research, 5, 169-170.

Beckett, M. B. (1983). The relationship between body size and strength in young women and men. Unpublished master's thesis, San Diego State University.

Berger, R. A. (1962). Optimum repetitions for the development of strength. Research Quarterly, 33, 334-338.

Berger, R. A. (1965). Comparison of the effect of various weight training loads on strength. Research Quarterly, 36, 141-146.

Berger, B. G., & Hecht, L. M. (1989). Exercise, aging, and psychological well-being: The mind-body question. In A.C. Ostrow (Ed.), Aging and Motor Behavior (pp.117-157). Indianapolis: Benchmark Press.

Berry, W. D., & Feldman, S. (1985). Multiple regression in practice. Sage University Paper series on Quantitative Applications in the Social Sciences, (50, Serial No. 7).

Brady, T. A., Cahill, B. R., & Bodnar, L. (1982). Weight training-related injuries in the high school athlete. The American Journal of Sports Medicine, 10, 1-5.

Braith, R. W., Graves, J. E., Leggett, S. H., & Pollock, M. L. (1993). Effect of training on the relationship between maximal and submaximal strength. Medicine and Science in Sports and Exercise, 25, 132-138.

Brown, A. B., McCartney, N., & Sale, D. G. (1990). Positive adaptations to weight-lifting training in the elderly. Journal of Applied Physiology, 69, 1725-1733.

Brown, C., & Wilmore, J. H. (1974). The effects of maximal resistance training on the strength and body composition of women athletes. Medicine and Science in Sports and Exercise, 6, 174-177.

Brown, E. W., & Kimball, R. G. (1983). Medical history associated with adolescent powerlifting. Pediatrics, 72, 636-644.

Brown, R. D., & Harrison, J. M. (1986). The effects of a strength training program on the strength and self-concept of two female age groups. Research Quarterly for Exercise and Sport, 57, 315-320.

Caldwell, L. S. (1963). Relative muscle loading and endurance. Journal of Engineering Psychology, 2, 155-161.

Charette, S. L., McEvoy, L., Pyka, G., Snow-Harter, C., Guido, D., Wiswell, R. A., & Marcus, R. (1991). Muscle hypertrophy response to resistance training in older women. Journal of Applied Physiology, 70, 1912-1916.

Clarke, D. H., Hunt, M.Q., & Dotson, C. O. (1992). Muscular strength and endurance as a function of age and activity level. Research Quarterly for Exercise and Sport, 63, 302-310.

Cress, M. E., Thomas, D. P., Johnson, J., Kasch, F. W., Cassens, R. G., Smith, E. L., & Agre, J. C. (1991). Effect of training on VO_{2max}, thigh strength, and muscle morphology in septuagenarian women. Medicine and Science in Sports and Exercise, 23, 752-758.

Cohen, J., & Cohen, P. (1983). Applied multiple regression/correlation analysis for the behavioral sciences (2nd ed.). Hillsdale, N.J.: Lawrence Erlbaum Associates.

Cureton, K. J., Collins, M. A., Hill, D. W., & McElhannon, F. M. (1988). Muscle hypertrophy in men and women. Medicine and Science in Sports and Exercise, 20, 338-344.

Dean, J. A., Foster, C., & Thompson, N. N. (1987). A simplified method of assessing muscular strength. Medicine and Science in Sports and Exercise, 19, S63.

DeLorme, T. L. (1945). Restoration of muscle power by heavy-resistance exercises. Journal of Bone and Joint Surgery, 27, 645-667.

DeLorme, T. L., & Watkins, A. L. (1951). Progressive resistance exercise: Technic and medical application. New York: Appleton-Century-Croft.

de Vries, H. A. (1986). Physiology of exercise: For physical education and athletics (4th ed.). Dubuque, IA: Wm. C. Brown.

Doyle, F., Brown, J., & LaChance, C. (1970). Relation between bone mass and muscle weight. Lancet, 1, 391-393.

Dummer, G. M., Clarke, D. H., Vaccaro, P., Vander Velder, L., Goldfarb, A. H., & Sockler, J. M. (1985). Age-related differences in muscular strength and muscular endurance among female masters swimmers. Research Quarterly for Exercise and Sport, 56, 97-110.

Fiatarone, M. A., Marks, E. C., Ryan, N. D., Meredith, C. N., Lipsitz, L. A., & Evans, W. J. (1990a). High-intensity strength training in nonagenarians: Effect on skeletal muscle. Journal of the American Medical Association, 263, 3029-3034.

Fiatarone, M. A., & Evans, W. J. (1990b). Exercise in the oldest old. Topics in Geriatric Rehabilitation, 5, 63-77.

Fleck, S. J., & Kraemer, W. J. (1987). Designing resistance training programs. Champain, IL: Human Kinetics Books.

Fox, E. L., Bowers, R. W., & Foss, M. L. (1989). Development of muscular strength, endurance, and flexibility. The Physiological Basis of Physical Education and Athletics (4th ed.). Dubuque, IA: Wm C. Brown.

Frontera, W. R., Meredith, C. N., O'Reilly, K. P., Knuttger, H. G., & Evans, W. J. (1988). Strength conditioning in older men: Skeletal muscle hypertrophy and improved function. Journal of Applied Physiology, 64, 1038-1044.

Frontera, W. R., Hughes, V. A., Lutz, K. J., & Evans, W. J. (1991). A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women. Journal of Applied Physiology, 71, 644-650.

Gettman, L. R. (1988). Fitness testing. In S. Blair, P. Painter, R. Pate, L. Smith, & C. Taylor (Eds.), Resource manual for guidelines for exercise testing and prescription (pp. 161-170). Philadelphia: Lea & Febiger.

Golding, L. A., Myers, C. R., & Sinning, W. E. (Eds.). (1989). Y's way to physical fitness: The complete guide to fitness testing and instruction (3rd ed.). Champaign, IL: Human Kinetics.

Grimby, G., & Saltin, B. (1983). The ageing muscle. Clinical Physiology, 3, 209-218.

Grimby, G., Danneskiold-Samsøe, B., Hvid, K., & Saltin, B. (1982). Morphology and enzymatic capacity in arm and leg muscles in 78-81 year old men and women. Acta Physiologica Scandinavica, 115, 125-134.

Gumbs, V. L., Segal, D., Halligan, J. B., & Lower, G. (1982). Bilateral distal radius and ulnar fractures in adolescent weight lifters. The American Journal of Sports Medicine, 10, 375-379.

Häkkinen, K., & Häkkinen, A. (1991). Muscle cross-sectional area, force production and relaxation characteristics in women at different ages. European Journal of Applied Physiology, 62, 410-414.

Häkkinen, K., & Keskinen, K. L. (1989). Muscle cross-sectional area and voluntary force production characteristics in elite strength- and endurance-trained athletes and sprinters. European Journal of Applied Physiology, 59, 215-220.

Hart, C. L., Ward, T. E., Mayhew, J. L., & Ball, T. E. (1990). Pushups as a measure of upper body strength in males. Journal of Human Movement Studies, 18, 287-294.

Heyward, V., & McCreary, L. (1978). Comparison of relative endurance and critical occluding tension levels of men and women. Research Quarterly, 49, 301-307.

Heyward, V. (1991). Assessing muscular strength and endurance. Advanced fitness assessment and exercise prescription (pp. 99-118, 2nd ed.). Champaign, Illinois: Human Kinetics.

Heyward, V. H. (1975). Influence of static strength and intramuscular occlusion on sub maximal static muscle endurance. Research Quarterly, 46, 393-402.

Heyward, V. H., Johannes-Ellis, S. M., & Romer, J. F. (1986). Gender differences in strength. Research Quarterly for Exercise and Sport, 57, 154-159.

Hoffman, T., Stauffer, R. W., & Jackson, A. S. (1979). Sex difference in strength. American Journal of Sports Medicine, 7, 265-267.

Holloway, J. B., & Baechle, T. R. (1990). Strength training for female athletes: A re view of selected aspects. Sports Medicine, 9, 216-218.

Ikai, M., & Steinhaus, A. H. (1961). Some factors modifying the expression of human strength. Journal of Applied Physiology, 16, 157-163.

Ikai, M., & Fukunaga, T. (1968). Calculation of muscle strength per unit cross-sectional area of human muscle by means of ultrasonic measurement. International Zeitschrift fur angewandte Physiologie einschliescclich Arbeitsphysiologie, 26, 26-32.

Invergo, J. J., Ball, T. E., & Looney, M. (1991). Relationship of pushups and absolute muscular endurance to bench press strength. Journal of Applied Sport Science Research, 5, 121-125.

Israel, S. (1992). Age-related changes in strength and special groups. In P. V. Komi (Ed.), Strength and power in sport (pp. 319-328). Oxford, England: Blackwell Scientific Publications.

