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The purpose of this study was to determine the effects of a power lifting weight training program on the dynamic strength, static strength and body composition of college females. Thirteen college females volunteered for the study. The subjects trained three days per week for a total of nine weeks which consisted of a two week pre-conditioning period followed by a seven week heavy resistance power lifting training period. Dynamic strength tests were administered at the beginning of the seven week training period, at two mid-training dates and at the end of the training period. Static strength and body composition were measured prior to the pre-conditioning period and at the end of the strength training period. The test data were statistically treated using a paired t-test, a Student's t-test for independent samples, one-way analysis of variance and Scheffe's test. The .05 level of significance was selected for accepting or rejecting the null hypotheses. The results of the imposed training program revealed a

significant increase in dynamic strength. Changes in static strength varied with the muscle group tested. Shoulder flexion strength increased significantly, but trunk flexion and knee extension strength did not appreciably change over the training period. Alterations in body composition also varied following the training program. Lean body mass did not increase significantly, whereas a slight, but significant increase was found in the body weight of the subjects. The results of this study have several implications towards physical training for females.

Power Weight Training Applied To College Females

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POWER WEIGHT TRAINING APPLIED TO COLLEGE FEMALES

I. INTRODUCTION

Introduction

The inherent value of physical training is to augment performance. The four basic components that individuals attempt to improve through training are strength, endurance, coordination and flexibility. Of the four components, strength is cited as the most important one for success in physical activities (36). Motor ability tests also often identify strength and power as important criteria for high levels of performance in a wide range of physical activities. DeLorme (21) stresses the importance of strength relative to endurance. He states the development of strength to an optimal level is primary to the development of endurance, especially in weak and atrophied muscles, indicating that strength and endurance are related, not opposite entities.

Exercise is essential to the restoration of function to skeletal muscles. Since muscles are trained to perform different functions, exercises are classified according to the muscle quality to be developed, whether it be endurance, strength, coordination or flexibility. Thus, it is necessary to discriminate between the different types of exercises to ensure the desired results of a given exercise program are achieved. Weight training has been shown by a number of researchers to be beneficial in the development of strength and an overall fitness level for individuals, especially athletes. An understanding of the underlying scientific principles of exercise and training is essential for a successful training program. The scientific principles central to the development of strength are the specificity of training principle and the progressive overload principle. An understanding of the physiological and neuromuscular adaptations of skeletal muscles to the duration, intensity, frequency and type of exercise is also necessary for the correct application of a training program to bring about the desired results.

The extent of weight training used by an individual depends on the purpose of the overall training program. Weight training can range from a supplemental segment of a specialized training program to a substantial part of an overall training program of an athlete. Numerous studies have been conducted to assess the effects of weight training on muscular strength. Controversy exists concerning the different progressive resistance training methods used and the acquisition of muscular strength. The problem is not whether the various programs are effective in increasing strength, but rather which combination of duration, frequency, intensity and type of exercises produces the most rapid and efficient increase in strength.

The majority of studies conducted to assess the effects of weight training on strength development have been done on male subjects, few have been conducted with female subjects (10, 12, 56, 64). With the rise in women's athletics and recreational opportunities for females, physical training has become an important aspect for the improvement of performance of females in sports. As with males strength is an important component for the attainment of an overall fitness level. But, of the factors contributing to successful performance in sports, strength fitness is the one component in which females are most frequently deficient (52). Social and cultural pressures and unsupported scientific beliefs are the major factors which have lead to this deficiency. Thus the effects of strength training on the physiology of females are relatively unknown.

The most common scientific belief that females face regarding strength training is that the female who participates in a weight training program will develop excess muscle bulk to an extent similar to weight trained males. The acquisition of muscle bulk with strength training in females is unlikely due to androgen hormone levels. The male hormone testosterone appears to control the increase in body size and muscle bulk that occurs with training and growth (34, 55). Since the testosterone levels of females are lower than males, the probability that females will develop excessive increases in muscle size with strength training is low.

A second common scientific belief is that females do not possess the same capacity as males to respond to strength training. Although several of the anatomical dimensions and physiological capacities of males are greater than females, the quality of the muscle has been found to be the same in males and females, as is the ability to acquire strength through weight training (64). Several researchers have concluded that no sex difference exists relative to the ability of females to profit from physical training (24, 62, 64). The major difference between males and females concerning physical performance has been cited to be morphological rather than physiological in nature (9, 45, 62).

Wilmore (64) conducted a study to determine the effects of a strength training program on both males and females. The results of the study revealed that significant gains in strength were made by both males and females. Between the two groups, the females were found to have made greater gains in both bench press and squat strength. Changes in body composition were similar in both groups, but muscle girth measurements increased more in males than females. The general conclusions of Wilmore's study were: (1) Although absolute strength between males and females varies considerably, when strength is expressed in terms of muscle cross-sectional area the values are nearly identical, indicating that the quality of the muscle is the same in males and females relative to the muscles' ability to exert force. (2) The lack of significant increases in the girth measurements for females suggests that muscle hypertrophy is not a necessary consequence of gains in muscle strength. And (3) the similar improvements in strength of both groups indicates females have the same potential to benefit from strength training as males.

Since females appear to have the same ability as males to benefit from strength training, a need exists to find the type of strength training program for females, based on scientific principles, which produces the most rapid and efficient increase in muscle strength. In sports or any physical activity, the end view is not success independent of physical equipment, but rather attainment of perfection within the limitations of each physical type (36).

Purpose

The purpose of this study was to assess the effects of a power lifting weight training program on the dynamic strength, static strength, and body composition of college females.

Hypotheses

The null hypotheses tested in this study were:

Hypothesis one: Dynamic strength as expressed by bench press and squat strength, will not be modified by a seven week power lifting weight training program in college females.

Hypothesis two: Static strength as expressed by shoulder flexion, trunk flexion and knee extension strength, will not be modified by a two week pre-conditioning and seven week power lifting weight training program in college females.

Hypothesis three: Body composition as expressed by body weight and lean body mass, will not be modified by a two week pre-conditioning and seven week power lifting weight training program in college females.

Assumptions

1. Dynamic strength is represented by bench press and squat strength.
2. Static strength is represented by shoulder flexion, trunk flexion and knee extension strength.
3. Body composition is represented by body weight and lean body mass.

Definition of Terms

Dynamic (isotonic) contraction: A muscle contraction against a load in which the contractile force of the muscle is greater than the load. The muscle fibers shorten, skeletal movement occurs, and work is performed.

Dynamic weight training: Utilization of a barbell or dumbell of varying loads during exercise. The muscle is forced to undergo repeated dynamic contractions through a full range of motion so a training effect takes place.

Static (isometric) contraction: A muscle contraction in which the load is greater than the force generated by the muscle. The fibers contract but do not shorten. No external work is done and the energy of the muscle is dissipated as heat. The tension developed by a static contraction is measured by the use of a cable tensiometer.

Repetition: The number of times a dynamic or static contraction is repeated in a given exercise set. One repetition maximum (1 RM) is the maximum load a muscle is able to contract against for one repetition. The 2 RM is the maximum load a muscle can contract against for two repetitions, etc.

Set: One series of repetitions without a rest for a given exercise. A set may be repeated any predetermined number of times.

Specificity of training principle: Biological adaptations of a muscle are specific to the exercise being performed.

Strength: The ability of a muscle or muscle group to produce force.

Power lifting: A method of weight training which utilizes exercises requiring power and the major muscle groups of the body (i. e., bench press and squat).

Limitations

The limitations of this study were:

1. Dynamic strength testing was subjective due to its trial and error method of evaluating strength.
2. Skinfold measurements are influenced by the turgor of the skin, thus the level of hydration of the subject at the time the skinfolds were taken may have affected the measurements.
3. The training period was limited to nine weeks, two weeks pre-conditioning and seven weeks strength training.

Delimitations

The delimitations of this study were:

1. The subjects consisted of thirteen females with varying degrees of weight training experience.

2. The training program was a dynamic, progressive, heavy resistance, power lifting program.

3. The training program's core exercises were the bench press and squat.

4. Strength was assessed using dynamic and static strength measurements.

5. Lean body mass was assessed using skinfold measures.

II. REVIEW OF THE LITERATURE

Introduction

Strength is a physiological function of the skeletal muscles. Strength fitness is the ability of the muscles to exert force, repeat contractions, contract in proper sequence with other muscles or muscle groups and allow mobility of joint action (53). From the above definition four components of strength fitness can be identified: muscular strength, muscular endurance, coordination and flexibility. A deficiency in strength fitness corresponds to one or more of the four components. A strength training program can correct deficiencies in strength fitness to varying degrees depending on the physiological quality of an individual's muscular and related body systems and the application of the type, duration, intensity and frequency of a given strength training program. The specificity of exercise principle states that a given exercise elicits a specific response in a specific individual at a specific point in time. The biological result of training is directly determined by the specific exercise performed. Thus, knowledge of muscle and exercise physiology is essential in order to prescribe the correct set and intensity of physical activity to meet the biological need of individuals and elicit the desired results from the given training program.

Since a specific exercise will elicit a specific response in a specific individual at a specific point in time, this researcher believes that in order to obtain the desired results of a strength training program in females a general understanding of muscle physiology and female physiology is required. Also, strength training studies, male and female, were reviewed to acquire an understanding of the effects of duration, intensity, frequency and type of training program on muscle physiology and the physiology of females. Thus, the literature was reviewed relative to muscle physiology, female physiology, weight training programs and female strength training.

Muscle Physiology

The expression of strength by an individual involves both the physiological capacity and neuromuscular activity of the muscle cells. A muscle consists of two or three major types of muscle fibers. Prince, et al (50) identified three fiber types, slow twitch(ST), fast twitch oxidative (FOG) and fast twitch (FT). The three fiber types differ histochemically, biochemically and metabolically, and thus differ in the type and intensity of the workload for which they are recruited. The ST fibers have a high oxidative, low glycolytic capacity and are recruited at low intensity, endurance type activities. Fast twitch fibers have low oxidative, high glycolytic capacities and are recruited for high intensity, short duration, anaerobic type activities. Fast twitch oxidative fibers are intermediate between FT and ST fibers and are recruited for intermediate workloads. The fiber composition, percentage of the three fiber types in a muscle, of an individual is established early in life and does not change with training (18). The percentage of the different fiber types varies considerably between individuals and dictates to an extent the potential performance of an individual.

Although the fiber composition of muscles does not change with training, the histochemical and biochemical qualities of the muscle fibers do change. The changes in the histochemical and biochemical properties cause changes in the metabolic quality, aerobic and anaerobic capacities, of the different muscle fibers. The metabolic quality of the muscle fiber dictates to an extent the performance capacity of an individual (17, 27, 28, 33). The type and intensity of an imposed workload influences the fiber type recruited, the energy source utilized and the physiological adaptations that take place in the muscle.

The response of the muscle fibers to strength training is specific to the type of stress imposed rather than the muscle fiber composition of a given muscle (33). Specific adaptations occur with weight training, but the underlying mechanism for the physiological changes are still unclear. Strength training is an intense, short duration type activity which predominately utilizes the anaerobic energy system.

Thus the main physiological changes that occur with strength training affect the anaerobic capacity of the individual (1, 59). Since FT fibers have a high anaerobic capacity compared to ST fibers, the FT fibers are selectively recruited in strength training type exercises. The recruitment of predominately one fiber type in a training program results in an increased size of that particular fiber type (17, 58). The selective recruitment of the FT fibers in strength training is supported by the studies of Prince (50) and Edstrom (27). In separate studies Prince (50) and Edstrom (27) found the FT fibers of highly trained weight lifters to be larger in size than the ST fibers and the FT fibers of control subjects. The increased size of the FT fibers coupled with a lower percentage of FOG fibers and fewer mitochondria resulted in increased amounts of contractile protein to meet the stresses placed on the muscle by power lifting. Prince and Edstrom both concluded that the FT fibers were the main muscle fibers involved in the adaptation of the muscle to strength training.

