# A STUDY OF THE EFFECTS OF LEG STRENGTHENING EXERCISES ON THE VERTICAL JUMPING AND SPEED OF RUNNING OF COLLEGE WOMEN

by

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The primary purpose of this study was to determine what effect a program of leg strengthening exercises would have on the leg strength, vertical jumping, and running speed of college women. A secondary purpose of this investigation was to determine the relationships among leg strength, vertical jumping, and running speed both before and after the administration of an exercise program designed to increase leg strength.

This study used twenty-nine women physical education major students of the University of North Carolina at Greensboro as subjects. These subjects were randomly selected and randomly assigned to either Group A, the exercise group, or Group B, the control group. Both groups were given initial and final tests of leg strength, vertical jumping, and running speed, measured respectively by a Back and Leg Dynamometer, the Modified Vertical Power Jump Test, and an electronic timing device designed specifically for use in this study. After the initial testing session, the exercise group, Group A, was given a four-week exercise program designed by the writer to increase leg strength. The exercise program consisted of eight exercises progressively increased in number of repetitions over the twelve sessions.

The analysis of covariance statistical technique was used to compare the groups. Since the two groups were not originally equated, it was necessary to use this particular statistical procedure in order to adjust any preexperimental differences which might have existed between the groups. The Product Moment method of Correlation was used to

determine the relationships among leg strength, vertical jumping and running speed based on the initial and final test data.

On the basis of the results of this study, the following conclusions were drawn:

1. The four week exercise program designed to increase leg strength had no significant statistical effect on the vertical jumping ability and speed of running of college women.
2. The four week exercise program designed to increase leg strength significantly improved the leg strength of the experimental group, Group A.
3. Leg strength was not significantly correlated with either vertical jumping or running speed based on the initial and final test data for Group A and Group B.

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# CHAPTER I

## INTRODUCTION

From the days of the Greeks to our modern times, athletes have conditioned themselves through various exercises and activities. (7) These training methods and activities have changed over the years in direct proportion to our increasing knowledge of man's physiological behavior. The basic purpose of athletic conditioning, however, has remained the same from the time of the Greeks until now; this purpose being to increase the efficiency of man's neuromuscular performance.

Coaches and trainers today seem to recognize two types of athletic conditioning programs. (14) One is an "all-around" training program which consists of equally extensive exercises to develop strength, endurance, and speed. The second type is specialized training which consists of exercises directed towards the development of only one of the three areas: strength, endurance, or speed. These three factors seem to be inseparable, however, as an increase in strength is accompanied by a speed and endurance increase to some extent. (14, 2)

Because strength has been considered a prerequisite of superior performance in any form of sports (10), its development has been and will continue to be one of the prime concerns of any athletic training program. McCloy (11) has called strength the most important element in motor performance.

Taking McCloy's statement as fact, one could assume that developing the strength of an individual to the utmost would inherently increase his or her ability to perform motor skills. Specifically, one could deduce that developing the strength of a certain body segment would inherently increase any motor performance which utilized this particular body segment.

Accepting McCloy's statement as prophetic judgment and using apriori reasoning, this writer decided to test this hypothesis of increased strength producing increased motor performance. For the motor skills, running and vertical jumping, two skills which are used in various sports and activities, were selected. Since the legs are utilized particularly in these skills, this writer wished to determine the effect of increased leg strength upon the performance of these two skills. To do this, it was necessary to design a specialized training program for leg strength development.

In a review of the literature concerning this hypothesis of increased performance through increased strength, this writer found many similar studies. The results of these will be cited in Chapter III. The majority of these studies, however, used men as subjects. Due to certain structural differences of men and women which have been found to influence running and jumping skills in particular, this writer doubts the validity of applying the conclusions of such studies to women under similar conditions.

The fact that there have been more studies using men as subjects is probably due to the more skilled performances demanded of men in numerous athletic events. Whereas highly skilled competition has been available for men for many years, it is a relatively new concept for women in athletics.

Through determining the factors which influence selected motor performances, it has been possible to identify potentially outstanding performers as well as to improve skills. It is hoped that this study will help in determining what influence leg strength has upon the basic skills of running and jumping in women.

## CHAPTER II

## STATEMENT OF PROBLEM

The purposes of this study were: (1) to determine if a program of leg strengthening exercises would affect the vertical jumping and speed of running of college women; and (2) to study the relationships among leg strength, vertical jumping ability, and speed of running both before and after the administration of an exercise program designed to increase leg strength.

## DEFINITION OF TERMS

For the purposes of this study, the following definitions have been accepted:

Static Strength--The ability to exert muscular force against an external resistance.

Dynamic Strength--The ability to utilize muscular force in a total or partial body movement.

Isometric Training--Exercises which involve static strength and require no shortening of the muscles in contraction.

Isotonic Training--Exercises which involve dynamic strength and require a shortening or lengthening of the muscles in contraction.

## LIMITATIONS OF THE STUDY

1. Although the use of women physical education majors as subjects enhanced the study in several ways, this writer felt that the motivation and competitive spirit inherently present among the students in the experimental and control groups may have altered the results.
2. Using such small samples, the predictive value of the results of this study was diminished considerably.

## CHAPTER III

## REVIEW OF LITERATURE

There has been much research which can be related to different aspects of this particular study. In order to facilitate the discussion of such studies, this author has divided the review of literature into the following sections: Strength: Its Definition, Development, and Measurement; The Vertical Jump; and Speed of Movement.

### STRENGTH: ITS DEFINITION, DEVELOPMENT AND MEASUREMENT

One of the first problems confronting an investigator in a study involving strength is establishing a good definition of the term. An extensive review of literature on strength and its development indicates that an adequate definition does not exist. This difficulty in defining strength seems to arise from the many different connotations of the word. (5)

Cureton (4) has described strength as the capacity of the body to exert force on some external resistance whereby the body pushes, pulls, kicks, lifts, or carries some object.

Mathews (12) defines strength as the force that a muscle or group of muscles can exert against a resistance in one maximum effort.

Larson (35), in his study on the factor analysis of strength variables, defines two types of strength. One is static dynamometrical strength, the ability to push, pull, squeeze, or lift as registered on a dynamometer. This he designated as strength. The second type is dynamic strength, or the ability to propel the body weight as in a vertical jump. This type he called power.

Glencross (57) has described muscle power principally as a coordinated combination of speed of movement and strength, with the former being the more important.

Davis and Logan (5) have concluded that the bulk of strength definitions seem to fall into two main categories. The first category generally defines strength as the ability to exert one maximum effort against resistance. The second category regards strength as the ability of the muscle to exert repetitious effort until it becomes fatigued.