Jackson, A., Watkins, M., & Patton, R. W. (1980). A factor analysis of twelve selected maximal isotonic strength performances on the Universal Gym. Medicine and Science in Sports and Exercise, 12, 274-277.

Janda, V. (1986). Muscle function testing. London: Butterworths.

Jette, A.M., & Branch, L.G. (1981). The framingham disability study: II. physical disability among the aging. American Journal of Public Health, 71, 1211-1216.

Kraemer, W.J., & Fleck, S.J. (1988). Resistance training: Exercise prescription (part 4 of 4). The Physician and Sportsmedicine, 16, 69-81.

Kreighbaum, E., & Barthels, K.M. (1990a). Neuromuscular aspects of movement. Biomechanics: A qualitative approach for studying human movement (pp. 63-92, 3rd ed.). New York: Macmillan.

Kreighbaum, E., & Barthels, K.M. (1990b). Biomechanical relationships in the upper extremity. Biomechanics: A qualitative approach for studying human movement (pp. 187-209, 3rd ed.). New York: Macmillan.

Larsson, L. (1982). Physical training effects on muscle morphology in sedentary males at different ages. Medicine and Science in Sports and Exercise, 14, 203-206.

Laubach, L.L. (1976). Comparative muscular strength of men and women: A review of the literature. Aviation, Space, and Environmental Medicine, 47, 534-542.

Lewis-Beck, M.S. (1980). Applied regression: An introduction. Sage University Paper series on Quantitative Applications in the Social Sciences, (22, Serial No. 7).

Lohman, T.G., Roche, A.F., & Martorell, R. (1991). Anthropometric standardization reference manual (abridged ed.). Champaign, Illinois: Human Kinetics

Matheson, G.O., MacIntyre, J.G., Taunton, J.E., Clement, D.B., & Lloyd-Smith, R. (1989). Musculoskeletal Injuries associated with physical activity in older adults. Medicine and Science in Sports and Exercise, 21, 379-385.

Mayhew, J., & Gross, P. (1974). Body composition changes in young women with high resistance weight training. Research Quarterly for Exercise and Sport, 45, 433-440.

Mayhew, J.L., Ball, T.E., Arnold, M.D., & Bowen, J.C. (1992). Relative muscular endurance performance as a predictor of bench press strength in college men and women. Journal of Applied Sport Science Research, 6, 200-206.

McArdle, W.D., Katch, F.I., & Katch, V.I. (1991). Exercise physiology: Energy, nutrition, and human performance (3rd ed.). Philadelphia: Lea & Febiger.

McDonagh, M.J.N., White, M.J., & Davies, C.T.M. (1984). Different effects of ageing on the mechanical properties of human arm and leg muscles. Gerontology, 30, 49-54.

Metheny, E. (1965). Connotations of movement in sport and dance. Dubuque, IA: W. C. Brown.

Moritani, T., & de Vries, H.A. (1979). Neural factors versus hypertrophy in the time course of muscle strength gain. American Journal of Physical Medicine, 58, 115-130.

Moritani, T., & de Vries, H. (1980). Potential for gross muscle hypertrophy in older men. Journal of Gerontology, 35, 672-682.

Morrow, J. R., & Hosler, W. W. (1981). Strength comparisons in untrained men and trained women athletes. Medicine and Science in Sports and Exercise, 13, 194-198.

National Strength and Conditioning Association. (1985). Position paper on prepubescent strength training. National Strength and Conditioning Association Journal, 7, 27-31.

National Strength and Conditioning Association. (1989). Position paper on strength training for female athletes. National Strength and Conditioning Association Journal, 11 (4), 43-55; 11 (5), 29-36.

Niederlander, G., & Cibrario, M. (1992). Biomechanics of weight training. Buffalo Grove, IL: SPRI Products.

Nelson, J. K. (1978). Motivating effects of the use of norms and goals with endurance testing. Research Quarterly, 49, 317-321.

Neter, J., Wasserman, W., & Kutner, M. H. (1989). Applied linear regression models (2nd ed.). Homewood, IL: Irwin.

Neviaser, T. J. Weight lifting: Risks and injuries to the shoulder. Clinics in Sports Medicine, 10, 615-621.

Nichols, J. F., Omizo, D. K., Peterson, K. K., & Nelson, K. P. (1993). Efficacy of heavy-resistance training for active women over sixty: Muscular strength, body composition, and program adherence. Journal of the American Geriatric Society, 41, 205-210.

O'Shea, J., & Wegner, J. (1981). Power weight training and the female athlete. The Physician and Sportsmedicine, 9, 109-120.

Ostrow, A., Jones, D., & Spiker, D. (1981). Age role expectations and sex role expectations for selected sport activities. Research Quarterly for Exercise and Sport, 52, 216-227.

Ostrow, A., & Dzewaltowski, D. (1986). Older adults' perceptions of physical activity participation based on age-role and sex-role appropriateness. Research Quarterly for Exercise and Sport, 57, 167-169.

Payne, V. G., & Isaacs, L. D. (1991). Human motor development: A lifespan approach (2nd ed.). Mountain View, CA: Mayfield Publishing.

Pollock, M. L., Carroll, J. F., Graves, J. E., Leggett, S. H., Braith, R. W., Limacher, M., & Hagberg, J. M. (1991). Injuries and adherence to walk/jog and resistance training programs in the elderly. Medicine and Science in Sports and Exercise, 23, 1194-1200.

Prohaska, T. R., Leventhal, E. A., Leventhal, H., & Keller, M. L. (1985). Health practices and illness cognition in young, middle aged, and elderly adults. Journal of Gerontology, 40, 569-578.

Reut, R. C., Bach, B. R., & Johnson, C. (1991). Pectoralis major rupture: Diagnosing and treating a weight-training injury. The Physician and Sportsmedicine, 19, 89-96.

Revicki, D. A., & Israel, R. G. (1986). Relationship between body mass indices and measures of body adiposity. American Journal of Public Health, 76, 992-994.

Risser, W. L., Risser, J. M. H., & Preston, D. (1990). Weight-training injuries in adolescents. American Journal of Diseases in Children, 144, 1015-1017.

Risser, W. L. (1991). Weight-training injuries in children and adolescents. American Family Physician, 44, 2104-2108.

Sale, D. G. (1987). Influence of exercise and training on motor unit activation. In K.B. Pandolf (Ed.), Exercise and Sport Sciences Review (pp. 95-152). New York: MacMillan Publishing Co.

Schantz, P., Randall-Fox, E., Hutchison, W., Tyden, A., & Astrand, P. O. (1983). Muscle fibre type distribution, muscle cross-sectional area and maximal voluntary strength in humans. Acta Physiologica Scandinavica, 117, 219-226.

Sienna, P. A. (1989). Definitions. One rep max: A guide to beginning weight training (pp. 13-18). Dubuque, IA: Brown & Benchmark.

Sinaki, M., & Mikkelsen, B. A. (1984). Postmenopausal spinal osteoporosis: Flexion versus extension exercises. Archives of Physical Medicine and Rehabilitation, 65, 593-596.

Sinaki, M., & Offord, K. P. (1988). Physical activity in postmenopausal women: Effect on back muscle strength and bone mineral density of the spine. Archives of Physical Medicine and Rehabilitation, 69, 277-280.

Staron, R. S., Malicky, E. S., Leonardi, M. J., Falkel, J. E., Hagerman, F. C., & Dudley, G. A. (1989). Muscle hypertrophy and fast fiber type conversions in heavy resistance-trained women. European Journal of Applied Physiology, 60, 71-79.

Staron, R. S., Leonard, M. J., Karapondo, D. L., Malicky, E. S., Falkel, J. E., Hagerman, F. C., & Hikida, R. S. (1991). Strength and skeletal muscle adaptations in heavy-resistance-trained women after detraining and retraining. Journal of Applied Physiology, 70, 631-640.

Start, K. B., & Graham, J. S. (1964). Relationship between the relative and absolute isometric endurance of an isolated muscle group. Research Quarterly, 35, 193-204.

Stone, M., & O'Bryant, H. (1987). Weight training: A scientific approach. Edina, MN: Burgess International.

Thomas, J. R. & Nelson, J. K. (1990). Research methods in physical activity (2nd ed.). Champaign, IL: Human Kinetics.

Thompson, C. (1989). Manual of structural kinesiology (11th ed.). St. Louis: Times Mirror/Mosby.

Tinetti, M. E., Speechley, M., & Ginter, S. F. (1988). Risk factors for falls among elderly persons living in the community. New England Journal of Medicine, 319, 1701-1707.

Tuttle, W. W., Janney, C. D., & Salzano, J. V. (1955). Relation of maximum back and strength to back and leg strength endurance. Research Quarterly, 26, 96-106.

Wells, C. L., & Plowman, S. A. (1983). Sexual differences in athletic performance: Biological or behavioral? The Physician and Sportsmedicine, 11, 52-63.