Thorstensson, et al (61) studied the effects of an eight week dynamic, progressive resistance, strength training program on selected enzyme activities and fiber characteristics of skelatal muscle. Fourteen male subjects with no previous strength training experience were used in the study. At the end of the eight week training period significant increases in leg strength (67%), total body K^+, calculated lean body mass (LBM), and total muscle mass were found. However, no significant changes were found in body weight or lower limb circumference. Metabolically, no significant changes in the ATP metabolizing enzyme activities of Mg^{++}-stimulated ATPase, creatine phosphokinase (CPK) or phosphofructokinase (PFK) were found. But, the activity of myokinase did increase significantly which implied enhanced potential of the muscle to replenish ATP. The distribution and areas of the FT and ST fibers did not change with eight weeks of training, but the FT/ST ratio did increase. Thorstensson's study did not support the findings of Prince and Edstrom, but he suggested that strength training should have had similar effects on the FT fibers as in the studies by Prince and Edstrom. He concluded that the lack of any specific changes in the FT fibers may have been due to the length of the training program and/or to other noncellular factors which contribute to increases in strength. The possible noncellular factors contributing to strength increases were: 1) improvement in technique, 2) changes in neural energy and the recruitment patterns of the motor units, and 3) better elastic quality of the muscle.

Increases in muscle strength are usually accompanied by increases in muscle size. The potential to develop tension in a muscle is related to the amount of contractile protein found in the muscle fibers. Increases in muscle strength and size that accompany strength training are associated with changes in the amount and type of muscle proteins. Protein synthesis is augmented in both endurance and strength training, but a difference exists in the type of protein synthesis. Strength training enhances protein synthesis directly responsible for muscle shortening and tension development, namely actin and myosin synthesis. Increases in muscle strength and muscle size are related to increases in the number of myofibrillar elements per muscle fiber and the total amount of protein (actin and myosin) (14, 41).

Several factors in addition to increases in muscle protein contribute to increases in muscle strength, suggesting that muscle hypertrophy may not be a necessary consequence to increases in strength. Several researchers have found increases in muscle strength without muscle hypertrophy (9, 47, 60). Brouha (9) found a three-fold increase in muscular strength without a proportional increase in muscle size. The lack of muscle hypertrophy with strength is related to an increase in packing density of the myofibrilar elements and changes in the actin/myosin ratios in the muscle fibers (47). The amount of hypertrophy associated with increases in muscle strength depends largely on the duration, intensity, frequency, and type of exercises of the imposed training program.

The activity of the neuromuscular system is considered an important factor in the expression of muscular strength. Neuromuscular adaptations with training may provide a possible explanation for the increase in muscle strength without a corresponding increase in muscle size. Knowlton (37) states that physiologically, conditioning can be considered as establishing a spectrum of neuron thresholds which will yield a reliable temporal pattern of recruitment and inhibition for effector excitation. Changes in the frequency and number of muscle fibers recruited have a direct affect on the amount of tension developed in the muscle, and thus the expression of strength (1, 23, 26, 61). The rapidity with which overload stress increases the capacity for severe exercise, such as strength training, suggests that the changes must be due in part to changes in the central nervous system related to motor learning, not, initially at least, changes in the physiological composition of the muscle fiber (14, 29, 40, 57). Because the skeletal muscle completely depends on the nervous system for achieving maximum muscular tension, the changes in the neuromuscular system are thought to be primary to the acquisition of strength, while the physiological changes are secondary (19). Kabat (35) states that heavy resistance exercise is the most effective method of activating the greatest number of motor units and of producing maximum activation of the entire neuromuscular pathway. Hellebrandt and Houtz (29) found that repetitions of movements which do not cause neuromuscular stress have little effect on the functional capacity of skeletal muscle.

Thus, changes in the central nervous system appear to be an important result of physical training. Partheniu (46) characterized well-trained athletes of both sexes as having better organized and

and more efficient neuromuscular systems than untrained individuals. The increased efficiency of the neuromuscular system enables trained athletes to tolerate and rapidly adapt to the stresses of imposed training programs.

The pulling power of the muscle is ultimately a function of the cross section and physiological state of the muscle fibers. But, the actual performance of the muscle, which fluctuates more rapidly and over a wider range than can be fully accounted for by changes in the physiological factors, is a function of the central nervous system. Thus, the capacity to express strength is set by the physiological capacity of the muscle fibers, whereas the performance is set by the psychological or neuromuscular aspects (31).

Female Physiology

Although modifications at the cellular and neuromuscular level determine the amount of tension that can be developed by a muscle, physique and body composition are also important factors in the performance of strength and motor activities (39). Several morphological differences exist between males and females that effect motor performance. The major morphological differences between the sexes are smaller hearts, respiratory and aerobic capacities of females compared to males. Also, females possess a higher percentage of adipose tissue than males. Since a high relationship exists between lean body mass, strength and endurance, a higher percentage of fat in the female means a lower percentage of lean body mass available for use in competitive sports which require strength or power, and ultimately affects the physical work capacity of the individual (49). Physical performances in which the body of the individual is forced to move depend on the percentage of lean body mass rather than the amount of lean body mass (38).

The strength of females is about 2/3 that of males. But, the differences in strength between the two sexes varies within the different muscle groups (1). When strength is expressed in terms of lean body mass, males have greater upper body strength than females, but females have demonstrated greater leg strength than males. The explanation of this phenomena has been contributed to function and related to the specificity principle which states that specific adaptations are specific to the work performed (41).

Although the female has a lower strength capacity than males, several researchers have found no differences in the quality of the muscles of males and females. Absolute muscular strength, the strength in relation to cross section of muscle, has been found to be equal in males and females (26, 30, 62, 64). The percentage of FT and ST fibers in the muscles of males and females are also approximately equal. Prince (51) and Costill (17) found the muscle fibers of trained and untrained females to be similar to males in distribution and histochemical properties, but smaller in size. Prince and Costill both concluded that the major difference between the sexes is muscular size, not physiology. In the same studies, the muscle fibers of trained females were found to be larger than the muscle fibers of untrained females. This observation indicates training has a similar effect on muscle fiber size in females as in males (17, 51). The amount of the hormone testosterone appears to dictate the changes in muscle size that accompanies strength. Since the testosterone levels are higher in males than females, a greater muscle mass and size is expected in males, and accounts for the lesser degree of muscle hypertrophy in females (42, 64).

The amount of improvement possible with strength training is similar for both sexes if the initial starting strength levels are taken into account (9, 23, 24, 64). In fact, females may actually make greater gains with strength training than males due to the lower level of strength at the start of the training program. The initial level of strength influences the rate of strength increases (26, 53). Edington and Edgerton (26) state that an increase in strength may occur at a rate of 5-12% per week, with the percentage of increase depending on the relative strength of an individual at the beginning of the training period. Muscle strength increases to a given level which is dependent on the genetic capacity of the muscle. A muscle close to its genetic limit of strength development does not have the same potential for improvement as the muscle that is far from its genetic capacity. Females, far from their genetic strength limit, due to lack of training, may show a greater increase in strength than males and highly trained female athletes engaged in a similar training program.

Based on the studies of the physiological differences between males and females, the following conclusions have been drawn relative to the capacity of females to respond to physical training: 1) The magnitude of changes in body composition with training depends on the duration, intensity, frequency and type of exercise program; not the sex of the individual (48). 2) The integrity of the muscles of males and females is similar, thus the trainability of males and females is similar (24, 64). 3) The performance differences between males and females are more a matter of morphology than physiology (9, 45, 62).

Weight Training Programs

The objective of any weight training program is to use the correct combination of intensity, frequency, and type of exercises that will lead to the greatest development of strength. A major difference in strength training programs is the type of muscular contraction used in the training program. The two types of muscular contractions used are dynamic and static. A dynamic contraction is a muscular contraction against a load in which the muscle fibers shorten as does the entire muscle, causing skeleton movement and external work to be done. A static contraction is a muscle contraction in which the individual fibers develop tension but do not shorten, therefore, the muscle as a whole does not shorten and no skeletal movement takes place. Thus, dynamic strength is defined as the maximum load that can be moved throughout a full range of motion and static strength is the maximum amount of tension developed against a resistance.

Both dynamic and static training methods have been found to be effective in increasing muscular strength, but controversy exists as to which type of training is most effective in developing strength. Chui (13) found no significant difference in strength development between dynamic and static training. Berger (7), Rasch (57), and Darcus (20) found dynamic training developed strength faster than static training and Whitely and Smith (63) reported static strength training better than dynamic training for developing strength.

The major discrepencies between the above studies and their findings could in part be due to the testing procedures used to measure muscular strength. As there are two types of muscle training, there are also two types of muscle testing, dynamic and static. It is questionable whether dynamic strength and static strength are the same. Physiological and neuromuscular differences exist between the two ways of developing tension which may result in different adaptations in the muscle fiber. Specific adaptations require specific tests to measure the adaptations, thus the different methods of measuring strength may not give comparable results. Berger (7), in a study comparing the increases in dynamic and static strength with dynamic and static training programs, found that dynamic strength increases to a greater extent than static strength when the training program involves dynamic contractions. He also found static strength increases more with static than dynamic weight training. Berger concluded from his study that static strength tests do not accurately measure dynamic strength and dynamic strength tests do not accurately measure static strength. Thus, indicating a need to distinguish between static training and testing and dynamic training and testing when interpreting the results of strength training programs.

The use of static or dynamic strength training depends on the purpose of training. Berger (6) states that dynamic strength is a better indicator of motor ability than static strength. Also since movement and control of the body primarily involve dynamic muscular contractions, dynamic training will be more specific to dynamic motor ability than static strength exercises. Thus, individuals training for dynamic activities should train using dynamic type exercises, which includes dynamic weight training.

Dynamic strength fitness is the ability of the muscles to: 1) exert force through a wide range of multiple joint motion, 2) repeat maximum or near maximum contractions, 3) contract the muscles in proper sequence with other muscle groups and 4) allow mobility of multiple joint action (53). The selection of exercises used to improve strength fitness requires the four requirements of strength fitness, namely, muscle strength, muscle endurance, coordination and flexibility to be met. Core exercises, which include pressing movements of all kinds, power cleans and squats; are exercises that require the utilization of the large major muscle groups of the body, flexibility and coordination with other muscle groups of the body. Strength and muscle endurance are also required in the repeated execution of the core exercises, thus satisfying the four requirements of strength fitness. The core exercises make up the foundation of strength training programs.

In addition to the type of muscular contraction and core exercises used in a strength training program, the duration, intensity and frequency of the program are also important components of strength training. Dynamic strength training will increase strength and muscle size to varying degrees depending on the setting of the duration, intensity, and frequency of the workouts (14, 29, 52).

The intensity of the training program is perhaps the most important requirement for increasing strength. The intensity is based upon the selection of the number of repetitions, sets and load utilized for each exercise. The progressive overload principle, first introduced by DeLorme and Watkins (22) in 1945, is primarily directed toward the intensity of workouts. The progressive overload principle states that the limits of adaptation can be extended only by a continuous increase of intensity of work, not by performance of work with uniform intensity throughout a training period.

DeLorme (21) was one of the first researchers to investigate the effectiveness of dynamic resistance training and introduced the concept of increasing the load as the muscle became stronger, known as the progressive overload principle. DeLorme's technique increased the weight of each set using increasing percentages of the 10 RM (repetition maximum). The program progressed from a set of 1/2 10 RM to a set of 3/4 10 RM and finally to a set of 10 RM. The weight was increased when the subject could perform the 10 RM weight easily, thus continually increasing the intensity. DeLorme's progressive resistance principle became the foundation of strength training programs.

Following DeLorme's study, many researchers investigated the effects of various progressive resistance training programs on the acquisition of muscular strength. Capen (11) compared four programs of varying numbers of sets and repetitions. He found that a program consisting of three sets of 5 RM, three times per week, was the best combination for increasing strength.