Similar to the general disagreement on a definition of strength is the dissension among physical educators regarding the best method to develop strength.

According to Davis and Logan (5), there are three methods currently in use for the development of strength. The first and most widely used is De Lorme's system of progressive resistance exercises. This system consists of determining the maximum resistance which can be overcome for ten repetitions. The second method, devised in England by Zinovieff, is known as the Oxford technique. It is essentially the opposite of De Lorme's procedures. The third and most recent technique is the procedure developed by Hettinger and Muller of Germany. The first two techniques utilize isotonic contractions through a range of motion, whereas the third method employs the use of isometric or static contractions.

All three of these methods employ the use of the overload principle for strength development. This is a process of progressively increasing the work done by a muscle in order to increase strength. Overload can be produced in several different ways. Lockhart (5:65) has presented the following four ways in which overload can be accomplished:

> (1) Gradually increase the speed of performance in a progressive manner;
> (2) Gradually increase the total load;
> (3) Progressively increase the total time that a given position can be held;
> (4) With a constant resistance, progressively increase the total number of performances. (5:65)

Much of the more recent literature on strength development has involved a comparison of isometric and isotonic training. Rasch and Morehouse (42), in a study comparing the effects of static and dynamic exercises on elbow flexor strength, found that isotonic training increased strength and hypertrophy significantly more than isometric training. However, the investigators reported that the isometric exercise group felt frustrated throughout the experiment because they could not see or feel the benefits of their training. Rasch and Morehouse concluded that this attitude might have affected the results of the experiment.

Mathews and Kruse (37) found that the isometric type exercise caused a greater number of subjects to gain significantly in elbow flexor strength when compared with an isotonic exercise group.

Liberson and Asa (9) also found that daily brief isometric exercises increased muscle strength more rapidly and at least as fully as classical isotonic exercises.

Berger (20), in a study of dynamic and static training programs, found that dynamic overload training was more effective for increasing vertical jump ability than static overload training.

Several factors can possibly explain the contradictory findings of the studies comparing the effects of isotonic and isometric exercises in strength development. One is the difficulty investigators encounter in equating the amount of energy expenditure produced by isometric training with that produced by isotonic training. (42) To date, no one has devised a formula which can be used to equate an amount of isometric contractions with a specified number of isotonic repetitions.

A second factor is concerned with the specific type of strength measure used in the studies. Many studies comparing strength changes due to static and dynamic training have used a static strength test as the initial and final measures. (37,42,42) This is assuming that an increase in dynamic strength will always result in a proportionate increase in measured static strength. This assumption has not been substantiated. (21)

Berger (21), in a comparison of static and dynamic strength increases, used both a static and a dynamic strength test to evaluate his results. He found that a static strength test is not as accurate as a dynamic strength test in measuring changes resulting from dynamic muscle training. He also concluded that the inverse was true: A dynamic strength test is not as accurate as a static strength test in measuring changes in strength resulting from static muscle training.

One of the oldest measures of static strength is the dynamometer. The use of the dynamometer dates back to the 17th century when it was first employed by French anthropologists for strength measurement. (12)

The measuring of specific leg strength through the use of a Back and Leg Dynamometer became well known when Sargent devised the Intercollegiate Strength Test in 1873. (12)

Everts and Hathaway (27) improved on the use of the dynamometer as a valid and objective means of measuring leg strength by adding the belt attachment in 1938.

Glencross (56) has recently identified several disadvantages of using the dynamometer for measuring leg strength. Among these are the unsuitability of the apparatus to the individual, the need for a maximum effort requiring much strain, and the difficulty of adjusting the equipment to the stature of the individual while still retaining the standard angle and strain of pull.

Another well-known measure of static strength is the Cable Tensiometer. This instrument was adapted to strength testing by Clarke and Peterson in 1945. (34) A recent study by Kennedy (34) indicated that the Cable Tensiometer may be substituted for the dynamometer for use in measuring back and leg strength. He found the objectivity for using the tensiometer to be .90 and the correlation between the two instruments to be .92.

Dynamic strength measurement has lagged far behind the development of static strength measures. Berger (21) attributes this to the trial and error procedure which must be used to devise a dynamic strength measure.

In an effort to measure dynamic leg strength, Smith (47) modified the use of the dynamometer by having his subjects place their hips and back against a wall and contract the leg muscles in a very explosive manner.

In 1960, Glencross (56) developed a measure of dynamic leg strength by measuring the leg power used in projecting the body weight vertically upward. He called this measure the Vertical Power Jump Test. This test involved the computation of each subject's center of gravity and use of the mathematical formula: Power=Work/Time.

Gray, Start and Glencross (28) modified this Vertical Power Jump Test in 1962 in order to increase administrative feasibility. They found the reliability of this Modified Vertical Power Jump to be .977 and the validity to be .989. The criterion measure used for validity, however, was the original Vertical Power Jump Test.

## THE VERTICAL JUMP

The vertical jump, originally called Sargent's Physical Test of Man (44), has been labeled a test of neuromotor efficiency (45), a test of dynamic strength (47), a measure of "explosive energy" (1), and a test of the ability of the body to develop power in relation to the weight of the individual himself (3).

Morehouse and Cooper (13) have identified three factors relative to the vertical jump. These are: (1) the force required in the jump is proportional to the mass of the body; (2) the factor of mass is coupled with leg length, since force can be applied over a greater range of motion if the legs are long; and (3) the explosive power of the leg muscles supply the force needed to lift the body in the jump.

Since the vertical jump is one of the oldest performance tests in physical education (47), it would be difficult to cite all of the studies pertaining to it. This author has attempted, however, to review many of the studies which relate leg strength and other selected factors to vertical jumping ability.

Ness and Sharos (63) conducted a study to determine the effect of weight training on leg strength and the vertical jump. The experimental group performed two exercises, deep knee bends and toe raising, three days a week for four weeks. Resistance was applied by placing a barbell across the shoulders of the individuals. This resistance was progressively increased each session. The control group had no formal conditioning. Ness and Sharos concluded that four weeks of weight training will significantly increase dynamometrical leg strength and vertical jumping ability.

Knudtson (59) used fifteen high school girl basketball players in an attempt to determine the effect of weight training and jumping exercises on vertical jumping ability. An exercise program was provided three times a week for six weeks to develop strength of the shoulders, arms and legs. Five of the exercises involved the use of barbells in some manner while one exercise was simply a jump for height, jumping ten times reaching with the right hand and ten times reaching with the left hand. There was a mean increase in heights jumped of .77 inch with the right hand and .68 inch with the left hand at the end of the six week training program. Knudtson concluded that there was a significant increase in the mean height jumped and that the program had increased the girls' effectiveness in jumping and rebounding.