Whipple, R. H., Wolfson, L. I., & Amerman, P. M. (1987). The relationship of knee and ankle weakness to falls in nursing home residents: An isokinetic study. Journal of the American Geriatric Society, 35, 13-20.

Wilmore, J. H. (1974). Alterations in strength, body composition, and anthropometric measurements consequent to a 10-week weight training program. Medicine and Science in Sports and Exercise, 6, 133-138.

Wilmore, J. H., Parr, R. B., Girandola, R. N., Ward, P., Vodak, P. A., Barstow, T. J., Pipes, T. V., Romero, G. T., & Leslie, P. (1978). Physiological alterations consequent to circuit weight training. Medicine and Science in Sports and Exercise, 10, 79-84.

APPENDIX A

Subject Advertisement

SUBJECTS NEEDED!

Midback Strength Study. Women in the age groups of 20-30, 40-50, 60-70 years are needed for a research study to assess the strength and endurance of the midback. Participants will be asked to perform two tests in one visit. Basic eligibility includes:

> No participation in strength/resistance training within the last 6 months and with less than two years experience.
>
> No orthopedic limitations to the neck, back, shoulder.
>
> No musculoskeletal limitations to the neck, back, shoulder.
>
> No cardiovascular or cerebrovascular disease.

Subjects will be given feedback on their muscular strength/endurance and provided individualized exercise guidance to meet their needs and goals. Please contact Anna Kuramoto, (408) 723-3826 for further details.

APPENDIX B

Informed Consent Form

You are invited to participate in a study investigating the relationship of muscular endurance and muscular strength in predicting strength of the muscles of the midback. This study will involve three age groups of women. We hope to learn more about the benefits of using muscular endurance in estimating muscular strength within and between age groups. The purpose of the study is to determine the feasibility of using a muscular endurance field test to establish strength training weight loads for women. The results obtained from this study may contribute to the design of physical fitness programs and muscular strength testing procedures.

If you decide to participate, testing will be conducted in one session. You will be asked to complete a brief medical questionnaire and several preliminary measurements consisting of height and weight. It is important that you do not participate in any new or unusual physical activity forty-eight hours before the test session.

Prior to testing you will be introduced to the issue of muscular strength and its important role in human performance. At the end of the introduction the muscular strength procedure will be demonstrated on the lat pulldown and you will be asked to perform this test. A strict protocol will be adhered to, to guard against musculoskeletal discomfort or injury. If, for any reason you feel or notice pain, you may stop the movement. The risks to you are reasonable in relation to anticipated benefits and the importance of the knowledge that may reasonably be expected to result.

After a rest period of 15 minutes the muscular endurance measure will be demonstrated and you will be asked to perform the test.

Your participation in this study should take approximately sixty minutes.

Subject's Initials:_________

If you have any doubts or questions about the procedure, you may ask for further explanation. Any question about your participation in this study will be answered by the researcher, Anna Kuramoto, at (408) 723-3826, or Dr. Greg Payne at (408) 924-3028, Department of Human Performance San Jose State University.

If you have any complaints about the procedure you may present them to Jim Bryant, Department Chair of Human Performance at (408) 924-3010. For questions about research subjects' rights, contact Serena Stanford (Associate Academic Vice President for Graduate Studies and Research) at (408) 924-2480.

Your participation in this study is completely voluntary. You may refuse to participate in this study and may withdraw at any time without prejudice to your relations with San Jose State University. You are free to decline to answer any specific question on the medical questionnaire. The data generated may be used for scientific purposes including publication and presentation at professional meetings. Your name will not be revealed. I appreciate your cooperation and participation very much.

I have read this form and I understand the test procedures that I will perform. I consent to participate in this project and I understand that I can withdraw any time. I have received a copy of this consent form for my files.

Signature:______________________________ Date:________________

Print Name:______________________________

Investigator's Signature:____________________ Date:________________

APPENDIX C

Medical/Training History Questionnaire

Please complete the following health history to the best of your ability. Contact your health care provider as necessary to ensure this record is as accurate and complete as possible. This information will be used in determining your eligibility to participate in this research study. All information will be kept confidential.

Name________________________________ Age_________ Date____________

Birthdate________________ Height_____________ Weight______________

Home Phone_________________ Work Phone_________________

Mailing Address____

Personal Physician (local)____

Address____

____

Phone____________________________

Person To Contact In Case Of An Emergency___________________________

Address____

____

Relationship To You____

Home Phone_________________ Work Phone_________________

DO NOT WRITE BELOW THIS LINE

Subject Code #_______________

Medical/Training History Questionnaire

Check X if Yes

1) Do you often suffer from neck pain? ( )

2) Do you often suffer from shoulder pain? ( )

3) Do you often suffer from back pain? ( )

4) Have you had acute back or neck or shoulder pain in the last two months? ( )

5) Has your doctor ever told you that you have a bone or joint problem such as arthritis, osteoporosis that might be aggravated with exercise? ( )

6) Do you currently take medications (over-the-counter or prescription)? ( )

If yes please list____

7) Has your doctor ever told you that you have high blood pressure? ( )

8) Has your doctor ever told you that you have a heart condition? ( )

9) Have you had any recent surgery? ( )

If yes please list____

10) Do you have any medical conditions or illnesses? ( )

If yes please list____

11) Do you currently practice any of the following physical activities on a regular basis (2 or more times/week)?

Aerobic Dance Classes

- High Impact ( )
- Low Impact ( )
- Step ( )

Body Sculpting Classes ( )

Swimming ( )

Tennis ( )

Running ( )

Medical/Training History Questionnaire

Gymnastics ( )

Walking ( )

Strength Training ( )

Other____

If yes please list requested information for each activity

How many times per week?______________________

How much time (minutes) is spent per session?________________

For cardiovascular exercise, how is the intensity gauged and what is the range or level?

Target Heart Rate__________ Perceived Exertion__________

Pace__________ Other__________ Not done______

For strength training,

Type of equipment used________________________________

Resistance (weight load) used

Light_____ Moderate_____ Heavy_____

Average sets/reps_____ Average time (minutes) per session_____

How many months or years did you train? (Please give approximate dates if known)____________________

If you have stopped strength training when was your last workout?

____

12) If taking an aerobic dance class is there a calisthenic or body sculpting section to the class? ( )

13) Do you have any experience in strength training? ( )

If yes please list last time participated______________________________

If yes please list amount of experience in months or years__________________

APPENDIX D

Anthropometric Techniques

Height

1) The subject was measured in barefeet or thin socks, shorts, and t-shirt.
2) The beam scale was placed on a hard and flat flooring.
3) The anthropometer on the beam scale was positioned with the movable rod at a right angle to the vertical graduated rod.
4) The subject distributed body weight evenly on both feet while the head is placed in the Frankfort Horizontal Plane.
5) The Frankfort Horizontal Plane places the left orbital margin into horizontal alignment of the left tragion which is the depression found superior to the tragus of the ear.
6) The arms remained to the sides of the torso with palms pointing towards the upper legs.
7) Height was recorded to the nearest 0.25 cm with the subject maintaining full inspiration.

Weight

1) The subject was measured in barefeet or thin socks, shorts, and t-shirt.
2) Measurements were taken on a hard and flat flooring using a beam scale.
3) The subject stood atop the center of the platform with weight evenly distributed between both feet.
4) Weight was recorded to the nearest 0.1 kg.

APPENDIX E

Slideshow Script

SLIDE 1

Muscular Endurance in Women Through Adulthood: A Predictor of Muscular Strength? You will now be briefed on the study you are about to participate in. Please proceed to the next slide when you hear ... So change the slide.

SLIDE 2

The focus of the study is on the muscular strength and endurance of the midback. But first let's answer the "Big" question, Does Anyone Know What the Midback is?

SLIDE 3

The midback is composed of several muscles. First, the lower portion of your trapezius, called IV and your pectoralis minor help to lower the shoulders down. Another role of the midback is to bring the shoulderblades together which includes your rhomboids and trapezius III. And finally, the midback muscles consisting of your latissimus dorsi, teres major, and large chest muscle pectoralis major help to pull the arms down and back. Still you may say, "So What?!".

SLIDE 4

Well, there are several important functions of the midback. First, the midback is used in many daily tasks such as bringing down items from a shelf, pulling a door open, as well as physical labor chores requiring pulling the body up or pulling objects towards you. Firemen, police officers, pilots, and those in the medical profession and armed services require this ability.

SLIDE 5

Second, a variety of sports depend on strong midback muscles. Examples include rope or rock climbing, swimming, gymnastics, martial arts, as well as other sports which use the arms in a pulling down or pulling back motion.

SLIDE 6

Third, good upper body posture relies on the midback to keep you in an upright position. Remember when mom told you not to slouch? She's telling you to stop promoting that round hunched over Quasi Modo look. Strengthening these muscles is important in avoiding upper neck and back problems as well as reinforcing bone strength in the area.