Berger conducted several studies on college males to determine the optimal training program for strength. In Berger's studies changes in strength were determined using the 1 RM in the bench press. In one study various combinations of sets and repetitions were used. He found that the combinations of three sets of 6 RM, three times per week produces the greatest increase in muscular strength (2). In a similar, but slightly expanded study, Berger found that when one set for each exercise was used three times per week, the optimal number of repetitions for increasing strength were four, six or eight (4).

Later, Berger again compared training programs of varied sets of repetitions. The subjects were divided into three groups. The groups performed six sets of 2 RM, three sets of 6 RM or three sets of 10 RM. All three groups made significant increases in strength with a 12 week, three times per week training program; but no significant difference was found between the three groups (5).

O'Shea (52) conducted a study similar to Bergers (5), varying the number of sets, duration and the exercise used. The subjects trained three times per week for six weeks using the 1 RM in the squat and a leg dynamometer for knee flexion, respectively. The subjects were divided into three groups, one group performing three sets of 10 RM, one group performing three sets of 5 RM and one group performing three sets of 2 RM. All groups made significant gains in static and dynamic strength, but no significant difference was found between the three groups.

Withers (66) confirmed the results found by Berger (5) and O'Shea (52). Three groups of subjects used various combinations of sets, repetitions and exercises. The three groups trained for nine weeks, two times per week, on the curl, bench press and squat. One group performed three sets of 7 RM, another group did four sets of 5 RM and the last group did five sets of 3 RM. The 1 RM in the three exercises was used to test dynamic strength. All three groups made significant gains in strength, but no group was significantly different from the other groups. Although no group was found to be significantly better in increasing strength, Withers recommended that the best strength development program for beginners was three to four sets of five to six repetitions, two times per week.

Berger (3, 8) also examined the effects of varied loads on the development of strength. He found that training with submaximal loads (90% 10 RM) was just as effective for increasing strength as training at maximum 10 RM. The lowest percentage of the 10 RM with which to train in order to produce the same increases in strength as training at maximum was not specified.

The intensity of the workload is important to the degree in which strength is increased with a training program. Several researchers state that muscular strength is best gained by using heavy resistance with few repetitions and muscular endurance is best developed using light loads and many repetitions (21, 52). Based on the distinction between strength and muscular endurance. O'Shea recommends three types of programs which develop muscular strength and endurance to varying degrees. The programs are:

(1) 6-8 sets, 1-3 repetitions at 90% 1-RM for maximum strength development;

(2) 4-5 sets, 4-10 repetitions at 75-85% 1-RM for strength and endurance;

and (3) 3-4 sets, 12-20 repetitions at 65-75% 1 RM for muscular endurance (54).

The duration and frequency of the training program also influences the degree of training achieved. Withers (66) recommends training two times per week, whereas Berger (2, 5) and O'Shea (53) recommend a training frequency of three times per week. Capen (11) found three times per week to be superior over training five times per week. O'Shea (53) also recommends a weekly schedule of heavy-light-medium training days to allow for adequate stress placed on the major muscle groups and adequate recovery from the stresses imposed.

The duration of the training programs cited varied from six to 12 weeks. Clarke (14) and Klafs and Lyons (36) both suggest that a minimum of six weeks are required for adaptations of the muscles to strength training to occur. Thorstensson (61) states that more than eight weeks may be required for adaptations at the cellular level to take place.

Female Strength Training

The type of muscular exercise, intensity, frequency and duration of the training program are all important factors in the development of strength in males. The rise of womens athletics and recreational opportunities for women has generated much interest in physical training, including strength training, for females. It has been determined that the quality of the muscles to contract and exert force is similar in males and females. Also no difference has been found in the ability of the sexes to develop muscular strength (24, 64). The effects of strength training on females has not been extensively researched. The few studies which have dealt with the subject have differed in the application of duration, frequency and intensity of the training program, as well as the exercises performed and subjects (athletes vs. nonathletes) and testing procedures used, making interpretation of the results difficult.

Capen (12) was one of the first researchers to study the effects of dynamic weight training on the strength and body composition of females. Fourteen college females trained three times per week for ten weeks using a progressive resistance type program which utilized heavy weights with few repetitions. Muscular strength, endurance and power measurements were taken using a dynamometer for leg, grip and back strength; pullups and situps for muscular endurance and strength and the broad jump for muscular power. After ten weeks of training significant increases in all the measures were found, with leg strength having the largest increase (137.15 pounds). The results were similar to the findings found with males involved in similar heavy resistance training programs. Thus, Capen concluded that weight training improves muscular strength, endurance and power equally in males and females.

Although the strength, endurance and power measures increased significantly in Capen's ten week program, few statistically significant alterations occurred in the skinfold and girth measurements of the female subjects. A few consistent changes in body measures (i.e., lean body mass) did occur with the training program, but the changes were not significant. Capen concluded that a longer experimental period may be required for significant changes in body composition to occur (12).

Wilmore (64) conducted a study using both males and females as subjects. The subjects were assigned to a ten week weight training program which met twice a week for 40 minute training sessions. The training format consisted of two sets of 7-9 RM of various strength training exercises. The exercises included half squats, curls and presses. The testing procedures utilized the leg dynamometer for leg strength, the 1 RM for bench press and curl strength and the hand grip dynamometer for grip strength. Significant increases in strength were recorded for both males and females following the training program. The female subjects exhibited greater relative increases in leg and bench press strength, 29.5% and 28.6%, respectively, than the male subjects. The body composition alterations in the two groups were similar. Little or no change occurred in body weight, but decreases in body fat and increases in lean body mass were observed. Gains in the girth measurements of the chest, shoulder, deltoids, biceps and forearm muscles were found in both groups. But the increases in girth measurements tended to be greater in the males than the females. The females increased less than 1/4 inch in all the girth measures.

Another study to determine the effects of strength training on females was conducted by Brown and Wilmore (10) using seven nationally ranked strength track athletes. The goal of the study was to achieve maximum strength through progressive, near maximum overloads, applied over a prolonged training period. The subjects were highly motivated and all had had prior weight training experience to varying degrees. The program consisted of six months, three times per week, of heavy progressive resistance training. The squat and bench press were used as the program's core exercises. The first two months of the program consisted of six sets of ten, eight, seven, six, five, four repetitions of 50, 60, 65, 70, 75 and 80% 1 RM, respectively. During this period the loads were increased five pounds in the bench press and ten pounds in the squat every two weeks. The last four months of the program consisted of four sets of ten, six, five and four repetitions at increasing near maximum loads. The weight was progressively increased as strength increased. The subjects also participated in a general conditioning program three to four times per week. Strength was assessed using the 1 RM in the squat and bench press. All the subjects made significant gains in strength at the end of six months. The strength in the bench press increased 15-44% and squat strength increased 16-53%. Although strength increased significantly, arm and thigh size increased by only 2.9% and 0.4%, respectively. The increases were not significant. Lean body mass increased by less than one kilogram after six months of training.

Michael (44) conducted a study to assess the effects of weight training on the leg density and strength of college females. Thirty females were subjected to a 12-week heavy resistance weight training program. Leg strength was determined using a leg dynamometer. An increase in leg strength of 11 pounds resulted over the 12-week program. The increase in strength was accompanied by an increase in leg density. Thigh girth and leg volume measurements decreased while body and leg weight did not change.

The studies on the effects of strength training on females differed in the application of duration, intensity, frequency and type of training, but several general conclusions can be made from the investigations: (1) Females are capable of making substantial gains in strength using a progressive resistance strength training protocol. (2) Slight changes in anthropometric measures occur following a strength training program, especially muscle girth measurements in females. Thus, muscle hypertrophy is not considered a necessary consequence of heavy resistance weight training in females. And (3) although muscular strength in males and females varies considerably, when expressed in terms of muscle cross-sectional area, the values are nearly identical indicating the quality of the muscle is similar in both sexes. Similar muscle quality suggests that females have the same potential to benefit from strength training as males (10, 12, 44, 64).

Summary

Although the effects of weight training on the strength and physiology of females has been researched, the optimal training program for strength increases in females is still unknown. Many strength training programs have been studied in order to find the combination of intensity, duration, frequency and type of training which will bring about the most rapid and efficient increase in strength. But, the majority of the studies have been conducted on males. Even though the quality of the muscle has been found to be equal in males and females, other physiological and morphological differences between the sexes may cause different responses to similar training regimes. Thus, the problem exists to find which combination of intensity, duration, frequency and type of training will cause the most rapid and efficient increase in strength in females. The present study attempts to determine the effectiveness of a power lifting weight training program in increasing dynamic strength and also the effect of such a program on the body composition of females. Static strength was measured in order to allow comparison of the results to other studies.

III. RESEARCH DESIGN

Introduction

The present study was conducted at Oregon State University, Corvallis, Oregon during the Winter term, 1980. The testing of the subjects was conducted in the Exercise Physiology Laboratory and the weight training room of the Department of Physical Education. The weight training room was also the site of the training portion of the study. The purpose of the study was to assess the effects of a power lifting weight training program on the dynamic strength, static strength and body composition of college females.

Subjects

Thirteen healthy college females associated with Oregon State University volunteered as subjects for the study. The population pool from which the subjects were taken consisted primarily of female students enrolled in physical education classes at Oregon State University, Winter term 1980. Individuals from the physical education classes interested in participating in the study volunteered as subjects. All the females that volunteered were used as subjects. Of the 13 subjects, three were Oregon State University athletes (track-field events) with some weight training experience. The remaining subjects were non-athletes with at least one term (10 weeks) of weight training experience, either in physical education class or as part of a previous athletic training program. The subject's ages ranged from 18-30 years with a mean age of 21.4 years.

Prior to the start of the seven week strength training period all of the subjects participated in a two week pre-conditioning program. The program consisted of general conditioning exercises and instruction in the skill demands of the training program.

Training Methods

A two-week pre-conditioning period preceded the seven week experimental training periods. During the two week period the subjects performed general weight training conditioning exercises and were instructed in the training procedures of the experimental period and the correct techniques for the bench press and squat as stated in the International Powerlifting Federation Rule Book (32). After the initial conditioning period the subjects were tested for their 1 RMs. The 1 RM was used as the baseline for the establishment of the workout intensity during the experimental period.

The subjects followed a progressive resistance type of weight training program in which the intensity of the workouts was increased weekly. The general workout schedule included a 10-15 minute warm-up consisting of stretching and flexibility exercises, warm-up sets for the bench press and squat, training sets for the bench press and squat, assistive exercise sets and warm-down stretching exercises. The assistive exercises consisted of stretching movements for the shoulder and lower back which included rounded back dead lifts, latissimus pull downs in the seated position, sit-ups and arm raises. A sample workout is illustrated in Appendix A. Each training session was closely supervised with special attention placed on proper technique in all of the lifts performed.

The subjects trained for one and one half to two hours, three times per week. The three workouts were divided into light and heavy days. Mondays and Fridays were designated as heavy days with Wednesdays designated as light, active recovery days. The Monday and Friday workouts consisted of four sets of three to five repetitions at 70% 1 RM in the bench press and squat. The light day workout consisted of three sets of eight repetitions at an intensity of 50% 1 RM. Each Monday the loads were increased five pounds in the bench press and ten pounds in the squat. After the initial increases in bench press strength took place (the first four weeks), not all of the subjects could continue to increase the load by five pounds each week and still complete the assigned workout. Thus, the schedule of increasing the load in the bench press was modified to the individuals ability. All the subjects were able to maintain the load increase schedule for the squat.

In addition to the core exercises, the bench press and squat, the subjects were required to perform several assistive exercises during the workout. The assistive exercises included rounded back and straight leg deadlifts (Figure I), seated latissimus pull downs (Figure II), situps and arm raises (Figure III). Generally three sets of 10-15 repetitions of the assistive exercises were performed with the intensity being set by the individual. The adjustment of the intensity did not follow the same schedule as the core exercises.