Gibson (55) studied the effect of a special training program for sprint starting on reflex time, reaction time, and the Sargent Vertical Jump. He used twenty-four eighth grade male students who were given a training program consisting of pull-ups, push-ups, sit-ups, side-straddle hops, Sargent jumps, and sprint starts. After eleven practice sessions of thirty-five minutes each, the subjects were retested. The mean increase of the Sargent Jump height was 1.13 inches, which was significant at the one per cent level of confidence.

Darling (53) conducted a study to compare the effects of the heel raise and the deep knee bends upon vertical jumping ability. He selected twenty high school varsity basketball players and equated them into two groups on the basis of their vertical jumping ability. Group A participated in the heel raising exercise while Group B participated in the deep knee bends. Both groups exercised three days a week for five weeks. A barbell was placed on the shoulders for resistance. Darling found that the heel raise exercise group increased 1.65 inches, and the deep knee bend exercise group increased 2.1 inches. Both increases were significant.

Chui (24) conducted a study to determine the effects of systematic weight training on athletic power. An experimental group performed varied resistance exercises two times a week for a period of forty minutes. This was done for three months. A control group participated in regular physical education activities for the same amount of time. Two of the six items used to measure athletic power were the Standing Sargent Vertical Jump and a 60-yard sprint. The data indicated that the experimental group improved significantly more than the control group in vertical jumping ability and speed of running the 60-yard dash.

Capen (23) also experimented with the effects of weight training on the vertical jump. His results supported the evidence of Chui (24) that a program of systematic weight training may aid in increasing leg strength which in turn may be converted into athletic power.

Marino (61) conducted a study to determine the effect of jumping exercises on foot extension strength and vertical jumping ability. The subjects were equated on vertical jumping ability and assigned randomly to the control and experimental conditions. The experimental group performed jumping exercises similar to rope skipping. The number of jumps increased gradually from 300 to 800 over the eighteen training sessions. The control group had no formal training program. As a result of the training program, the experimental group showed a mean increase of .97 inch which was significant at the one per cent level. Marino concluded that there was a low but significant relationship between preferred foot extension and vertical jumping ability.

Pacheco (38) experimented with the effects of three types of warm-up exercises on vertical jumping performances. The data indicated that jumping performance was improved by each of the three preliminary exercises. She concluded that stationary running as a preliminary exercise was 4.79 per cent more effective than deep knee bends and 2.68 per cent more effective than stretching exercises.

Talag (65) studied the relationship of hip, knee, and ankle flexibility to leg strength, the standing broad jump, and the jump reach. She found that flexibility of the right and left hips correlated .63 and .48 respectively with the standing broad jump. She also found that there was a correlation of .54 between flexibility of the right hip and the jump reach. She concluded that a person with a high degree of flexibility in that area would have a better chance of jumping higher than a person who had less flexibility in the right hip. She also found that leg strength did not play as important a role as hip joint flexibility in the performance of the standing broad jump and the jump reach.

Brown and Riley (52), using an exercise group and a control group, conducted a study to evaluate the results of weight training on leg strength and the vertical jump. The exercise group worked with weights three days a week for five weeks. The weights were made progressively heavier from day to day. They concluded that a weight training program using the heel raise exercise will increase leg strength, ankle plantar flexion, and the vertical jump height.

Garth (54) also conducted a weight training program three days a week for six weeks to determine its effect on the vertical jumping ability of the varsity basketball team at the University of Iowa. Five exercises to develop muscles of the shoulder girdle, arms, hands, and fingers were given to increase endurance, strength, speed of movement, and upward thrusting power when jumping. Two other exercises were used to develop the muscles of the legs in order to improve the jumping height of the subjects. At the conclusion of the weight training program, the increase in heights jumped by the individuals varied from .75 inch to six inches. From these data, Garth concluded that a systematic weight training program will significantly increase the vertical jumping ability of basketball players.

Rose (64), in a study of the relation of selected anthropometric measures to the vertical jumping ability and speed of running in women, found there was no significant relationship between standing height, sitting height, leg length, and angle of femur obliquity and either vertical jumping ability or speed of running. She also found that a slight negative relationship, significant at the five per cent level of confidence, does exist between body weight and vertical jumping ability. A negative correlation of -.64 existed between speed of running and vertical jumping ability. This relationship of a lower running time to a higher jumping height was significant at the one per cent level.

Wells (67) conducted a study of the relationships of the leg strength/body weight ratio and lengths of the lower limb segments to the vertical jump. He concluded that there was no significant relationship between any one of the proposed hypotheses.

Lewis (60), in a study of the relationships of various selected factors to the vertical jump, drew the following conclusions:

1. There is a relationship of calf and ankle girths, ankle strength, ankle dorsal flexion, and movement time to the vertical jump when the jumper is aided by the natural use of her arms.
2. Height, weight, and ankle plantar flexion are not significantly related to vertical jumping ability.
3. Movement time had a higher relationship to vertical jumping ability than did any of the other factors involved.

4. An increase in ankle dorsal flexion and ankle strength might possibly bring about better results in vertical jumping ability. (60)

Brees (51) studied the effect of a trampoline jumping program on the vertical jump and speed of running a 30-yard dash. He used two experimental groups and one control group in the experiment. One group trained by jumping up from the floor for three minutes for three days a week over a five week period. A second group trained by jumping on a trampoline the same amount of time as the first jump group. A third group had no formal training. The trampoline group showed an increase in vertical jumping ability and speed of running the 30-yard dash. None of the increases was statistically significant.

A review of the majority of studies seems to indicate that an increase in leg strength will result in an increase in vertical jumping ability. Recognizing this fact, one might assume there is a high correlation between leg strength and vertical jumping ability. However, this assumption has not been substantiated by previous correlation studies.

In 1924, L. W. Sargent (45) found a correlation of .23 between the Sargent vertical jump and strength as measured on a Back and Leg Dynamometer without a belt.

In 1937, Rarick (41) reported an average correlation of r=.11 between leg lift strength and a vertical jump using arm action. He used fifty-one male college students as subjects.

Also in 1937, Harris (30), in testing 163 junior high school girls, found a correlation coefficient of .215 between leg lift strength and the ordinary Sargent jump test, which allows considerable arm action.