SLIDE 7

The value of upper back strength is obvious, but what's the connection to this study? Again, this investigation will focus on the use of a muscular endurance test for predicting strength of the midback. Let's review the reasons for conducting this study.

SLIDE 8

First, the American College of Sports Medicine, an organization well-known for providing us with the major guidelines for adult exercise has recently included strength training for the first time. They are saying maintaining one's bone, muscle mass and strength is an important part of health and fitness.

SLIDE 9

Just as with cardiovascular exercise where a training zone is considered a method of improving one's cardiovascular fitness. Strength training also requires a training zone. By using a percentage of your maximal effort against a weight load you are better able to alter body composition in favor of muscular improvements.

SLIDE 10

Focusing on women specifically, both the natural aging process and inactivity can bring on declines in muscle mass, strength, and mobility. It is fairly common knowledge that the average woman has a weak upper body compared to a man. When this is coupled with the natural aging declines in lower body strength an older woman is very susceptible to falls, fractures, and an inability to carry on with daily chores and tasks requiring strength.

SLIDE 11

Elderly strength training studies using 70 to 90 year olds have proven the importance of choosing the optimal training or intensity zone. By using a weight load at 80% of their maximal effort they made significant improvements in strength and gained a great deal of muscle that had been withered away by inactivity.

SLIDE 12

Maximal effort is synonymous with one repetition maximum and muscular strength. But determining one's maximal effort requires expert guidance and supervision and may not be feasible or appropriate for the beginner, elderly or those with special medical conditions.

SLIDE 13

Recent field tests using muscular endurance for predicting upper and lower body strength have been quite promising and can offer an alternative when one repetition maximums are not obtainable.

Shown is a fictitious example of a prediction equation to give you a better idea of how this works. The total number of repetitions performed during the muscular endurance test is placed into the equation along with other variables such as age. The end product is the 1-RM or the amount of weight lifted on one maximal effort. This can now be used to base the percentage weight load for training.

SLIDE 14

Therefore, the purpose of this study is to use a muscular endurance field test to predict muscular strength of the midback.

SLIDE 15

The study will be conducted on 3 age groups of women. The reason for the breaks between groups, which removes women in their thirties and fifties is to create clear and distinct groups of early, middle, and late adulthood.

SLIDE 16

You will first perform a one repetition maximum. The one repetition maximum simply means you will give your maximal effort with the greatest weight load. You will bring the lat pulldown bar down for one repetition. More detailed instructions will be shown and given to you during the actual testing. Now you may ask, "Hey! Why am I doing a 1-RM? You're supposed to be predicting it." This measurement is necessary under study conditions to compare how closely the predicted value matches the real one repetition maximum.

SLIDE 17

Muscular endurance is the ability of a muscle or groups of muscles to contract over a period of time until they fatigue. Well-known muscular endurance tests include the timed sit-ups and push-ups. For the lat pulldown, a predetermined weight load will be used. You will lower and raise the bar to a set taped cadence until you either break the rhythm or can no longer continue. The number of repetitions will be counted and used in the prediction equation for strength.

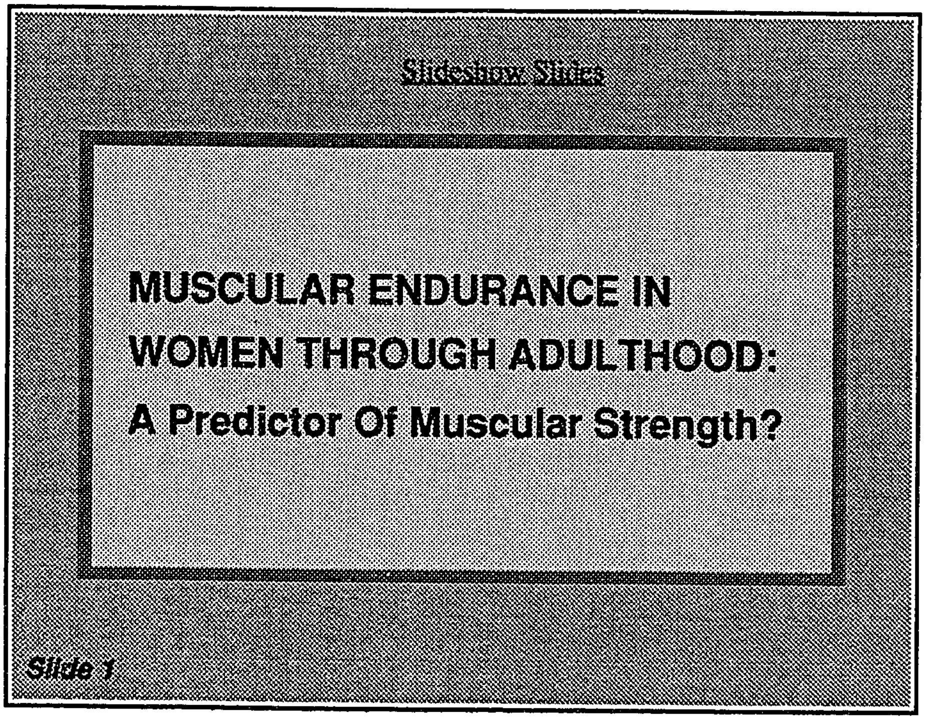
SLIDE 18

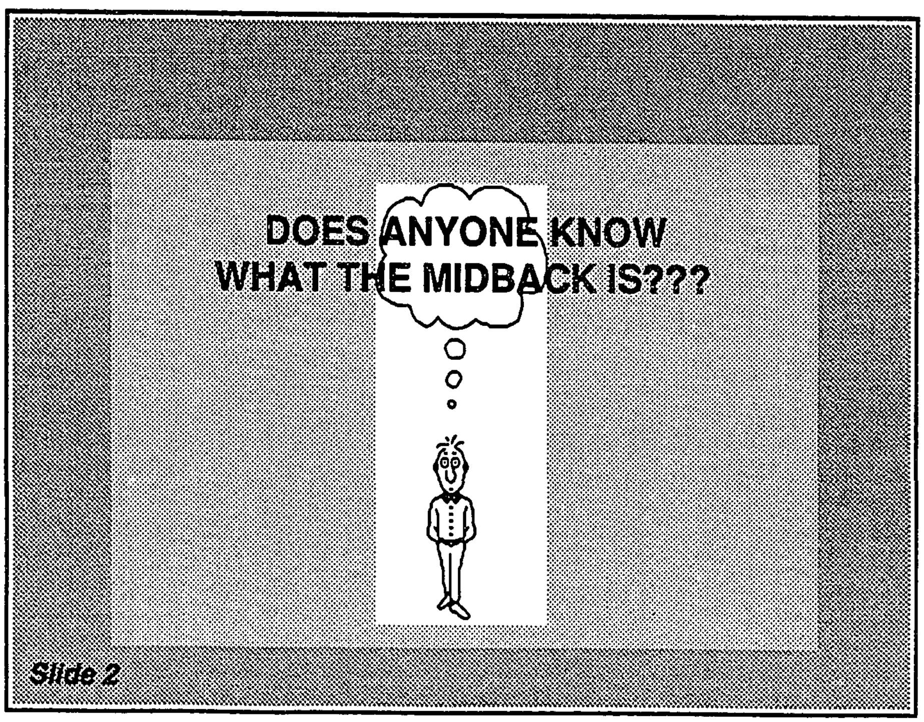
As a special thank you, you will be given a personalized exercise program in the area of strength and flexibility appropriate to your strength results.