The majority of the injuries in training are due to muscle imbalances. Most of the subjects were not involved in an intensive training program prior to the study which would have tended to eliminate muscle imbalances. Thus, during the study special care was taken to avoid stress injuries. To reduce injuries the subjects participated in a two week pre-conditioning program prior to the seven week heavy resistance training period. The subjects were also required to perform assistive exercises during each workout and advised to use a weightlifting belt and knee wraps when executing the squat. Technique and workloads were closely supervised to further eliminate the chance of injury. Since no injuries occurred during the course of the training period, the safety precautions taken seemed worth the time.

Figure I. Assistive exercise - straight leg dead lifts.

Figure II. Assistive exercise - latissimus pull downs - seated position.

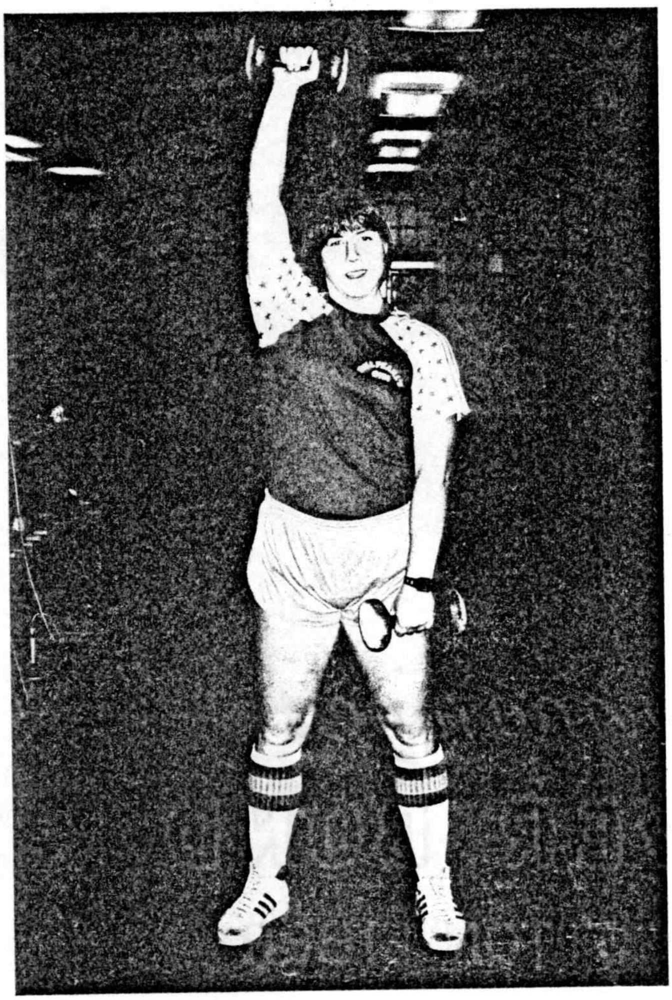


Figure III. Assistive exercise - arm raises.

Instrumentation

The null hypotheses tested in this study were that at the end of a power lifting weight training period no significant modification in: (1) dynamic strength, (2) static strength or (3) body composition would occur. To test the hypotheses it was necessary to measure the pre- and post-training values of dynamic strength, static strength and body composition.

Three types of measurements were taken which corresponded to the parameter being assessed. The 1 RM (repetition maximum) for the bench press and squat was used to measure dynamic strength. The criteria for judging the lifts was outlined in the Official Rules of the International Powerlifting Federation (32). Dynamic strength testing is a trial and error procedure, and thus subjective in nature. Static strength was assessed through the use of three cable tensiometer strength tests described by Clarke (15). The three tests, shoulder flexion, trunk flexion and knee extension, were selected relative to the major muscle groups exercised in the training program. The objectivity coefficients for the three tests are 0.94, 0.90 and 0.94 for shoulder flexion, trunk flexion and knee extension, respectively (15). Lean body mass was calculated using three skin-fold measures, body weight and a regression equation formulated by

Wilmore and Behnke. The standard error of estimate for the regression equation is 1.940, and R = 0.916 (65).

Testing Procedures

A. Strength: Static and dynamic strength were both measured to allow for comparisons to previous studies. Due to possible diurnal variations in strength, all of the strength tests were conducted at the same time of day (67).

1. Dynamic strength: Maximum dynamic strength was determined by the one repetition maximum (1 RM) for the core exercises utilized in this study. Dynamic strength testing was conducted a total of four times over the training period. The initial measurement was taken after a two week pre-conditioning period in which the subjects were instructed in the proper techniques of the squat and bench press. The two week conditioning period was deemed essential to eliminate learning effects, and thus permit an accurate assessment of dynamic strength changes. The other testing dates were at weeks three and five and at the end of the seven week training period.

The bench press and squat were executed, in testing and training, according to the International Powerlifting Federation Rules (32). The 1 RM's for the bench press and squat were determined the same day with a half hour rest period between each test. Prior to the testing the subjects were allowed to stretch and warm-up with light weights.

Since dynamic strength testing is a trial and error process, to eliminate part of the subjective nature of the test a projected 1 RM was determined for each subject based on pre-test performances. The projected 1 RM was used as a baseline for the lifts leading to the 1 RM attempt. The testing procedure consisted of a warm-up set of eight repetitions at 60% of the projected 1 RM, a set of three repetitions at 75% of the projected 1 RM, one repetition at 90% of the projected 1 RM and an attempt at the projected 1 RM. A rest period of at least three minutes was given between each 1 RM attempt. If the 1 RM attempt was successful weight was added, five pounds in the bench press and 10-15 pounds in the squat, and another 1 RM was attempted. Each subject was allowed as many attempts as necessary to reach their 1 RM. The projected 1 RM was accurate within five pounds for the bench press and ten pounds for the squat for all subjects.

The testing for 1 RMs took place on Mondays. Due to daily variations in both the physiological and psychological conditions of the subjects (i. e., stress of school, lack of sleep) the subjects were allowed to retest on Friday of the same week if they felt the 1 RM attempt on Monday was not their actual maximum.

The International Powerlifting Rules (32) governing the bench press and squat were used as criteria for judging a lift successful. The bench press attempt was successful if the position of the head and trunk (including buttocks) extended on the bench and the feet flat on the floor, was maintained during the lift. Also the subject was required to lower the bar from an arms extended position down to the chest and then evenly press the bar vertically back to the straight arm position with no bouncing (Figure IV). To execute the squat the lifter was required to first lift the barbell off the squat rack, onto the shoulders and assume a standing starting position. The squat was deemed successful if the lifter bent the knees and lowered the body until the top of the thighs were parallel to the floor and then extended the knees evenly back to the starting position without bouncing (Figure V).

The equipment required for the dynamic strength tests were a seven foot standard Olympic barbell, standard weights, a squat rack for supporting the barbell until the subject placed the barbell on the shoulders to perform the squat and a 14 inch high bench with vertical supports to support the bar until handed to the subject for execution of the bench press. Weight lifting belts and knee wraps were also provided for the subjects.

2. Static Strength: Static strength tests were administered prior to the start of the two week pre-conditioning period and at the end of the seven week strength training period. In order to measure the major muscle groups exercised during the training program, three static strength tests were used. The tests used were shoulder flexion,

Figure IV. Bench press.

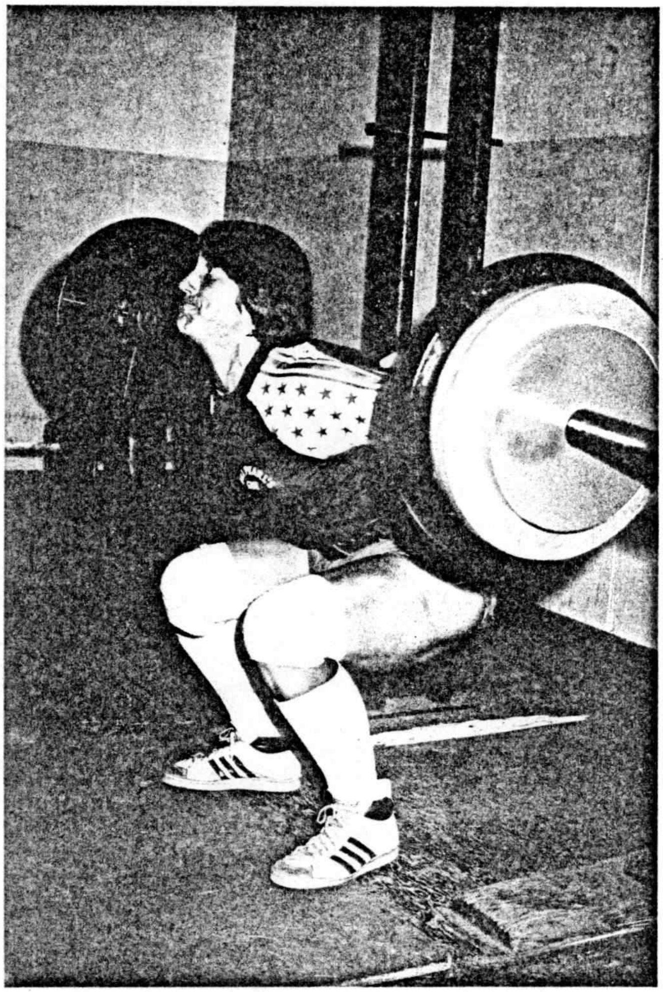


Figure V. Squat - bottom position.

trunk flexion and knee extension.

The equipment required for the static strength tests consisted of a standardized cable tensiometer, a pulling assembly composed of a chain, strap, and cable and a standard cable testing bench. The pulling assembly and tensiometer were not used for any other research during the course of the study. Two testers were required to administer the tests.

Prior to testing all of the subjects were given test instructions as a group and an opportunity to stretch and warm-up with light weights. The order of subject testing was established with the shoulder flexion test by a volunteer basis. After the first test the same order was maintained throughout the testing period. To eliminate competition between the subjects, no one was allowed to see their test results until all were tested.

The three static strength tests were conducted on the same day. The order of testing was shoulder flexion, trunk flexion and knee extension. A half hour rest period separated the three tests. Each subject was given three attempts with a minute rest between each attempt. The maximum value of the three attempts was recorded as the subject's 1 RM (repetition maximum).

The general procedure for the static strength testing was: positioning the subject, mounting the pulling assembly and tensiometer, checking for proper joint angles and cable tautness, instructing the subject to perform a 1 RM and taking the reading on the tensiometer. The proper starting positions for the static tests were (15):

Shoulder flexion: The subject assumed a supine lying position on the bench with the knees and hip flexed and the feet resting flat on the bench. The right arm was positioned close to the subject's side with the shoulder flexed to 180 degrees and the elbow flexed to 90 degrees. The regulation strap was positioned around the humerus midway between the shoulder and elbow joints. The pulling assembly ran vertically from the arm to the cross piece on the bench below the subject's arm. The left arm rested on the chest. The subject was held by a tester to prevent shoulder and hip elevation during each trial (Figure VI).

Trunk flexion: The subject assumed a supine lying position on the bench with the hips flexed to 180 degrees and adducted. The knees were fully extended and the arms were folded across the chest. A trunk strap was placed around the chest close under the armpits. The pulling assembly was attached beneath the subject through a slit in the table. The subject was held by a testor to prevent hip elevation (Figure VII).

Knee extension: The subject assumed a seated, back leaning position. The arms were extended to the rear with the hands grasping the sides of the table. The right leg was tested in all subjects. The knee was positioned to 115 degrees of extension at the start of the test.