Phillips (40), in a factor analysis study of several physical education tests, found that the Jump-Reach vertical jump had a correlation coefficient of .215 with leg strength, as measured on a leg dynamometer.

In a study of the relationship of leg strength and hip flexibility to the vertical jump, Hult (58) found a correlation of .24 between leg strength and the vertical jump for a high motor ability group. She also found a negative correlation of -.15 between leg strength and the vertical jump for the low motor ability group.

In 1961, Smith (47), in his study on the relationship of explosive leg strength to vertical jumping ability, found that there was no significant correlation bwtween the height jumped and either the strength/mass ratio or simple strength.

Smith (47) further concluded that strength in action is unrelated to dynamometric strength. These data support the Henry and Whitley (32) hypothesis that isometric strength as exerted against a Dynamometer involves a different neuromotor pattern from that exerted during a dynamic movement.

One factor which might have an influence on a low correlation between leg strength and vertical jumping ability is the type of jump used. Most modifications of the vertical jump test first devised by Sargent (44) in 1921 involve considerable arm action in propelling the body upward. One exception to this is the Modified Vertical Power Jump devised by Gray, Start, and Glencross (28). This jump allows no arm action.

Van Dalen (49) found in a study of five types of vertical jumps that the use of the arms made considerable differences in the height of the jump. He stated that a final thrust downward with the arms at the height of the jump increased the actual height attained.

## SPEED OF MOVEMENT

In a study on the factorial structure of speed, Henry (31) defined speed of movement as "the result of strength in action". From his data, he concluded that there is a possibility that the speed of a movement can be increased by strengthening per se the muscles which cause that movement.

This hypothesis is also shared by others. Steinhaus (48) believes that an increase in speed can be brought about by an increase in strength, although he admits that strength and speed are not directly proportional to each other.

Larson and Yocum (8) state: "The muscular power component and speed are highly related. Success in sprinting cannot be accomplished without the muscular strength necessary to move the legs with speed."

Several studies concerning this strength-speed relationship have been conducted. Many of these were to determine the effects of increased strength through a process of weight training upon speed of movement.

A study by Masley, Harrabedian, and Donaldson (36) was conducted to determine the effect that weight training has on strength, speed and endurance. The experiment consisted of three groups: a weight-training group, a group participating in volleyball, and a group not participating in physical activity. At the end of the eight weeks, the weight training group increased far more in strength than did the volleyball or inactive groups. A greater increase in speed and endurance was also observed in the weight training group.

Wilkin (50) conducted a study to determine the effect of weight training on speed of movement. In his research he used three groups of subjects from the University of California. Subjects in Group A, consisting of twenty-four students who had no previous weight training experience, were placed in the weight training class. Group B consisted of fifteen subjects who were members of the University weight lifting team. Group C consisted of twenty-one subjects enrolled in elementary swimming and golf classes. The three groups were tested for speed of movement in an arm action after a weight training program for Group A had been completed. Wilkin concluded that neither the one semester weight training group nor the chronic weight lifting group was impaired or improved in their speed of movement.

Chui (24) and Capen (23) concluded that an increase in strength through systematic weight training programs resulted in a significant increase in speed of movement.

Pierson and Rasch (39), in a study of the effect of arm strength development on reaction time and speed of arm extension, concluded that increases in general arm strength do not affect the speed of reaction or arm extension.

Karpovich and Zorbas (33) attempted to determine whether heavy weight lifting would develop slower or faster muscular contractions. The experimental group consisted of 300 weight lifters who at that time were engaged in the activity and who had at least six months prior experience. The control group consisted of 300 college men. Each subject made twenty-four rotary movements of the arm. The faster time of two trials was recorded. The results showed that the weight lifters were significantly faster in the speed of rotary arm motion than were the non-lifters.

Meisel (62) conducted a study in 1957 concerned with the effect of a weight training program upon the speed of running. The purpose of the study was to determine if leg training by progressive weight resistance exercises would produce change in the maximum speed of running a distance of ten yards. Two equated groups of male college students were given a six-week training program. One group trained using standard progressive resistance methods, while the other group attended a sports lecture and refrained from any type of organized activities. Meisel found that the weight training group lost in speed of running time. This loss was significant at the three per cent level of confidence. The sports lecture group showed no significant difference in running speed.

Clarke and Henry (25), in a study of speed and strength development, found that the average of the weight training group increased in speed, strength, and strength/mass ratio whereas the control group declined from the first test administration. They further concluded that in the arm movement studied, individual differences in the amount of change in the strength/mass ratio had a low but significant correlation with individual changes in maximal speed of movement.

Morehouse and Cooper (13) have identified several factors which influence running speed. These are: leg weight and length; flexibility of the hip joint; leg strength and power; reaction time at the beginning of a race; the pace set during the race; endurance; and motivation. They further state that great flexibility in the ankles, hips, and trunk may overcome some of the disadvantages of possessing legs which are not extremely long.

Concerning women, Williams (19:143) has concluded that the size of the pelvis may have an influence on an individual's running speed. He states: "In all movements of the lower extremities there is likely to be a marked lateral sway of the pelvis, the extent of this oscillation determines the speed of the individual in getting over the ground."

In a study of the limiting factors in speed of leg movement in sprinting, Slater-Hammel (46) found that neuromuscular efficiency was not a limiting factor of leg speed in sprinting. He determined this from a study in which twenty-six subjects could all cycle faster than they could take strides in running. He concluded that it is apparently the load or weight the leg muscles must move which determines the rate of movement in running.

Harris (30), in testing 163 junior high school girls, found a low correlation of .19 between leg lift strength and speed of running a 40-yard dash.

In 1962, Gray, Start, and Walsh (29) found a correlation of .47 between leg speed, as measured by a bicycle ergometer, and leg power, as measured by the Modified Vertical Power Jump Test.

## SUMMARY

Physical educators generally define strength in one of the two following ways: (1) the ability of the muscle to exert one maximum effort against resistance, known as static strength; or (2) the ability of the muscle to exert repetitious effort until it becomes fatigued, known as dynamic strength.

All methods of developing strength employ the overload principle. This is a process of progressively increasing the load of work done by a muscle in order to bring about an increase in strength. Several methods of producing overload have been identified.

Comparisons of strength development through isometric and isotonic training have produced varied results. It is generally believed that a proper program of isometric exercises will develop muscle strength and hypertrophy faster than a program of isotonic exercises, however. For the most part, measures of these compared strength increases have been by static strength tests.