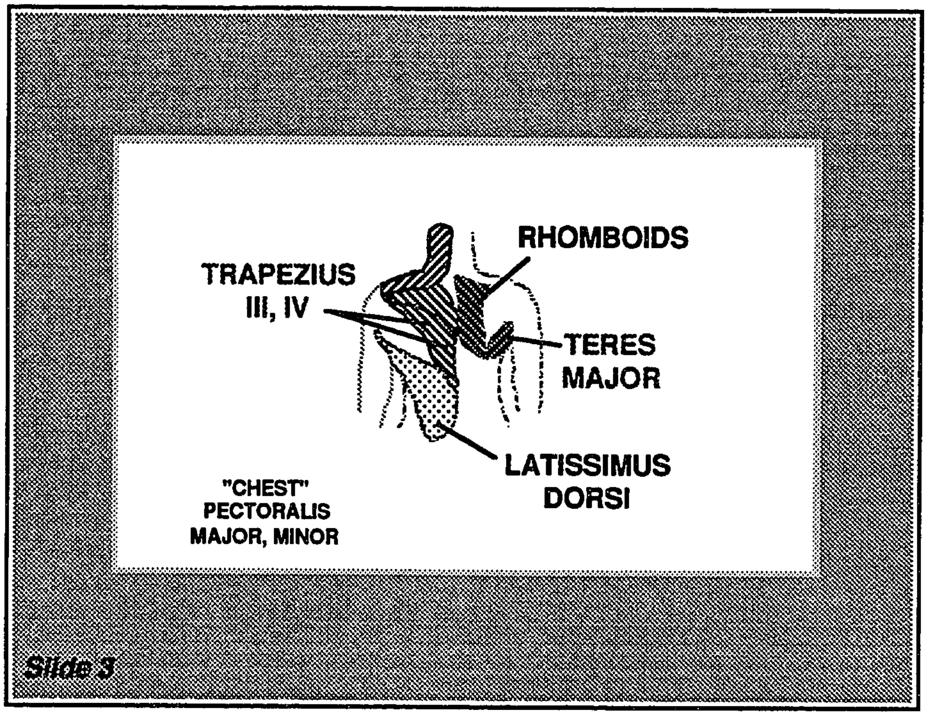
SLIDE 19

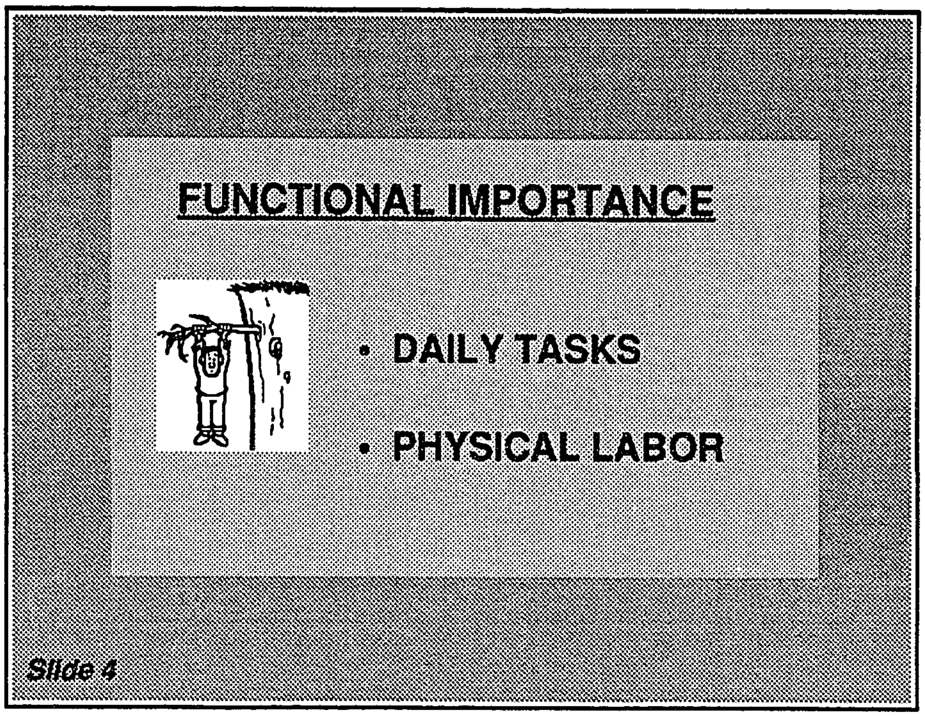
So, let's begin!

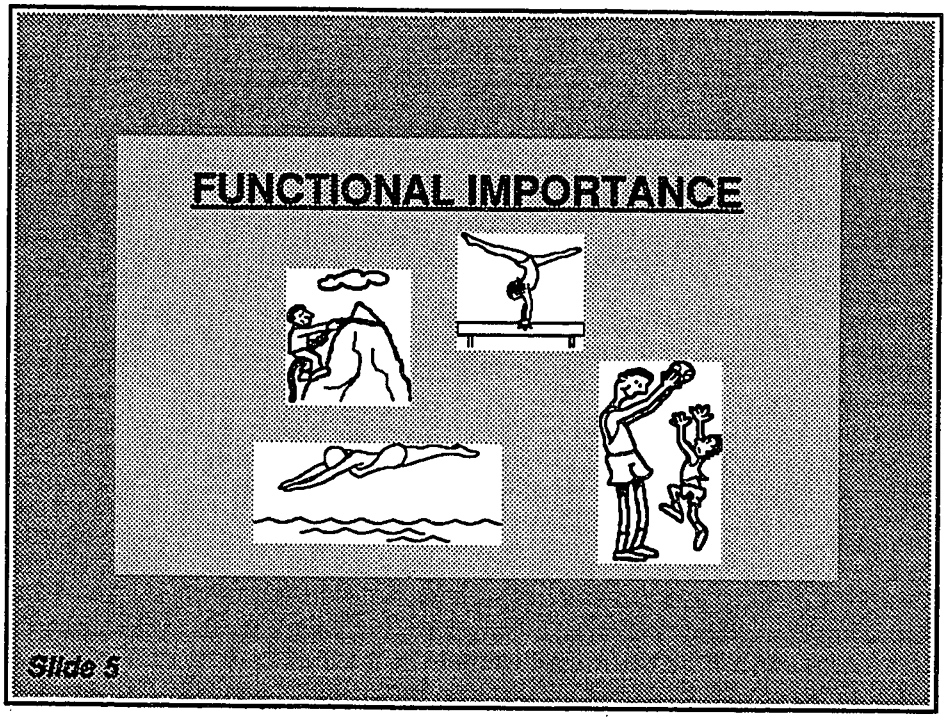
Appendix F

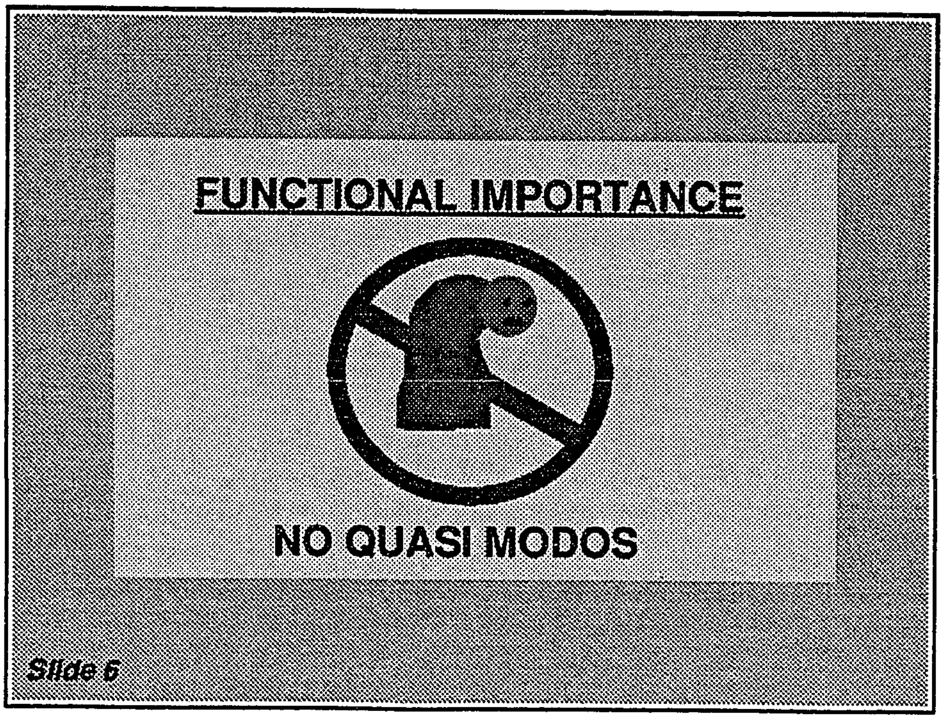

Slideshow Slides
MUSCULAR ENDURANCE IN
WOMEN THROUGH ADULTHOOD:
A Predictor Of Muscular Strength?
Slide 1