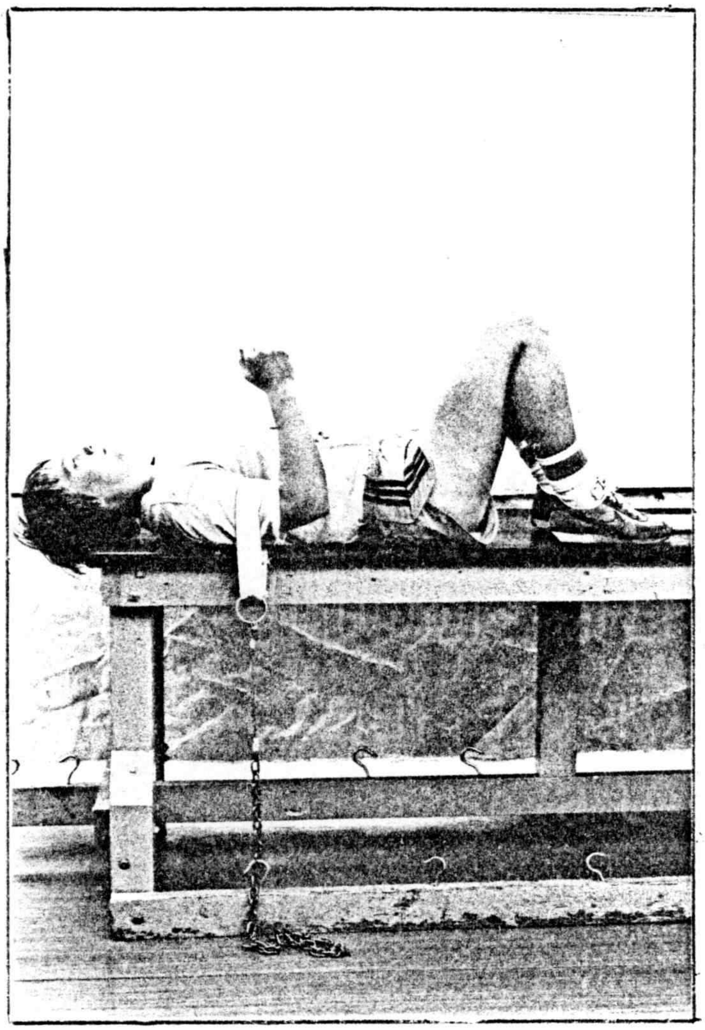


Figure VI. Static strength test - shoulder flexion.

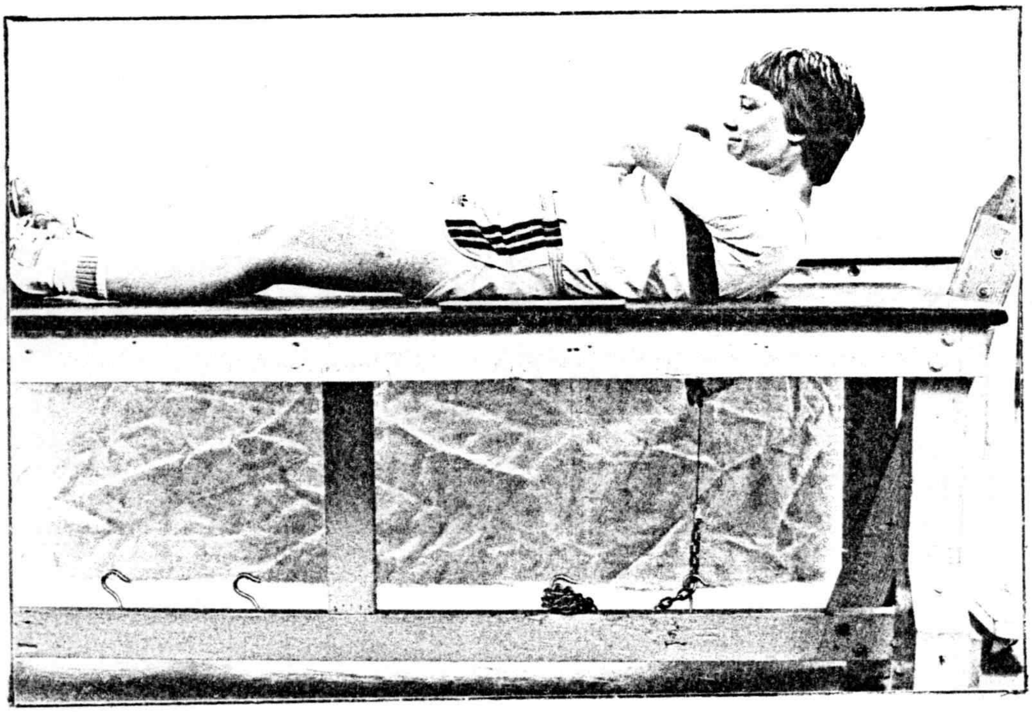


Figure VII. Static strength test - trunk flexion.

Figure VIII. Static strength test - knee extension.

The pulling assembly was placed around the leg midway between the knee and ankle joints and attached to a hook at the lower end of the testing bench. The subject was not allowed to lift the buttocks or flex the arms during the test (Figure VIII).

B. Body Composition: The lean body mass was estimated using three skinfold measures, body weight and the multiple regression equation formulated by Wilmore and Behnke for young females (65). The regression equation used was:

$$LBW = 8.629 + 0.680X_1 - 0.163X_2 - 0.100X_3 - 0.054X_4$$

where:

LBW = lean body weight (kg)

X_1 = weight (kg)

X_2 = scapula skinfold (mm)

X_3 = triceps skinfold (mm)

X_4 = thigh skinfold (mm).

The standard error of estimate for the regression equation is reported to be 1.940 with R = 0.916 (65).

The equipment required to measure lean body mass were a calibrated Lange Skinfold Caliper, tape measure and a standard scale. The skinfold caliper was not used for any other research during the course of the study.

The location of the three skinfolds measured were (65):

Scapula: The skinfold site was located at the inferior angle of of the scapula. The skinfold was parallel to the axillary border of the scapula.

Triceps: The skinfold site was located midway between the acromion and olecranon processes on the posterior aspect of the upper arm. The arm was in a relaxed position next to the body. The skinfold was parallel to the length of the arm.

Thigh: A vertical skinfold on the anterior aspect of the thigh midway between the hip and knee joints.

All the skinfold measurements were taken with the subject in a relaxed state, thus allowing the measurement of the subcutaneous fat layers with no muscle. The skinfolds were taken at the same time as the static strength measurements, prior to the pre-conditioning period and after the seven week strength training period. Body weight and skinfolds were taken after the static strength tests were completed and followed the same subject order as in the static strength tests. Three skinfold measurements were taken at each site with the average of the three measurements used as the skinfold value for the given site. Due to fluctuations in skinfold measurements caused by changes in body water, the pre- and post-measurements were taken at approximately the same time of day and month (16).

Lean body mass can also be expressed in terms of percent body fat. The equation used to convert lean body mass to percent body fat was:

$$\%\ \text{body fat} = \frac{\text{actual body weight (kg)} - \text{lean body mass (kg)}}{\text{actual body weight (kg)}} \times 100$$

Statistical Analysis

The tests selected for analysis of the data were the paired t-test, the Student's t-test for independent samples, one-way analysis of variance and Scheffe's test. The between trials and between variables correlations were calculated using the Pearson Product-Moment Correlation procedure. The .05 level of significance was selected for acceptance or rejection of the hypotheses formulated. The percent of change for strength and body composition measures and dynamic strength to body weight ratios were also calculated and analyzed.

IV. ANALYSIS AND INTERPRETATION OF THE DATA

Introduction

The purpose of this study was to assess the effects of a seven week power lifting weight training program on the dynamic strength, static strength, and body composition of college females. The data gathered were analyzed to determine the amount of change and the significance of the changes in dynamic strength, static strength and body composition over the experimental training period.

Results

The paired t-test was used to test the hypotheses formulated in this study. Other statistical tests used to analyze the data were the Student's t-test for independent samples, one-way analysis of variance, Scheffe's test and Pearson Product-Moment Correlation. The .05 level of significance was selected for acceptance or rejection of the hypotheses. The mean dynamic strength changes over the experimental period and t-test results for dynamic strength are summarized in Table 1. Table 2 contains the correlation coefficients for between trials and between variables of the dynamic strength, static strength and body composition parameters. The summary of the one-way analysis of variance of changes in dynamic strength between test dates and Scheffe's test results are presented in Table 3. Tables 4 and 5 contain

Table 1. Summary of pre-test and post-test data and t-test results dynamic strength and strength to body weight ratios.

Parameter	Pre-test Mean	Mid-test Mean (I)	Mid-test Mean (II)	Post-test Mean	Mean Change	Total % Change	Standard Deviation	Between trial r
DYNAMIC STRENGTH								
Bench Press (lbs)	94.23	101.15	105.00	107.69	13.46*	12.50	5.55	0.98
Squat (lbs)	160.00	177.50	190.83	211.25	51.25*	24.31	13.34	0.89
BP/SQ	0.60	0.57	0.55	0.52	-0.08*	13.33	-0.06	0.81
STRENGTH TO BODY WEIGHT RATIOS								
BP/BW	0.67	--	--	0.75	0.08*	10.67	0.03	0.98
SQ/BW	1.15	--	--	1.49	0.34*	22.82	0.10	0.78

t-Test Results

Parameter	t-value
Bench Press	8.75*
Squat	13.31*
BP/SQ	-4.96*
BP/BW	8.73*
SQ/BW	11.34*
Starting Poundages BenchPress-Squat	6.02*
Strength Gains Bench Press-Squat	9.39*

BP = Bench Press
SQ = Squat
BW = Body Weight

* Significant at .05 level of significance.

Table 2. Between variable correlation matrix.

	BW	LBM	SF	KE	TF	BP	SQ
BW	--	.95	-.03	.05	.29	.40	.24
LBM	--	--	-.07	-.05	.13	.50	.24
SF	--	--	--	.55	-.23	.31	.13
KE	--	--	--	--	-.03	.10	-.07
TF	--	--	--	--	--	.11	-.51
BP	--	--	--	--	--	--	-.03
SQ	--	--	--	--	--	--	--

Table 3. Summary of statistical analysis -- one-way analysis of variance changes in dynamic strength between test dates.

Parameter	Source	Numerator	df	-Q	F-value
Bench Press	Between	124.36	2	62.18	---
	Within	265.38	36	7.37	---
					8.43*
Squat	Between	304.17	2	152.09	---
	Within	1764.58	33	53.47	---
					2.84

SCHEFFE'S TEST RESULTS (BENCH PRESS)

S	$X_1 - X_2$	$X_2 - X_3$	$X_1 - X_3$
2.72	3.07*	1.16	4.23*

X_1 = mean change in strength between pre-test and mid-test (I).

X_2 = mean change in strength between mid-test (I) and mid-test (II).

X_3 = mean change in strength between mid-test (II) and post-test.

* significant at .05 level of significance.

Table 4. Summary of pre-test and post-test data and t-test results static strength.

Parameter	Pre-test Mean	Post-test Mean	Mean Change	Total % Change	Standard Deviation	Between trial r
Shoulder Flexion (lbs)	83.73	98.13	14.40*	14.67	16.87	0.61
Knee Extension (lbs)	142.43	159.23	16.79	10.55	27.33	0.79
Trunk Flexion (lbs)	84.23	83.20	-1.03	1.23	16.83	0.83

t-Test Results

Parameter	t-value
Shoulder Flexion	2.96*
Knee Extension	2.13
Trunk Flexion	-0.21

* Significant at .05 level of significance.

Table 5. Summary of pre-test and post-test data and t-test results body composition.

Parameter	Pre-test Mean	Post-test Mean	Mean Change	Total % Change	Standard Deviation	Between trial r
Body weight (lbs)	138.62	140.92	2.30*	1.63	3.79	0.97
Lean body mass (kg)	45.65	45.91	0.26	0.57	0.91	0.98
Percent body fat	26.30	26.92	0.62*	2.30	0.89	0.93

t-test Results

Parameter	t-value
Body weight	2.20*
Lean body mass	1.00
Percent body fat	2.40*

* Significant at .05 level of significance.