Static strength tests are more widely accepted and used than dynamic strength tests. This has been attributed to the trial and error procedure which must be used to establish a measure of dynamic strength.

The majority of studies concerning the relationship of leg strength and vertical jumping ability have found that a significant increase in strength will generally result in a significant increase

in vertical jumping ability. Studies of correlations between the two variables, however, have found very low statistical relationships.

Most of the vertical jump studies have used a jump which allows considerable arm action. Use of the arms in jumping has been found to increase significantly the height jumped.

There is much controversy concerning the relationship of strength and speed. Several studies found that a strength increase will result in a speed of movement increase. Other studies found that a strength increase will sometimes cause a decrease in speed of movement or will produce no significant change at all. Other factors which are known to influence running speed have been identified.

## CHAPTER IV

## PROCEDURE

The purpose of this study was to determine the effects of leg strengthening exercises on the vertical jumping and speed of running of college women. A second purpose was to examine the relationships of leg strength, vertical jumping, and speed of running both before and after the administration of the exercise program.

### SELECTION OF SUBJECTS

The subjects for the study were women physical education majors randomly selected from the freshman, sophomore, and junior classes at the University of North Carolina at Greensboro. Since the exercise program in this study was designed to increase leg strength significantly in only twelve sessions, it was, of necessity, a somewhat strenuous program. For this reason, the writer felt it would be an advantage to use physical education majors as subjects. Also, the writer felt that most college girls, lacking an orientation to physical education practices and objectives, would be reluctant to perform exercises to develop leg strength for fear of muscle hypertrophy.

Letters were sent to thirty-six physical education major students explaining the purpose of the study and asking them to participate. Slips of paper were enclosed with instructions to return them with the desired information to the writer. Copies of the letter and enclosed slip are included in the Appendix.

Completed slips were returned by thirty-five students. Of this number, thirty-two were willing to serve as subjects. Sixteen of the subjects were randomly assigned to the control group, and the remaining sixteen subjects to the experimental group. Two of the subjects in the experimental group and one subject from the control group were dropped from the study because of inadequate data. This left a total of twenty-nine subjects; fourteen in the experimental group and fifteen in the control group.

The writer met with the original thirty-two subjects on February 18, 1965, in order to explain further the purpose of the study, testing procedures, and obligations of the two groups.

The control group was scheduled to meet only for the initial and final testing of leg strength, vertical jumping, and speed of running. They were instructed to follow in their normal school routine with respect to physical activity.

The experimental group was also scheduled for the initial and final testing sessions. After the initial tests were administered, subjects in the experimental group were asked to attend and participate in a leg strengthening exercise program designed by the writer. This involved three meetings a week for four weeks. The writer arranged seven separate times on four different days a week from which the subjects could choose to come three times on three different days. This arrangement was necessary because of the schedule variations of the subjects.

## SELECTION OF TESTS

### Leg Strength

A Back and Leg Dynamometer with belt attachment was used to measure leg strength. The procedure employed was the method described by Everts and Hathaway (27). This particular test was used because of the accessibility of the instrument and its acceptibility as a reliable and valid measure of leg strength. A thick walnut crossbar twenty-two inches long was placed across the thighs of the subjects. A hook through the middle of the crossbar was attached to the dynamometer. This in turn was connected to a wooden platform by an adjustable chain. The test was administered with the knees bent to a 120 degree angle. This angle was checked by placing a wooden elbow, constructed at a 120 degree angle, against the side of the knee joint. A heavy piece of webbing over five feet long and five inches wide was used as the belt. It was looped around one end of the crossbar, then around the lower back of the subject, and finally was wrapped around the other end of the crossbar. The loose end was next to the body so that it would remain tight during the pull.

Once the subject was in the correct position with knees bent, head erect, arms and back straight, she was asked to try to straighten her legs. This created the pull which was recorded on the dynamometer. The score for the maximum effort was taken when the subject's legs were nearly straight at the end of the pull. On occasion, the administrator adjusted the belt and chain length between trials. Each subject was given two trials. The results of these trials were recorded in kilograms on the subject's score card. A calibrated correction chart prepared by the Physics Department of the University was used to adjust the scores. A copy of this calibrated correction chart may be found in the Appendix. These scores were later converted to pounds. The subject's best strength score was considered her test score.

Vertical Jump Test

The Modified Vertical Power Jump Test, as described by Gray, Start, and Glencross (28), was used to measure the vertical jumping ability of the subjects. This test involved a measurement of the distance between the height of the fingertips of the preferred hand extended above the head while standing and the height of the fingertips of the same hand at the height of the jump. Chalk dust was placed on the fingertips to facilitate accurate measurement of the height jumped. A chalk jump board, measuring twenty-four inches by thirty-six inches with lines painted every inch and with a yard stick attached permanently in a vertical position on the side, was used to measure all jumps. This chalk jump board was attached to a portable standard at a height of fifty-seven inches above the floor. All measurements were recorded to the nearest tenth of an inch. Three consecutive jumps were recorded for each subject, with the height of the best jump being used as the subject's initial score for vertical jumping.

Before jumping, each subject was asked to warm-up by running-in-place vigorously for twenty-five times, counting one each time the left foot touched the floor. The starting position for the jump was a squat position, with the subject on the balls of her feet, back straight, and preferred arm and side next to the jump board. Her preferred arm was fully extended straight up and adjacent to the head, fingertips facing the jump board. The other arm was folded behind the body and held adjacent to the body during the entire jump. The position of the arms before and during the jump permitted no upward arm motion as an aid in propelling the body vertically. The squat starting position did not permit body momentum prior to the jump. Considering these two factors, it was assumed that leg power was the major factor influencing the vertical jump height attained by each subject.

A picture of the vertical jump board and the subject's starting position may be found in the Appendix.

Speed of Running Test

The subjects were timed for their speed of running twenty yards without regard to starting reaction time. This test was measured by an electronic device designed specifically for use in this study. The device used two selenium photoelectric cells with external light sources to form two light beams across the running path. One light beam, when broken by the body of the runner, instantaneously initiated a relay circuit to start the clock. At the end of the twenty-yard dash, a second light beam, when broken by the body of the runner, initiated the relay to stop the clock. The clock used to time the dash was one produced by the Hunter Manufacturing Company of Iowa City, Iowa. The Hunter Clock was used to time each subject's speed to the nearest one-hundredth of a second. Each subject was given two trials with a minute's rest between the trials. The times for both trials were recorded with the faster time being used as the subject's initial speed score.