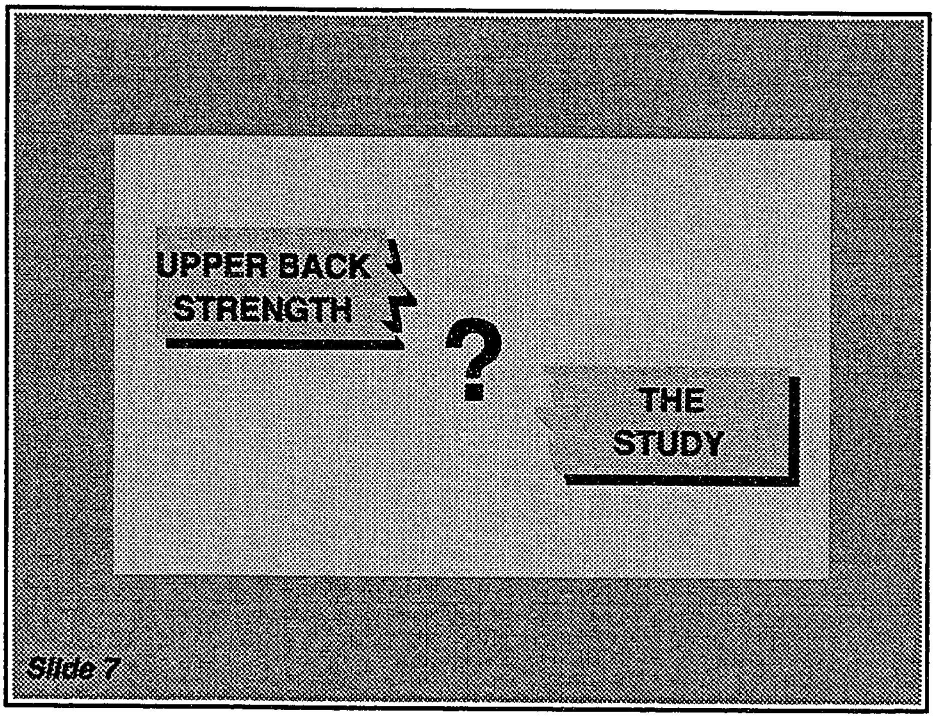

DOES ANYONE KNOW
WHAT THE MIDBACK IS???
Slide 2

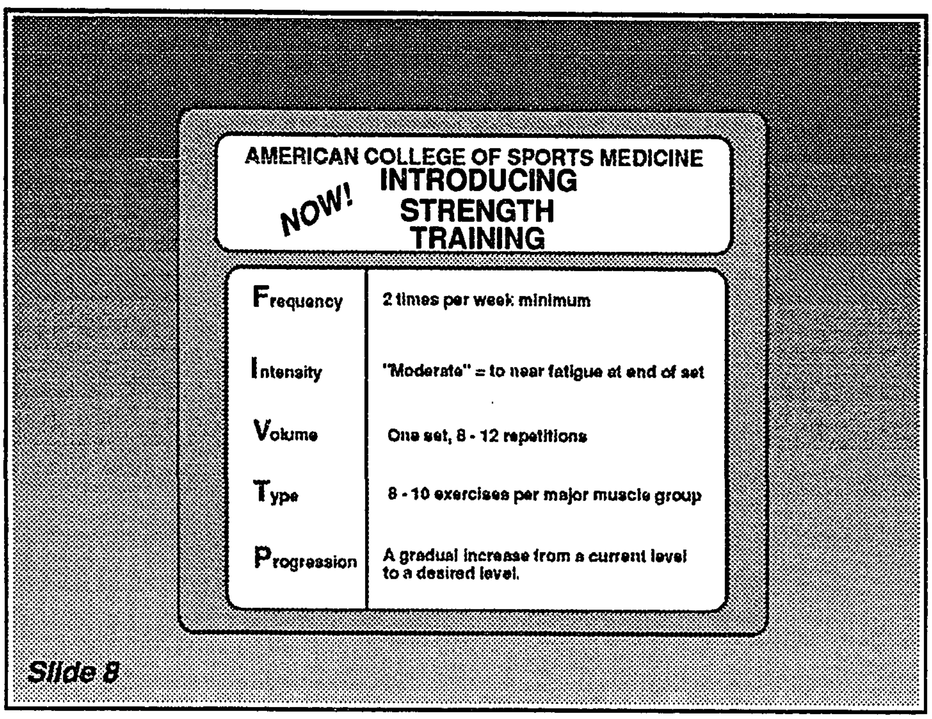

RHOMBOIDS
TRAPEZIUS
III, IV
TERES
MAJOR
LATISSIMUS
DORSI
"CHEST"
PECTORALIS
MAJOR, MINOR
Slide 3

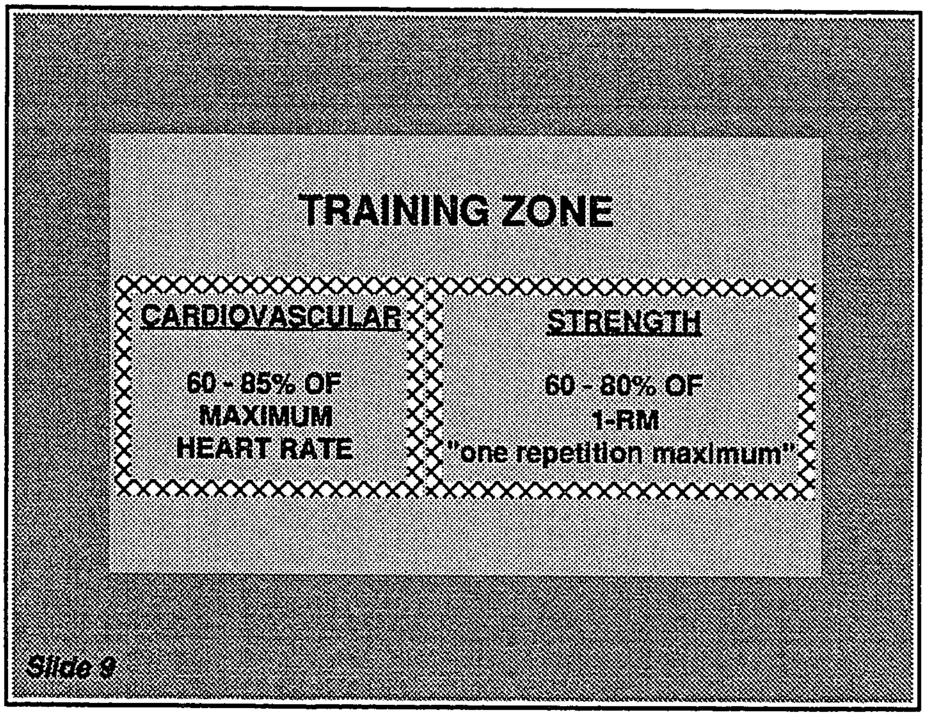

FUNCTIONAL IMPORTANCE
• DAILY TASKS
• PHYSICAL LABOR
Slide 4

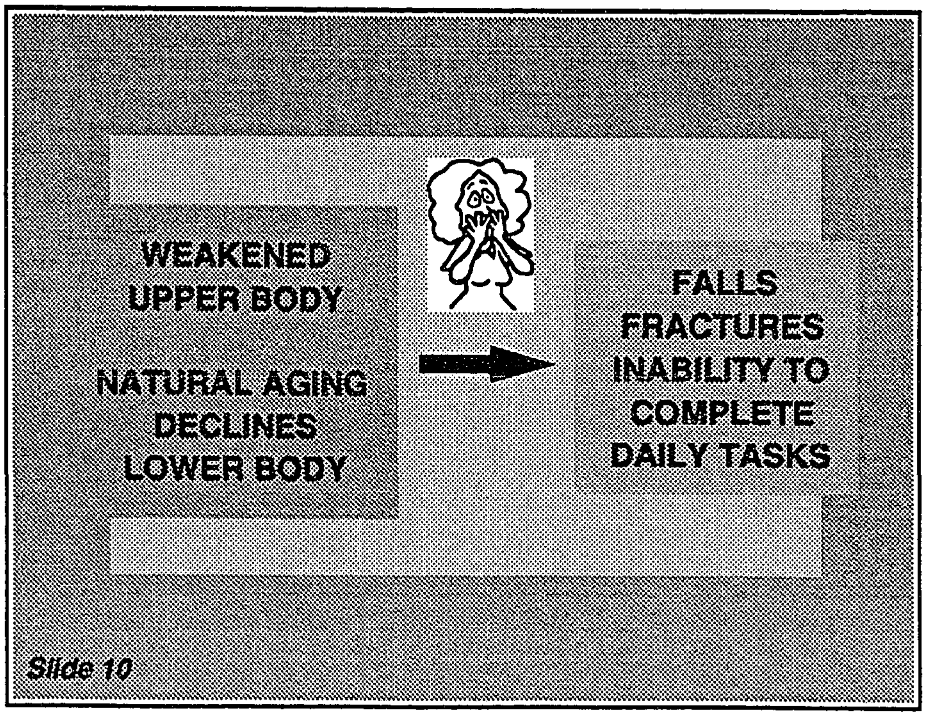

FUNCTIONAL IMPORTANCE
Slide 5

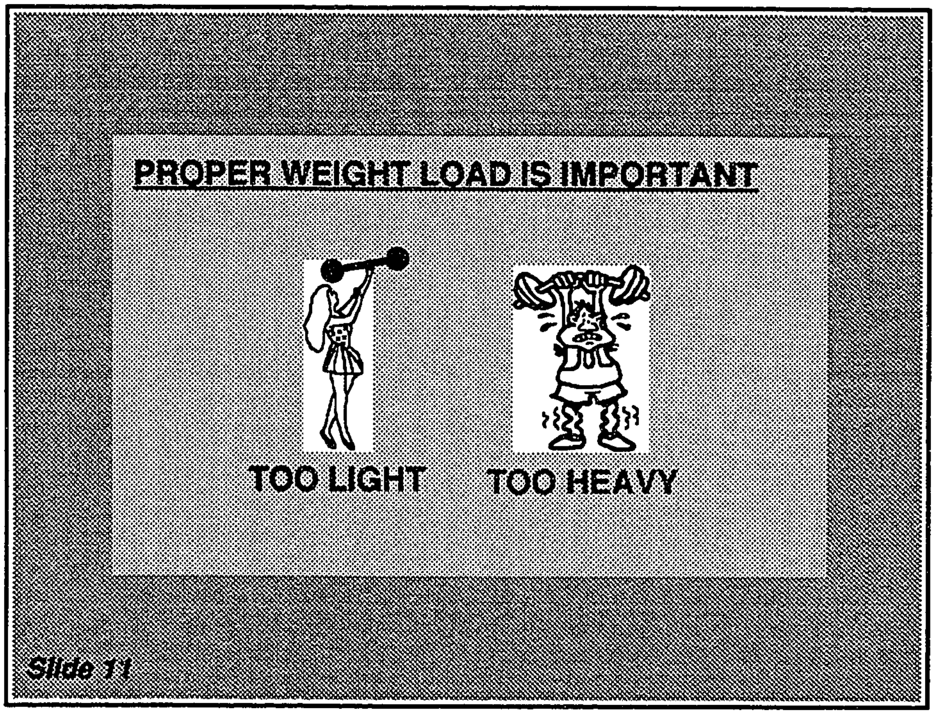

FUNCTIONAL IMPORTANCE
NO QUASI MODOS
Slide 6


UPPER BACK
STRENGTH
?
THE
STUDY
Slide 7


AMERICAN COLLEGE OF SPORTS MEDICINE
NOW!
INTRODUCING
STRENGTH
TRAINING
Frequency
2 times per week minimum
Intensity
"Moderate" = to near fatigue at end of set
Volume
One set, 8 - 12 repetitions
Type
8 - 10 exercises per major muscle group
Progression
A gradual increase from a current level to a desired level.
Slide 8


TRAINING ZONE
CARDIOVASCULAR
60 - 85% OF
MAXIMUM
HEART RATE
STRENGTH
60 - 80% OF
1-RM