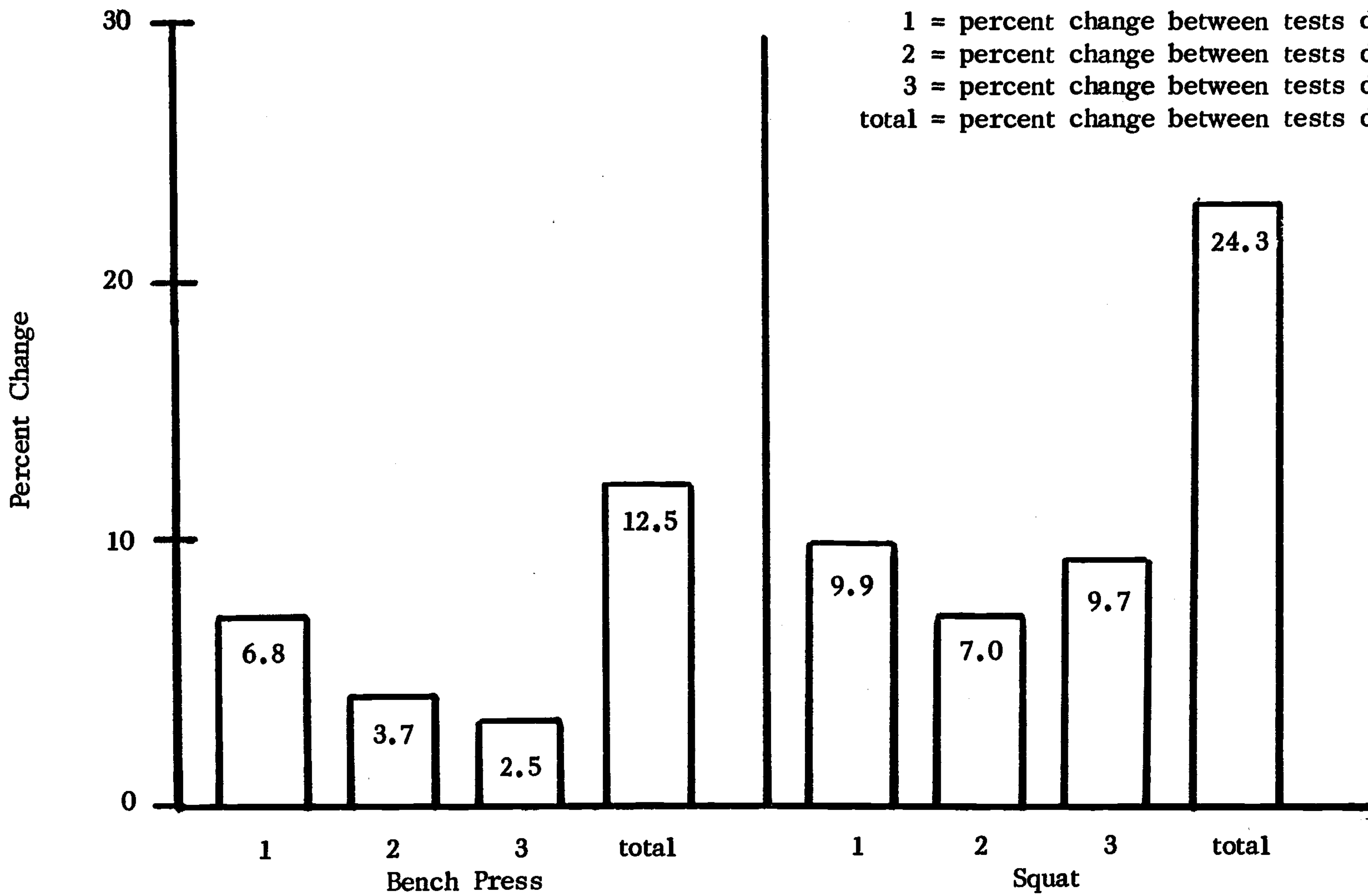
the summaries of the pre- and post-test data and t-test results for static strength and body composition, respectively. The demographic data for each subject are found in Appendix B.

Dynamic Strength

Changes in dynamic strength occurred over the training period (Table 1, Figure IX). Bench press strength increased an average of 13.5 pounds or 12.5% and squat strength increased an average of 51.3 pounds or 24.3%. The increases in the bench press and squat ranged from five to 25 pounds and 25 to 70 pounds, respectively. The correlation between the pre- and post-bench press tests was r = .98, and r = .89 for the squat (Table 2). Both of the changes in dynamic strength were significant at the .05 level.

In addition to analyzing the absolute changes in dynamic strength over the training period, the differences between the starting poundages and the strength changes of the bench press and squat were also examined (Table 1). Results of the analysis revealed that the 24.3% increase in squat strength was significantly greater than the 12.5% increase in bench press strength. The correlation between the changes in squat strength and bench press strength was r = -.03 (Table 2). The differences between the initial poundages for the bench press and squat were also found to be significant with initial squat strength being appreciably greater than initial bench press strength.

Figure IX. Percent changes in dynamic strength.



Dynamic strength was also analyzed in terms of strength to body weight ratios and bench press to squat ratio (Table 1). Both the bench press to body weight (BP/BW) and squat to body weight (SQ/BW) ratios increased significantly over the seven week training period. The bench press to squat ratio (BP/SQ) decreased significantly, indicating squat strength increased to a greater degree than bench press strength as was shown above by the comparison of the changes between the bench press and squat.

An one-way analysis of variance was used to examine the dynamic strength gains between the four testing dates (Table 3, Figure IX). No significant difference was found in the amount of change that took place between the four squat test dates. The lack of an appreciable difference indicates the rate of increase in the squat was equal throughout the training period. A significant difference did exist between the four bench press test dates. The Scheffe's test was used to determine which changes in the bench press were significantly different. The results revealed that the average change in bench press strength between the initial and second test dates was significantly greater than the changes that occurred between the second and third and third and final test dates. The changes between the second and third and third and final test dates were not appreciably different from each other. Thus, the greatest amount of change in the bench press occurred in the first two weeks of the strength training program and then increased at a constant rate throughout the remainder of the training period.

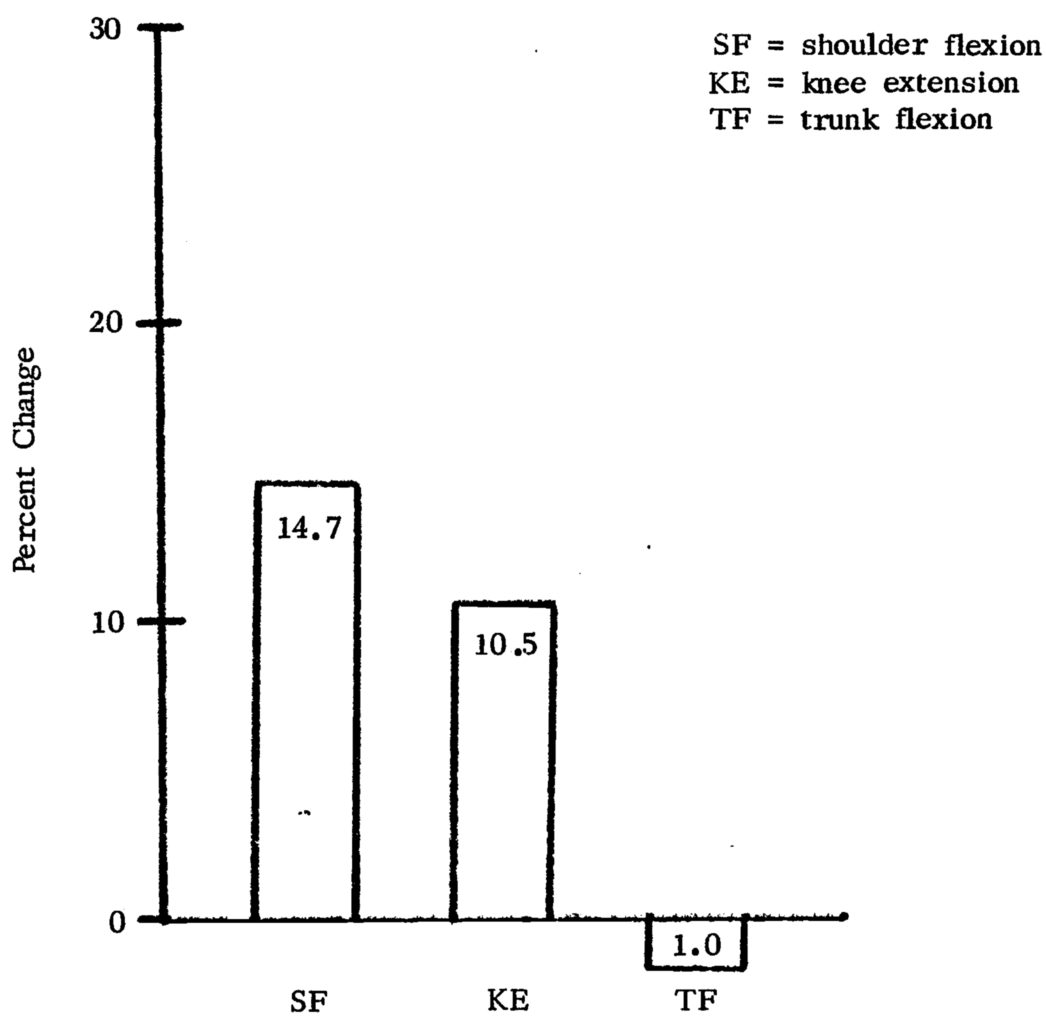
Static Strength

The changes in static strength over the experimental training period consisted of an average increase of 14.4 pounds in shoulder flexion, a 16.8 pound average increase in knee extension, and an average decrease of 1.03 pounds in trunk flexion (Table 4, Figure X). The ranges of static strength scores were -15.0 to 50.0 pounds, -10.0 to 60.0 pounds and -20.8 to 37.5 pounds for shoulder flexion, knee extension and trunk flexion, respectively. The correlation between the pre- and post-test scores were r = .61 for shoulder flexion, r = .79 for knee extension and r = .83 for trunk flexion (Table 2). Of the changes in static strength, only the increase in shoulder flexion proved to be significant at the .05 level. The changes in knee extension and trunk flexion were not significant.

Body Composition

Body weight, lean body mass and percent body fat were all measured before and after the training period. Body weight and percent body fat increased an average of 2.3 pounds and 0.61%, respectively. Both of the increases were significant at the .05 level. Lean body mass also increased, 0.26 kilograms, but the increase

Figure X. Percent changes in static strength.



was not significant (Table 5, Figure XI). The correlations between the pre- and post-test body composition tests were r = .97, r = .98 and r = .93 for body weight, lean body mass and percent body fat, respectively.