The running event was set up with the subjects running lengthwise in Coleman Gymnasium. This allowed each subject approximately thirty feet in which she could build up running speed before breaking the first light beam. Hopefully, the subjects were all running close to their top speed when they broke the first light beam and started the clock. At the end of twenty yards, the second light beam was set up. Again there was approximately thirty feet in which the subject could stop before reaching the wall. A mat was placed against the wall at the end of the gymnasium to prevent any injuries.

One test administrator was used to give a verbal signal to begin each subject's run, to re-set the clock before each run, and to record the scores. The actual timing of the subjects' running, however, was as much as possible without human error. By eliminating the factor of starting reaction time, the writer felt that a more accurate measure of each subject's true speed of running could be obtained.

A circuit diagram of the electronic device used to time the runners is included in the Appendix. This writer has found, however, that a much simpler version of the electrical circuit used in the device could be constructed to perform the same function.* Therefore, this writer would advise anyone desiring to construct a similar device to check with an expert for possible modification and simplification of this circuit diagram.

*Knowledge obtained from personal communication with Mr. Bob Best of Best Television Company, Greensboro, North Carolina

## ADMINISTRATION OF TESTS

Two initial and two final testing periods were arranged so that half of the subjects could be tested at each time. Each subject received a score card when she arrived for the testing. A copy of this score card can be found in the Appendix. The leg strength test was administered first to every subject. Although it may have been a fatiguing factor, this writer felt that any influence that this might have had on subsequent test results would be near constant for all of the subjects.

After two trials using the Back and Leg Dynamometer to determine leg strength, each subject went to the vertical jump station. All subjects were asked to warm-up prior to jumping by running-in-place vigorously for twenty-five times. Each time the left foot touched the floor counted one.

After three consecutive jumps, the subject progressed to the running station. To allow sufficient running room, this event took place in Coleman Gymnasium.

Although each subject was tested on all three variables in one session, the writer felt, and the subjects agreed, that there was sufficient rest time between the stations so as not to fatigue the subjects excessively. Also, since both the initial and final testing sessions were identical as to procedure and time allotment, this writer felt that any fatigue effects would be constant for both sessions.

Two graduate students and the writer were the test administrators for the three testing stations for both the initial and final test sessions.

## EXERCISE PROGRAM

The exercise program was composed of eight exercises designed to develop strength of the legs and ankles. The majority of exercises were taken from fitness pamphlets. A complete description of each exercise and its reference can be found in the Appendix.

Subjects participating in the exercise sessions came three days a week for four weeks. The subjects performed the exercises under the supervision of the writer. When it was necessary for a subject to miss an exercise session and she was unable to attend any of the other sessions for that week, she was allowed to perform the exercises in her dormitory.

The number of repetitions for each exercise gradually increased for most of the twelve sessions. The exercises and number of repetitions required for each of the twelve sessions are as follows:

| First Week | 1st day | 2nd day | 3rd day |
|---|---|---|---|
| Running-in-place | 25 | 25 | 25 |
| Sprinter | 8 | 12 | 16 |
| Rocker | 10 | 15 | 20 |
| Hop-in-place | 50-25-25-50 | 50-25-25-50 | 50-25-25-50 |
| Sit-ups | 8 | 12 | 16 |
| Half Knee Bends | 10 | 15 | 20 |
| Jump-in-Place | 10 | 15 | 20 |
| Flutter Kick | 10 | 20 | 30 |

| Second Week | 1st day | 2nd day | 3rd day |
|---|---|---|---|
| Running-in-place | 25 | 50 | 50 |
| Sprinter | 20 | 24 | 28 |
| Rocker | 25 | 30 | 34 |
| Hop-in-place | 50-25-25-50 | 50-25-25-50 | 60-35-35-60 |
| Sit-ups | 18 | 20 | 22 |
| Half Knee Bends | 24 | 28 | 30 |
| Jump-in-place | 22 | 24 | 26 |
| Flutter Kick | 36 | 40 | 44 |

| Third Week | 1st day | 2nd day | 3rd day |
|---|---|---|---|
| Running-in-place | 50 | 50 | 75 |
| Sprinter | 30 | 34 | 38 |
| Rocker | 38 | 40 | 44 |
| Hop-in-place | 60-35-35-60 | 60-35-35-60 | 60-35-35-60 |
| Sit-ups | 26 | 28 | 30 |
| Half Knee Bends | 32 | 34 | 36 |

| | | | |
|---|---|---|---|
| Jump-in-place | 28 | 30 | 32 |
| Prone arch | 15 | 20 | 20 |
| Fourth Week | 1st Day | 2nd Day | 3rd Day |
| Running-in-place | 75 | 75 | 75 |
| Sprinter | 40 | 44 | 48 |
| Rocker | 44 | 48 | 48 |
| Hop-in-place | 75-50-50-75 | 75-50-50-75 | 75-50-50-75 |
| Sit-ups | 32 | 34 | 36 |
| Half Knee Bends | 38 | 40 | 40 |
| Jump-in-place | 34 | 36 | 38 |
| Prone Arch | 25 | 30 | 30 |

## TREATMENT OF DATA

The analysis of covariance statistical technique was used to determine if there was a significant difference between the experimental and control groups on each of the three variables. It was necessary to use this technique to adjust any preexperimental differences there may have been between the groups. If the covariance analysis proved significant for any of the three variables, further statistical procedures were computed to adjust the mean scores of the variable for the experimental and control groups. This adjustment of mean scores enabled the writer to determine which group was significantly better.

Fisher's "t" test of significance for correlated means was used to determine if any of the increases from initial to final testing for each group was statistically significant.

The Product Moment Method of Correlation was used to determine the relationships of leg strength, vertical jump, and speed of running for each group. This involved correlations based on the initial and the final test scores. To determine if there was a significant difference between the initial and final correlations for each relationship, the "z" Test of Differences Between Correlation Coefficients was computed.

CHAPTER V

ANALYSIS AND INTERPRETATION OF DATA

The purposes of this study were: (1) to determine whether a program of leg strengthening exercises would affect the vertical jumping and speed of running of college women; and (2) to study the relationships of leg strength, vertical jumping, and speed of running both before and after the administration of an exercise program designed to increase leg strength.

The design of this study involved the use of two groups of subjects. Group A, the experimental group, participated in a four-week program of leg strengthening exercises. Group B, the control group, had no formal program of exercises. Both groups were administered initial and final tests on the variables of leg strength, vertical jumping, and speed of running.

## Statistical analysis

The first statistical treatment was to determine the means and standard deviations of the initial and final tests for Group A and Group B. The means of all three variables showed improvement from initial to final testing for both Groups A and B.