"one repetition maximum"
Slide 9


WEAKENED
UPPER BODY
NATURAL AGING
DECLINES
LOWER BODY
FALLS
FRACTURES
INABILITY TO
COMPLETE
DAILY TASKS
Slide 10


PROPER WEIGHT LOAD IS IMPORTANT
TOO LIGHT
TOO HEAVY
Slide 11


1-RM=STRENGTH
"MAXIMAL EFFORT AGAINST A MAXIMAL LOAD FOR ONE REPETITION"
• REQUIRES EXPERT GUIDANCE
• NOT APPROPRIATE FOR ALL
Slide 12

A SAFE ALTERNATIVE

PREDICTION EQUATION

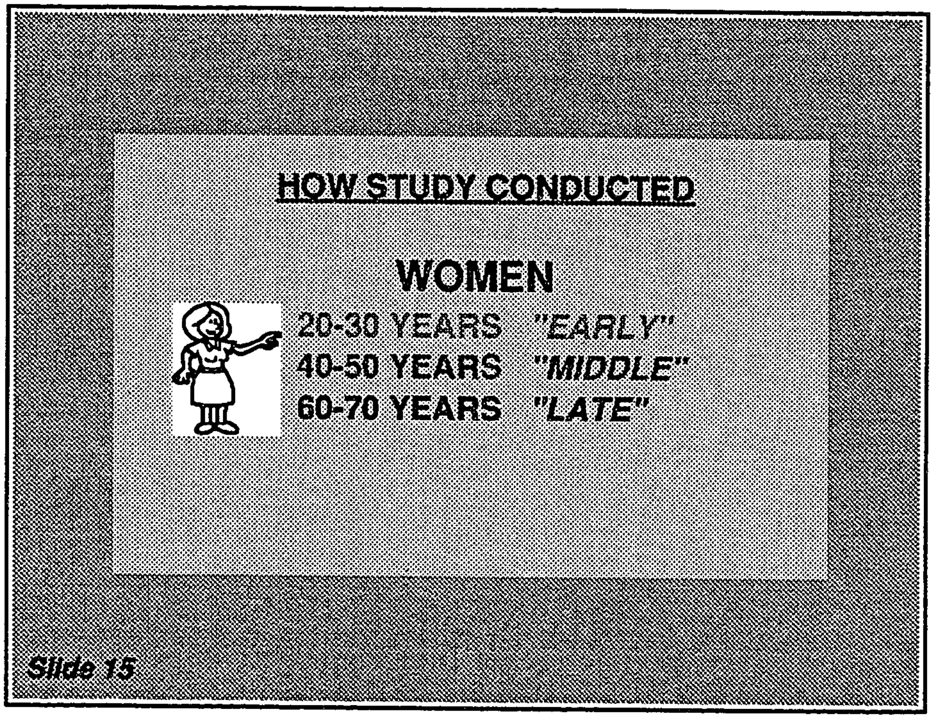
(.0024 X REPS) + (.0443 X WT LOAD) = 1-RM

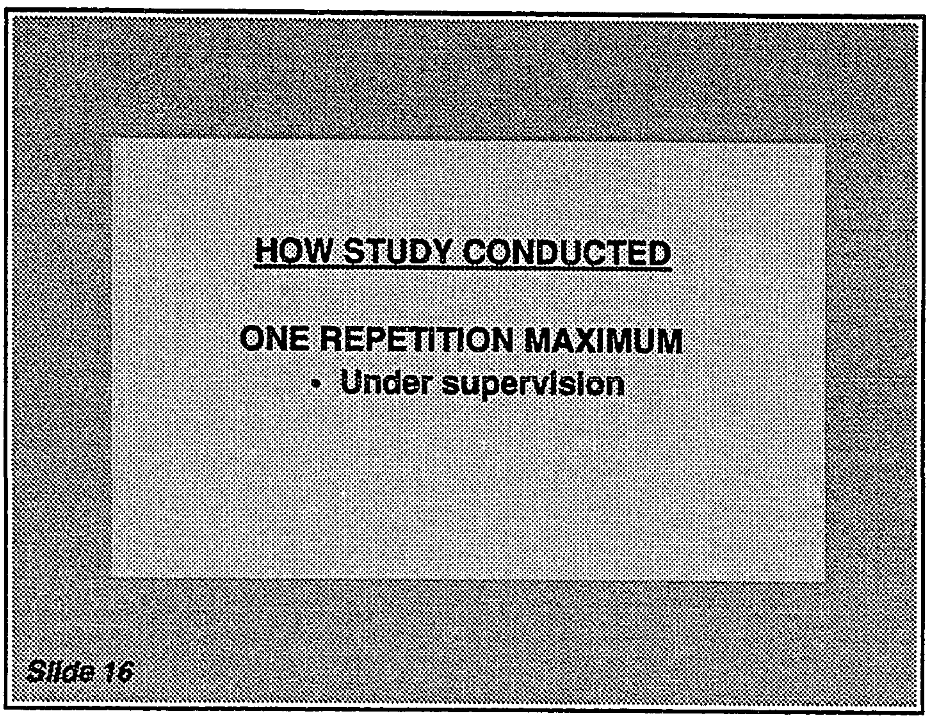
Slide 13

PURPOSE

To use a muscular endurance field test to predict muscular strength (1-RM) of the midback.

Slide 14


HOW STUDY CONDUCTED
WOMEN
20-30 YEARS "EARLY"
40-50 YEARS "MIDDLE"
60-70 YEARS "LATE"
Slide 15


HOW STUDY CONDUCTED
ONE REPETITION MAXIMUM
• Under supervision
Slide 16

HOW STUDY CONDUCTED

MUSCULAR ENDURANCE

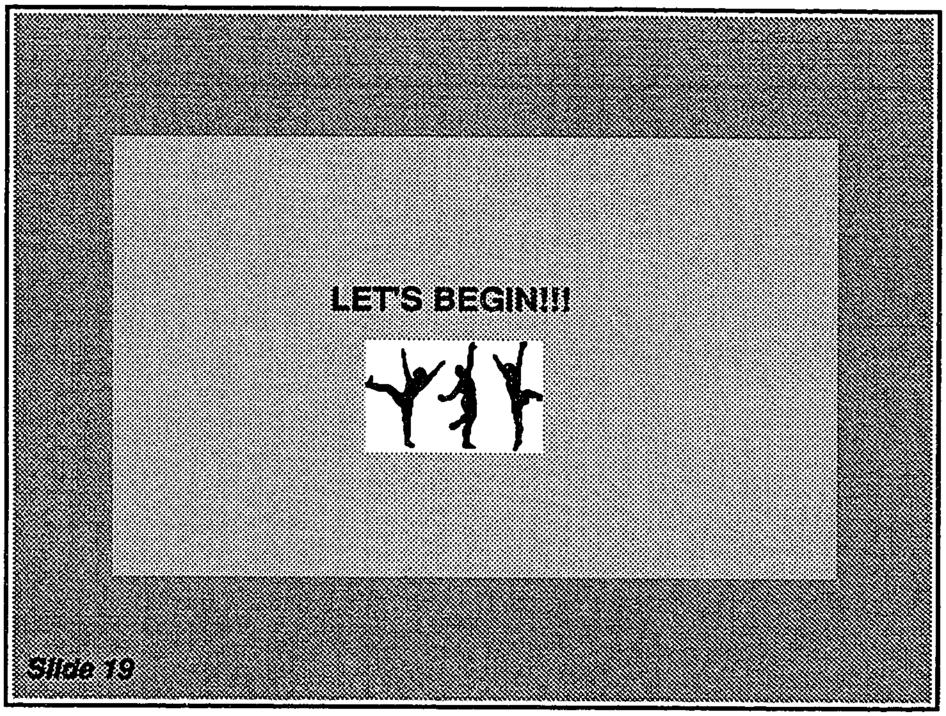
- Repetitions to a taped cadence

Slide 17

A SPECIAL THANK YOU!