Summary

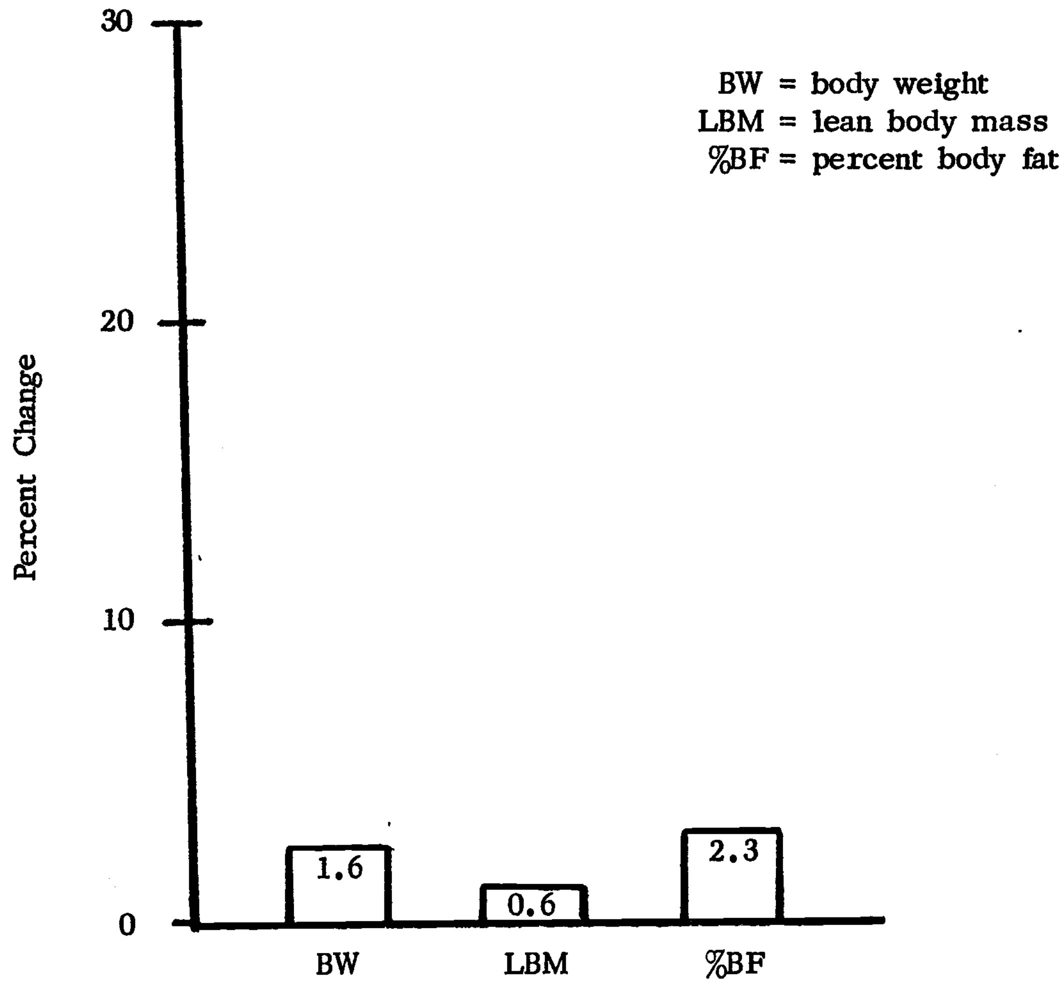
The changes in strength over the experimental training period varied depending on the type of strength tested and the muscle groups tested. Both types of dynamic strength tested, bench press and squat, increased significantly. The changes in static strength were less consistent. Shoulder flexion strength increased significantly, but neither trunk flexion nor knee extension strength changed appreciably. Alterations in body weight and lean body mass also took place over the training period. Only the increase in body weight was significant.

Discussion

Dynamic Strength

A significant finding of this study was the increase found in dynamic strength following the seven week strength training period (Table 1). The data of this study supports the findings of other strength training studies involving female subjects in which dynamic strength

Figure XI. Percent changes in body composition.



was measured (10, 64). Direct comparison of the dynamic strength results of this study to the previous studies is difficult due to the type of strength testing used, the duration of the studies, the subject population and the exercises utilized in the training program.

The major difference between this study and previous studies is the amount of change in dynamic strength that took place over the training period. Increases in strength are dependent upon several factors. One set of factors is related to the training program imposed. The intensity, frequency, duration and type of exercises of an imposed training program all influence to varying degrees the gains in strength (14, 29, 52).

Subject selection relative to the amount of weight training experience also influences the final outcome of a training program. The initial level of strength affects the rate of strength increases in a weight training program (26, 53). Muscle strength increases to a given level which is dependent on the genetic capacity of the muscle. A trained muscle, closer to its genetic limit than an untrained muscle, does not have the same potential for strength development (26, 53). In this study no distinction was made between the subjects relative to weight training experience. Thus, no relationship could be made between the strength changes in trained and untrained individuals.

Subject selection relative to the type of previous and current training practices, aerobic versus anaerobic, may also influence the results of a strength training program. Anaerobic and aerobic training elicit different physiological adaptations. The imposition of a strength training program, which is anaerobic in nature, thus may affect the physiology of an aerobically trained muscle and individual differently than the physiology of an anaerobically trained muscle and individual. The subjects in this study were not described in aerobic or anaerobic terms, thus comparisons could not be made.

Another major factor which accounts for the differences in strength gains between this study and previous ones is the techniques used for the execution of the bench press and squat. This study followed the techniques outlined in the Official Rules of the International Powerlifting Federation (32). The bench press and squat as described by the International Power Lifting Federation are performed through a full range of motion. Previous female strength training studies did not follow the techniques outlined by the International Power Lifting Federation for the bench press and squat and did not execute the exercises through a full range of motion.

A difference in the difficulty exists between the execution of the full squat as compared to the partial squat. The leverage, angles of muscle pull and contributions of the numerous one- and two-joint muscles involved in the squat dictate the difficulty of execution (43). At the bottom position in the full squat (top of thighs parallel to the floor) the leverage and angle of muscle pull of the knee and hip extensors are at a disadvantage, thus making the completion of the squat (back to the standing position) more difficult. Also at the bottom position the knee and hip extensors become isolated requiring greater strength in the isolated muscle groups to complete the lift. In the partial squat the leverage and angles of muscle pull are at an advantage, and the muscle groups are working synergistically rather than separately. These factors allow the partial squat to be performed with less difficulty than the full squat.

Therefore, increases in strength for the squat or other exercises performed through a full range of motion require improvements in technique, balance and muscle group coordination in addition to increases in isolated and synergistic muscle group strength. The differences in the execution of an exercise, partial versus full range of motion, thus influence the gains in strength made from a given training program.

The increase in squat strength was significantly greater than bench press strength in this study. Brown and Wilmore (10) also found a greater increase in squat strength relative to bench press strength. The greater gains found in the squat can be attributed to two major factors. One factor is the muscle groups utilized in the bench press and squat. The major muscle group exercised in the bench press is the anterior deltoids which are smaller and weaker than the muscle groups used in the squat, namely the hip flexors and extensors; the quadriceps, gluteus maximus, abdominals and the erector spinae. Utilization of a larger muscle mass creates a greater potential for increases in strength since more muscle fibers are able to adapt to the stresses of a training program.

The second factor is related to the specificity of training principle. Greater daily use of the legs compared to the upper body results in a greater training stimulus for the leg muscles. One adaptation of training is an increased efficiency of the neuromuscular system which leads to a greater ability of the muscles to adapt to the stresses of weight training and thus to increase strength (46). The fact that the subjects were able to maintain a steady increase in workload for the squat but not the bench press throughout the training period supports the concept of a greater adaptability potential of a trained muscle due to increased efficiency of the neuromuscular system.

Even though both bench press and squat strength increased significantly, the correlation between the gains in bench press and squat strength ($r = -.03$) indicates that the development of strength in the upper body is not influenced by the development of strength in the lower body or visa versa. Thus, the training effect is specific to the area being trained.

The specificity of training principle may also provide an explanation for the greater increase in bench press strength between the first and second testing dates than between the other testing dates. Since females do not ordinarily use the upper body to any great extent, initial training of the upper body causes adaptations to occur rapidly. These primary adaptations are reflected in rapid increases in strength. Once the upper body is conditioned to training, adaptations, and thus strength increases, occur at a slower rate.

Strength to Body Weight Ratios

The dynamic strength to body weight ratios, BP/BW and SQ/BW, can be used to indicate strength relative to body weight. Strength expressed as force exerted per pound of body weight allows for comparison of the strength of females of different weight classes. No previous research was found which expresses strength in a ratio to body weight. Thus, comparison of the strength ratios computed in this study was not possible.

The ratio of BP/BW was less than the ratio of SQ/BW for all subjects in this study. This finding can be attributed to the amount of muscle and body mass involved in the execution of the respective lifts. The larger muscles used in the squat allows for a greater percentage of body weight to be lifted, resulting in a greater SQ/BW ratio. The execution of the squat also requires a greater proportion of body mass to be moved which involves the utilization of more muscle groups. The execution of the bench press isolates the upper body muscle groups.

The SQ/BW ratio also increased more than the BP/BW ratio over the seven week training period (Table 1). This finding results from the greater increase in squat strength compared to bench press strength over the training period.

Neuromuscular Aspects of Strength

The rapid increase in dynamic strength which occurred in this study can not be totally attributed to physiological adaptations of the muscle fiber. Adaptations of the neuromuscular system are considered primary to early increases in muscular strength (14, 29, 40, 57). With training the neuromuscular system becomes better organized and more efficient which results in a greater expression of strength without changes in the physiology of the muscle. Increased neuromuscular efficiency also improves the ability of the muscle to adapt to imposed stresses of a training program imposed in this study.

The major difference between machine and free weight strength training is the effect of the respective training methods on the neuromuscular system. Machine training does not require the same amount of balance and muscle group coordination as free weight training.

Therefore the stimulus for adaptations relative to the neuromuscular system is reduced. Since the early gains in strength are attributed to alterations in the neuromuscular system, machine training may elicit different rates of strength gain than free weights during a strength training period.

Although adaptations in the neuromuscular system are given the majority of credit for the early increases in strength, physiological adaptations in the muscle and body in general also take place and influence the increases in strength. Little information on the effects of strength training on the physiology of females is available. Thus, the actual contributions of the physiological adaptations to gains in strength in females are unknown.

The information that is available relative to female physiology and physical training mainly pertains to the physiological differences that exist between males and females. The ability of the muscle to exert force has been found to be equal in males and in females, but other physiological differences between the sexes (i. e., hormonal) may cause different responses to a similar training stimulus. Studying the development of strength between males and females thus may generate valuable information relavant to physical training for females.

Psychological Aspects of Strength

The psychological state of the subject is also important in the expression of strength. Throughout the training period the subjects seemed to gain confidence in both their skill and potential to increase strength. The observed increase in confidence was a subjective assessment made by this researcher based on the attitudes expressed by the subjects toward their own improvements in strength and interest in continuing strength training. The increased confidence appeared to create a motivation to continue progressive overload training and to achieve greater 1 RM's.

The dynamic strength testing and training environments also provided considerable psychological input for the subjects. Support and encouragement from fellow subjects was given throughout the testing and training periods. A presence of psychological input can greatly influence the performance capacity of an individual. Although the ultimate capacity to exert force depends on the physiological nature of the muscle, individual performances can be limited by psychological and neuromuscular factors (31). Even though not measured in this study, psychological factors seemed to make considerable contributions to the increases found in muscular strength.

Static Strength

Three static strength tests were used in this study, shoulder flexion, trunk flexion and knee extension. The tests were selected in an effort to measure the muscle groups emphasized in the bench press and squat.

The shoulder flexion test was used relative to the bench press. Although shoulder flexion strength increased significantly with an increase in bench press strength (Table 4), the correlation between the gains in bench press and shoulder flexion strength was low ($r = .31$) implying no relationship between the two gains. This implication supports the conclusions made by Berger (7) that static strength tests do not adequately measure changes in strength due to a dynamic strength training program. No previous female dynamic strength training studies were found in which shoulder flexion strength was measured, thus no comparison of the data could be made.

Knee extension and trunk flexion were measured relative to the squat. Squat strength increased significantly in this study, but knee extension and trunk flexion strength did not parallel the increase. The correlation between the gains in knee extension and trunk flexion strength and squat strength were $r = -.07$ and $r = -.51$, respectively. The low correlations suggest no relationship exists between dynamic strength and static strength gains, again supporting the conclusions made by Berger (7). Trunk flexion tests were not used in previous studies, thus the relevancy of the lack of increase in trunk flexion could not be determined. The lack of significant increase in knee extension strength contradicts the findings of Capen (12) and Wilmore (64) who found appreciable increases in knee extension strength in females following dynamic strength training.

Abdominal strength (trunk flexion) and quadricep strength (knee extension) are considered necessary in the execution of the squat (53). Thus, the lack of significant increase in trunk flexion and knee extension is difficult to explain. One possible explanation may be the technique used to execute the squat. The actual contributions made by abdominal and quadricep strength are influenced by biomechanical factors of the squat. McLaughlin, et al (43) found the degree of trunk lean determines the contribution of the quadriceps and trunk extensors in the performance of the squat, thus influencing the degree of muscle strength gained in the respective muscle groups. Trunk lean was not specified in the Official Rules of the International Powerlifting Federation, and thus was not controlled during this study.