In Group A, the exercise group, the strength mean increased 147 pounds and the vertical jump mean increased .7 inch from the initial to the final testing. The speed of running mean decreased

.03 second from the initial to the final testing, indicating an improvement in performance due to the inverse relationship of the time factor.

Group B, the control group, also showed mean improvement in each of the three variables. The strength mean increased 41 pounds and the vertical jump mean increased .5 inch from the initial to the final testing. The speed of running mean decreased .01 second from the initial to the final testing, indicating a small performance improvement.

The means and standard deviations of leg strength, the vertical jump, and running speed for the initial and final tests can be found in Table I.

Analysis of Covariance

The analysis of covariance statistical technique (18) was used to determine if there was a significant difference between the group means of each of the three variables. Since the two groups were not originally equated, it was necessary to use this particular statistical procedure to adjust any preexperimental differences which might have existed between the groups. An analysis of covariance was computed for each of the three variables.

The analysis of covariance computed on the leg strength variable revealed an F of 8.98. This difference between group means was significant at the one per cent level of confidence. Although the writer assumed that this difference was due to the treatment effect (the exercise program), this assumption had to be substantiated by further statistical computation. A statistical adjustment of the means

TABLE I

MEANS AND STANDARD DEVIATIONS FOR INITIAL AND FINAL TESTS OF LEG STRENGTH, THE VERTICAL JUMP, AND RUNNING SPEED

| VARIABLES | GROUP A N=14 | | | | GROUP B N=15 | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial | | Final | | Initial | | Final | |
| | M | σ | M | σ | M | σ | M | σ |
| LEG STRENGTH | 543 | 118 | 690 | 106 | 428 | 176 | 469 | 194 |
| VERTICAL JUMP | 12.6 | 1.37 | 13.3 | 1.10 | 12.5 | 2.28 | 12.9 | 2.08 |
| RUNNING SPEED | 2.72 | .125 | 2.69 | .122 | 2.81 | .134 | 2.80 | .124 |

(17) was computed using the following formula:

$$\bar{Y}_k - b(\bar{X}_k - \bar{X}..)$$

This adjustment of the means revealed that the mean of the experimental group, Group A, was significantly higher than the mean of the control group, Group B. Therefore, this writer concluded that the exercise program was the apparent cause of the significant strength increase in the experimental group. A comparison of the initial, final and adjusted mean scores for leg strength may be found in Table II.

TABLE II

COMPARISON OF INITIAL, FINAL AND ADJUSTED MEANS FOR LEG STRENGTH

| LEG STRENGTH | INITIAL | FINAL | ADJUSTED |
|---|---|---|---|
| GROUP A (EXERCISE) | 543 | 690 | 634 |
| GROUP B (CONTROL) | 428 | 469 | 521 |

This significant leg strength increase following the administration of an isotonic training program is similar to the results found in several previous studies. Ness and Sharos (63), Brown and Riley (52), Masley, <u>et</u>. <u>al</u>. (36), and Berger (21) all concluded that a program of dynamic exercises will increase strength significantly.

The analysis of covariance for the strength data also included a computation of two tests for nonadditivity of treatment effects.

In both tests, the null hypotheses--the observed differences between sample variances and between sample correlations are due to error--were rejected. These data indicate that the treatment effect was not constant and additive for the subjects within each group; i.e., the subjects in each group did not increase the same amount in strength. This fact was apparent in the strength raw scores for the subjects. (See Appendix) This nonadditivity characteristic of the strength data may be explained by the physiological fact that the subjects who were initially low in strength had much more room for improvement than the subjects who were initially high in strength. Authorities have found that this characteristic of nonadditivity has little effect on the significance of the mean differences, but its presence should not be overlooked in any statistical treatment using the analysis of covariance. (17)

The analyses of covariance computed on the vertical jump and speed of running data revealed F's of .773 and .00 respectively. Neither of these F's was significant, indicating that the observed differences between the groups were apparently due to error. Knowing these facts, it was not necessary to compute the two tests of non-additivity for these data.

The analyses of covariance data for leg strength, the vertical jump, and running speed may be found in Table III.

The results of this study were found to support the hypotheses of similar isolated studies: namely, that a significant increase in static leg strength does not guarantee a significant improvement in vertical jumping or speed of movement. (20,47,50,62)

TABLE III

ANALYSES OF COVARIANCE FOR LEG STRENGTH, THE VERTICAL JUMP AND SPEED OF RUNNING

| COMPONENT | SS | df | V | F* |
|---|---|---|---|---|
| LEG STRENGTH | | | | |
| TREATMENT EFFECT | 105,001 | 1 | 105,001 | 8.98** |
| ERROR | 303,868 | 26 | 11,687 | |
| VERTICAL JUMP | | | | |
| TREATMENT EFFECT | .34 | 1 | .34 | .773 |
| ERROR | 11.52 | 26 | .44 | |
| SPEED OF RUNNING | | | | |
| TREATMENT EFFECT | .00 | 1 | .00 | .00 |
| ERROR | .04 | 26 | .0015 | |

*Criterion F = 7.72 to be significant at the one per cent level.

**Significant at the one per cent level.

This writer feels, however, that it is possible that these results were influenced by certain factors.

In the opinion of this writer, the most likely influencing factor was the motivation and competitiveness seemingly inherent among the physical education major students used as subjects. This writer felt that the majority of subjects in both groups, having seen their initial test scores on the score cards, were competing both as individuals and as a group in an attempt to better their scores on the final testing. This may have been the reason for the mean score increases on all three variables for the control group. The fact that the control group did improve in vertical jumping and running speed along with the experimental group obviously minimized the possibility of obtaining a significant F on the respective analyses of covariance. Perhaps this motivation factor could have been alleviated or reduced considerably if the subjects had been allowed no knowledge of their initial scores prior to taking the final test.

Product Moment Correlations

The Product Moment Method of Correlation was used to determine the relationships of leg strength, vertical jumping, and speed of running based on the initial and final test scores of each group. This writer was interested in the change, if any, in the relationships after the completion of the four week exercise program.

In the exercise group, Group A, the initial correlation between leg strength and the vertical jump was .358. After the exercise program, the correlation between the two variables decreased to .032. The writer assumed that this was due to the fact that the strength increase was so much greater in proportion than the increase in the vertical jump. Neither of these correlation coefficients was significant.

The initial correlation between leg strength and speed of running for Group A was .369. This relationship decreased to .198 on the final test after exercises. The writer again assumed that the great strength increase in proportion to the speed increase was responsible for this decrease of the correlation coefficient. Neither of these coefficients was significant.