PERSONALIZED EXERCISE PROGRAM

Slide 18


LET'S BEGIN!!!
Slide 19

APPENDIX G

Instructions For One Repetition Maximum Test

(This was the videotape script of instructions for subjects.)

Videotape Introduction

The following instructions are for the one repetition maximum test. This test measures the muscular strength of your midback. Or phrased as a question, How much weight can you pulldown in an all-out effort? This is done in a progressive manner by first warming-up on the machine with a light weight load. Afterwards, increasingly heavier weight loads will be pulled down for a one-repetition-maximum until the maximum weight load is achieved. A rest period will allow for sufficient recovery between each trial.

Body Positioning

1. Sit upright with feet planted on the floor and extend your arms above your head to grasp the bar at the specified markers.
2. DO NOT arch the lower back or rock back and forth during the test and DO NOT rock the head back and forth during the test.
3. Instead, position yourself with hips and trunk in a slight lean forward and gently tuck the chin towards the body.

Technique

1. The tester will bring the bar down to your reaching level.
2. DO NOT hold your breath. ALWAYS exhale when pulling the bar down.
3. Warm-up by pulling the bar down to the marker at the base of your neck and returning it to the start position. Repeat for the specified repetitions.

1-RM Test

1. Begin the movement in an overhead reach. With each test weight load you will be given a verbal instruction to start and complete the movement. Once you start the movement down you will be given a light tap to the marker at the base of your neck to orient you to your endpoint.

2. Start the movement down with elbows moving downwards and ending behind you. Your shoulderblades move towards each other. The bar will end on the marker at the base of your neck. Complete the effort in one continuous movement without stopping and starting.
3. You will be assisted in bringing the bar back to the start position. DO NOT release the bar without assistance! You will continue this process with three minute rest periods until your maximal weight load is achieved. Should you have any pain or discomfort during the test notify the tester immediately.

Repeated Shots of 1-RM

Shown are several maximal efforts on the lat pulldown machine for a better idea of the movement in its entirety.

APPENDIX H

Protocol For One Repetition Maximum Test

1-RM Lat Pulldown Test

1) The weight stack is blocked from view of the subject.
2) The subject is positioned in the seat with the knee pads comfortably securing the thighs and knees level with hips.
3) Wooden platforms are placed beneath the feet to create a firm contact surface and maintain hip and knee alignment.
4) The subject is positioned perpendicular to the lat pulldown bar.
5) The subject is positioned with the midline of the body in alignment with the midline of the lat pulldown bar/pulley cable system.
6) For hand placement, tape markers are applied to the pulldown bar at a distance of 73.7 cm.
7) Tape is applied to the seventh cervical vertebrae.
8) With arms raised overhead holding the bar, trunk is in a neutral spine position with hips slightly flexed.
9) Head is upright, but slightly flexed forward to create a clear path for bar contact.
10) The subject warms-up with a weight load of 13.64 kg (30 lb) for 8 repetitions.
11) The test load is initially set at 22.72 kg (50 lb) and immediately before each attempt at 1-RM, the tester asks the subject to "Begin, concentrate".
12) During the attempt, the tester continues to encourage the subject by shouting phrases of encouragement such as: "Great effort.", " Keep it up.", "You can do it." in a sequential and repeated fashion.
13) The subject is instructed to exhale during the effort and not to hold their breath.
14) The subject is instructed not to rock the hips/trunk or fully flex the head forward.
15) A three minute rest period is observed between maximal efforts.
16) The next weight load is increased in .57 - 2.27 kg (1.25 - 5 lb) increments depending on the effort observed by the tester.

17) A successful pull downwards is contact of the bar to the marker on the seventh cervical vertebrae in one continuous movement down without extraneous movements of the hips or head.

APPENDIX I

Instructions for Muscular Endurance Test

(This was the videotape script of instructions for subjects.)

Videotape Introduction

The following instructions are for the muscular endurance test. This test measures the muscular endurance of your midback. Or phrased as a question, How many times can you pull down the bar using your midback muscles until they fatigue? This is done in a progressive manner by first warming-up on the machine with a light weight load. Afterwards, a designated amount of weight will be pulled down for as many repetitions as possible until you are unable to keep pace with the beat.

Body Positioning

1. Sit upright with feet planted on the floor and extend your arms above your head to grasp the bar at the specified markers.
2. DO NOT arch the lower back or rock back and forth during the test and DO NOT rock the head back and forth during the test.
3. Instead, position yourself with hips and trunk in a slight lean forward and gently tuck the chin towards the body.

Technique

1. The tester will bring the bar down to your reaching level.
2. DO NOT hold your breath. ALWAYS exhale when pulling the bar down.
3. Warm-up by pulling the bar down to the marker at the base of your neck and returning it to the start position. Repeat for the specified repetitions.

Muscular Endurance Test

1. Begin the movement in an overhead reach. You will be given a verbal instruction to start the test. Once you start the movement down you will be given a light tap to the marker at the base of your neck to orient you to your end point.
2. Start the movement down with elbows moving downwards and ending behind you. Your shoulderblades move towards each other. The bar will end on the marker at the

base of your neck. Complete each repetition in one continuous movement without stopping and starting.

3. When you can no longer maintain rhythm with the beat or for whatever reason can not continue you will be instructed to stop and to slowly return the bar with assistance to the start position. DO NOT release the bar without assistance! Should you have any pain or discomfort during the test notify the tester immediately.

APPENDIX J

Protocol For Muscular Endurance Test

Relative Muscular Endurance Lat Pulldown Test

1) A fifteen minute rest period is observed between the 1-RM and muscular endurance test.
2) The weight stack is blocked from view of the subject.
3) The subject is positioned in the seat with the thigh pads comfortably securing the thighs and knees level to hips.
4) Wooden platforms are placed beneath the feet to create a firm contact surface.
5) The subject is positioned perpendicular to the lat pulldown bar.
6) The subject is positioned with the midline of the body in alignment with the midline of the lat pulldown bar/pulley cable system.
7) For hand placement, tape markers are applied to the pulldown bar at a distance of 73.7 cm.
8) With arms raised overhead holding the bar, trunk is in a neutral spine position with hips slightly flexed.
9) Head is upright, but slightly flexed forward to create a clear path for bar contact.
10) Tape is applied to the seventh cervical vertebrae
11) The subject warms-up with a weight load of 9.09 kg (20 lb) for 10 - 12 repetitions to the taped cadence.
12) The taped cadence is a 2 to 4 count using the words, "Pull-down, and-then-move-up".
13) The test load is set at 45% of total body weight, the taped cadence begun, and immediately before the endurance test, the tester asks the subject to "Begin, concentrate".
14) During the attempt, the tester continues to encourage the subject by shouting phrases of encouragement such as: "Great effort.", " Keep it up.", "You can do it." in a sequential and repeated fashion.
15) The subject is instructed to exhale during the efforts and not to hold their breath.
16) The subject is instructed not to rock the hips/trunk or fully flex the head forward.

17) The number of repetitions is recorded by the tester.

18) A successful test consists of repeated contact of the bar to the marker on the seventh cervical vertebrae in cadence with the taped beat. Improper hip and upper body movements are not observed.

APPENDIX K

Recording Form

RECORDING FORM

Date	
Subject Code #	
Age	
Birthdate	

Body Weight (lb/kg)	lb	kg
Height (in/cm)	in	cm
Resting BP		
Resting HR		

Last Time/Date Participated		Time/Date
in Sports/Physical Activity		Type

1-RM TEST

		lb	kg		lb	kg		lb	kg		lb	kg		lb	kg
Trial # & Wt Load to 1-RM	1			2			3			4			5		

1-RM (lb/kg)	lb	kg

Reason for 1-RM Test Termination

Successful	
Other, explain.	

MUSCULAR ENDURANCE TEST

Wt Load (%BW)	
Total Repetitions	

Reason for Muscular Endurance Test Termination

Fatigue	
Other, explain.	