Another possible explanation for the lack of significant increases in knee extension and trunk flexion may be the differences in the testing environments for static and dynamic strength. Dynamic strength testing was conducted in the same room where the training took place and with fellow subjects present. The environment provided both emotional and psychological input which could have affected the results of the dynamic strength tests. The static strength testing environment did not offer the same psychological input. Each subject was tested alone and no encouragement was given during the testing period. Competition between subjects was also eliminated. Thus, the lack of psychological input may have influenced the amount of change found in static strength relative to dynamic strength in this study.

Body Composition

The lack of significant increase in lean body mass in this study supports the findings of other female strength training studies (10, 12, 64). Since the dynamic strength increases found in this study are partially attributed to noncellular adaptations of the muscles, slight changes in the physiological aspect of the muscle will reflect slight alterations in body composition, specifically lean body mass.

A slight, but significant increase in body weight occurred over the training period (Table 5). Wilmore (64) reported little or no change in body weight in females over a ten week training period. The differences in the results of the two studies may be attributed to the differences in the intensities of the programs imposed.

Although lean body mass was the body composition parameter of interest in this study, knowledge of the changes in percent body fat is useful in the interpretation of the body composition results. Individuals involved in anaerobic training are usually characterized as having greater amounts of body fat than aerobically trained individuals (25). Statistical analysis of the changes in body fat over the training period demonstrated a slight, but significant increase in body fat. Since in this study lean body mass did not change significantly, the changes in body weight can be attributed to alterations in body fat. Thus, the significant increase in body weight may have been due to the training program being anaerobic in nature rather than to the actual changes in strength.

Applications

Strength is considered an essential element in the attainment of an optimal level of fitness. Yet, of all the components of fitness, strength is the one most frequently deficient in females. The reason for the deficiency can be attributed to social pressures and unsupported scientific beliefs regarding the effects of strength training on females. The finding in this study that females can tolerate a heavy resistance strength training program, and significantly increase strength without a significant increase in muscle bulk refutes several of the common myths regarding females and strength training as presented in Chapter I. Thus, a step can be made in the direction of allowing females to attain their full physical potential without the restraints of social pressures or myths.

The finding that females have the ability to tolerate a heavy resistance powerlifting training program which significantly increases dynamic strength also has important implications for the female athlete. Succèssful performance in athletic events, especially the shotput, javelin and discus, not only demand an optimal level of strength, but also require an ability to generate that strength through a full range of joint motion. The major cornerstone of athletic training is the specificity concept. Thus, to attain maximum performance capacity in an athletic event, the female must participate in a training program which meets the demands of the event, neuromuscularly and physiologically, and utilizes the fundamental scientific strength building principles like those used in this study.

V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The puspose of this study was to assess the effects of a seven week power lifting weight training program on the dynamic strength, static strength and body composition of college females. Thirteen college females volunteered for the study. The training program consisted of a two week pre-conditioning period followed by a seven week power lifting training program. The subjects trained three days per week. Static strength and body composition were measured at the beginning and end of the experimental period. Dynamic strength tests were administered following the pre-conditioning period, at two mid-training dates, and at the end of the training period. The test data were statistically analyzed using a paired t-test, Student's t-test for independent samples, one-way analysis of variance, Scheffe's test and Pearson's Product-Moment Correlation. The .05 level of significance was selected for accepting or rejecting the null hypotheses.

The results of the statistical analysis of the test data required rejecting hypothesis one which states that the dynamic strength of college females, as expressed by bench press and squat strength, will not be modified by a power lifting weight training program. Hypothesis two which states that the static strength of college females, as expressed by shoulder flexion, trunk flexion and knee extension strength, will not be modified by a power lifting weight training program could not be totally accepted or rejected due to the varied results of the changes in static strength. Shoulder flexion strength increased significantly, but trunk flexion and knee extension strength did not. Hypothesis three which states that the body composition of college females, as expressed by body weight and lean body mass, will not be modified by a power lifting weight training program also could not be totally accepted or rejected. Body weight increased slightly, but significantly, whereas lean body mass did not change significantly following the experimental training period.

Conclusions

The following conclusions have been formulated from the data presented by this study:

1. A seven week power lifting weight training program did significantly increase the dynamic strength of college females.
2. A two week pre-conditioning and seven week power lifting weight training program significantly increases shoulder flexion strength, but not knee extension or trunk flexion strength.
3. A two week pre-conditioning and seven week power lifting weight training program does not significantly increase the

lean body mass of college females. A slight, but significant increase in body weight does occur.

Recommendations

The results of this study and the lack of research in the area of strength training for females are the basis for the following recommendations:

1. Further research should be conducted with a larger female subject population on the long term effects of dynamic strength training.
2. Further research should be conducted to compare the changes in strength between weight trained and untrained females subjected to a similar strength training program.
3. Further research should be conducted to compare the changes in strength between males and females involved in similar strength training programs.
4. Further research should be conducted to determine the physiological changes (i. e., hormonal, blood composition, muscle enzymes, and muscle fiber composition) that occur in females due to strength training.
5. Further research should be conducted to compare the effects of dynamic strength training between aerobically trained and anaerobically trained female athletes.

6. Further research should be conducted to compare the effects of dynamic strength of females involved in machine training versus free weight strength training.

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APPENDIX A

SAMPLE WORKOUT

Week 1

Subject: Mary Doe

Body Weight: 120

1-RM	
Bench Press	120
Squat	170

Exercises	Reps.	Sets	Weight
1. Flexibility and stretching 8-10 minutes			
2. Seated front latissimus pull down to the chest.	8-10	2	50 pounds
3. Standing front lateral dumbell raise	8-10	2	10
4. Bench press*	6-8	1	60
	5	1	75
	3-5	4	85
5. Seated front latissimus pull down to the chest	8-10	1	50
6. Rounded back deadlift	8-10	1	50
	8-10	1	65
7. Squat*	8-10	1	75
	5	1	100
	3-5	4	120
8. Flexibility and stretching of lower back 5-6 minutes			

* Starting poundages are 70 percent of 1-RM
Each Monday training loads are increased by 5 and 10 pounds respectively in the bench press and squat.

APPENDIX B

INDIVIDUAL DEMOGRAPHIC DATA

		Body Weight Test Periods (lbs)			Lean Body Mass Test Periods (kg)			Percent Body Fat Test Periods		
Subject	Age	1	2	Change	1	2	Change	1	2	Change
GA	30	122	125	+ 3	42.1	42.9	+0.8	23.8	23.7	-0.1
LB	18	152	163	+11	49.5	51.6	+2.1	27.9	29.3	+1.4
TC	19	151	156	+ 5	50.7	51.7	+1.0	25.3	26.4	+1.1
PD	22	121	124	+ 3	41.5	41.7	+0.2	24.1	25.3	+1.2
LF	20	145	141	- 4	47.5	46.5	-1.0	27.2	26.7	-0.5
TG	21	150	153	+ 3	51.5	----	----	23.8	----	----
NG	20	144	147	+ 3	48.3	48.3	0.0	25.5	27.1	+1.6
VH	20	132	131	- 1	42.8	42.3	-0.5	28.0	28.4	+0.4
JK	24	132	135	+ 3	42.1	41.6	+0.5	29.2	31.2	+2.0
CR	29	125	128	+ 3	43.0	44.0	+1.0	23.6	23.6	0.0
TR	19	135	132	- 3	45.2	44.7	-0.5	25.7	24.8	-0.9
SR	18	161	165	+ 4	51.4	52.3	+0.9	29.0	29.4	+0.4
JT	18	132	132	0	43.7	43.3	-0.4	26.3	27.1	+0.8

APPENDIX B (Continued)

Subject	Shoulder Flexion Test Periods (lbs)			Knee Extension Test Periods (lbs)			Trunk Flexion Test Periods (lbs)		
	1	2	Change	1	2	Change	1	2	Change
GA	80.0	87.5	+ 7.5	160.0	150.0	-10.0	110.0	95.0	-15.0
LB	71.7	92.5	+20.8	135.0	193.3	+58.3	80.0	77.5	- 2.5
TC	100.0	125.0	+25.0	176.7	175.0	- 1.7	95.0	100.0	+ 5.0
PD	75.0	75.0	0.0	137.5	173.3	+35.8	57.5	95.0	+37.5
LF	97.5	147.5	+50.0	170.0	223.3	+53.3	163.3	150.0	-13.3
TG	122.5	---	---	228.5	---	---	63.3	---	---
NG	102.5	105.0	+ 2.5	226.7	220.0	- 6.7	75.0	87.5	+12.5
VH	75.0	82.5	+ 7.5	120.0	120.0	0.0	67.5	46.7	-20.8
JK	71.7	87.5	+15.8	137.5	137.5	0.0	57.5	57.5	0.0
CR	73.3	80.0	+ 6.7	87.5	105.0	+17.5	75.0	55.0	-20.0
TR	120.0	105.0	-15.0	113.3	113.3	0.0	90.0	87.5	- 2.5
SR	75.0	95.0	+20.0	105.0	100.0	- 5.0	80.0	95.0	+15.0
JT	63.0	95.0	+32.0	140.0	200.0	+60.0	60.0	51.7	- 8.3

APPENDIX B (Continued)

Subjects	Bench Press Test Periods (lbs) 1	2	3	4	Total Change	Squat Test Periods (lbs) 1	2	3	4	Total Change
GA	85	90	95	100	+15	165	180	190	210	+45
LB	85	95	100	105	+20	130	150	165	190	+60
TC	130	140	140	140	+10	205	220	240	255	+50
PD	70	80	80	85	+15	140	150	150	165	+25
LF	90	100	105	105	+15	175	195	210	225	+50
TG	145	150	150	150	+ 5	200	220	240	250	+50
NG	90	95	100	100	+10	150	170	190	220	+70
VH	70	75	80	85	+15	---	---	---	---	---
JK	80	85	90	95	+15	135	150	170	200	+65
CR	70	75	80	85	+15	135	155	165	205	+70
TR	130	135	135	135	+ 5	160	175	175	200	+40
SR	105	115	125	130	+25	200	220	230	240	+40
JT	75	80	85	85	+10	125	145	165	175	+50

OREGON STATE UNIVERSITY

Committee for Protection of Human Subjects

Chairman's Summary of Review

Title: Power Weight Training Applied to College Females

Program Director: John P. O'Shea, Physical Education

Recommendation:

X Approval*

____ Provisional Approval

____ Disapproval

____ No Action

*The informed consent forms obtained from each subject need to be retained for the long term. Archives Division of the OSU Department of Budgets and Personnel Service is willing to receive and archive these on microfilm. At present at least, this can be done without charge to the research project. Please have the forms retained in Archives as well as in your files.

Remarks: 1. The following should be added to the informed consent form as a separate terminal paragraph:

Oregon State University, as an agency of the State of Oregon, is covered by the State Liability Fund. If any injuries are suffered as a result of the research project, compensation would be available only if it is established that the injury occurred through a fault of the University, its officers or its employees.

2. To provide complete anonymity, it would be better to identify subjects by number in any report, rather than by initials.

Date: December 5, 1979 Signature Redacted for Privacy

If the recommendation of the committee is for provisional approval or disapproval, the program director should resubmit the application with the necessary corrections within one month.

The Department of
Physical Education

Oregon State University

Corvallis, Oregon 97331

INFORMED CONSENT RELEASE

In consideration of the benefits to be derived and the data to be generated, the undersigned, a student at Oregon State University, agrees to participate in the research project, "Power Weight Training Applied to College Females," under the direction of J. P. O'Shea, Professor of Physical Education, Oregon State University.

The undersigned states that she has read an outline of the proposed study, including the possible risks and benefits, and is participating, voluntarily and consents to following the testing and training program outlined. The undersigned also agrees to the use of the data generated therefrom as the above agencies may desire.

At any time during the study, if circumstances should arise and the undersigned cannot complete the study, she is free to discontinue.

Oregon State University, as an agency of the State of Oregon, is covered by the State Liability Fund, If any injuries are suffered as a result of the research project, compensation would be available only if it is established that the injury occurred through a fault of the University, its officers or its employees.

____
Participant

____
Date