The initial speed of running and vertical jump correlation for Group A was .657. The final correlation of these two variables was .585. Both of these coefficients were significant at the five per cent level of confidence. Again, this showed a slight decrease in degree of relationship from the initial to the final testing. This writer observed that certain subjects improved proportionately more in one of the variables than the other; therefore causing a slight decrease in the correlation of the two variables. This observation can be seen in the raw score data found in the Appendix.

Table IV contains the Product Moment Correlation Coefficients for Group A.

In the control group, Group B, the initial correlation between leg strength and the vertical jump was -.245. The final correlation between these two variables was -.232. Neither of these correlations was significant. Since the means of the raw scores for leg strength and the vertical jump did show small increases from initial to final testing, this writer assumed that, generally, the subjects who increased in leg strength did not necessarily increase in vertical jumping, and vice versa.

TABLE IV

PRODUCT MOMENT CORRELATION COEFFICIENTS
FOR GROUP A (EXERCISE GROUP)

| VARIABLES | INITIAL r* | FINAL r* |
|---|---|---|
| LEG STRENGTH-VERTICAL JUMP | .358 | .032 |
| LEG STRENGTH-RUNNING SPEED | .369 | .198 |
| RUNNING SPEED-VERTICAL JUMP | .657** | .585** |

*Criterion r for 12 df = .532 to be significant at the five per cent level

**Significant at the five per cent level

The initial correlation between leg strength and speed of running for Group B was .402. The final correlation between these two variables was .281. Again, neither of the coefficients was significant. This decrease in the degree of relationship could possibly be due to the fact that the control group showed a small mean increase in strength which was proportionately more than the .01 speed mean improvement.

The initial correlation between running speed and the vertical jump for Group B was .484. The final correlation coefficient for these two variables was .676. The final correlation coefficient was significant at the one per cent level of confidence. The increase in this relationship for the control group is difficult to explain. Judging from the raw data, however, the writer assumed that this increase resulted from several of the subjects improving their performances simultaneously in the vertical jump and the running event.

Table V contains the Product Moment Correlation Coefficients for Group B.

TABLE V

PRODUCT MOMENT CORRELATION COEFFICIENTS FOR GROUP B (CONTROL GROUP)

| VARIABLES | INITIAL r* | FINAL r* |
|---|---|---|
| LEG STRENGTH-VERTICAL JUMP | -.245 | -.232 |
| LEG STRENGTH-RUNNING SPEED | .402 | .281 |
| RUNNING SPEED-VERTICAL JUMP | .484 | .676** |

*Criterion r for 13 df = .641 to be significant at the one per cent level.

**Significant at the one per cent level

The relatively low and nonsignificant correlations between dynamometrical leg strength and the vertical jump as found in this study support the results of several previous studies. Sargent (45) reported a low correlation of .23 between these same two variables. Phillips (40) and Harris (30) both reported nonsignificant correlations of .215 between leg strength and the vertical jump in separate studies employing women as subjects. In a more recent study, Hult (58) reported a negative correlation of -.15 between these two variables for a low motor ability group and a positive correlation of .24 for a high motor ability group. She also used women as subjects.

In 1961, Smith (47) found no significant correlation between leg strength and vertical jumping ability.

The correlations between leg strength and running speed as found in this study were also nonsignificant, but these coefficients were generally not as low as the coefficients for the leg strength-vertical jump relationships. Again, these results support the conclusions of certain previous studies. Harris (30) reported a low correlation of .19 between leg strength and running speed. In a more recent study, Gray, Start and Walsh (29) reported a correlation of .47 between leg speed and leg power.

The three significant correlations between running speed and the vertical jump as found in this study were similar to the results reported in a recent study by Rose (64). Using women as subjects, Rose (64) found a correlation of .64 between these two variables. This correlation coefficient was significant at the one per cent level.

<u>"z" Test of Differences Between Correlation Coefficients</u>

Since one of the purposes of this investigation was to study the relationships of the three variables both before and after the administration of a four-week exercise program, this writer desired to know if there was a significant difference between the initial and final relationships for each group. To determine this, the "z" Test of Differences Between Correlation Coefficients (6) was computed.

For Group A, the exercise group, the highest difference was between the initial and final leg strength-vertical jump correlations, but this failed to be statistically significant. For Group B, the control group, the highest difference was between the initial and final running speed-vertical jump correlations. Again, this difference failed to be statistically significant.

From these data, this writer found that none of the changes in correlation from initial to final testing was statistically significant for either Group A or Group B. Therefore, this writer concluded that the administration of the four-week exercise program did not cause a significant change in any of the variable relationships.

The data for these "z" tests of differences between correlation coefficients for Group A and Group B may be found in Table VI.

TABLE VI

"z" TEST OF DIFFERENCES BETWEEN CORRELATION COEFFICIENTS FOR GROUP A AND GROUP B

| VARIABLES | GROUP A t* | GROUP B t** |
|---|---|---|
| LEG STRENGTH-VERTICAL JUMP | .81 | .07 |
| LEG STRENGTH-RUNNING SPEED | .44 | .31 |
| RUNNING SPEED-VERTICAL JUMP | .25 | .75 |

*Criterion t = 2.056 to be significant at the five per cent level

**Criterion t = 2.048 to be significant at the five per cent level

Fisher's "t" Test of Significance for Correlated Means

This final statistical treatment of the data was done to satisfy the writer's personal curiosity. This writer was interested in determining if any of the increases from initial to final testing for the experimental and control groups were statistically significant. To determine this, the Fisher's "t" Test of Significance for Correlated

Means was computed.

It was found that, for the experimental group, Group A, increases in all three variables were significant at the five per cent level. For the control group, Group B, only the vertical jump increase was statistically significant at the five per cent level. These data for both groups may be found in Table VII.

TABLE VII

FISHER'S "t" TEST OF SIGNIFICANCE FOR CORRELATED MEANS

| VARIABLES | GROUP A t* | GROUP B t** |
|---|---|---|
| LEG STRENGTH | 4.17* | 1.83 |
| VERTICAL JUMP | 3.81* | 2.36** |
| SPEED OF RUNNING | 2.77* | 2.04 |

*Criterion t for 13 df = 2.160 to be significant at the five per cent level

**Criterion t for 14 df = 2.145 to be significant at the five per cent level

From inspection of the raw scores, this writer had rightful reason to suspect a significant increase in vertical jumping and speed of running for the experimental group. These significant increases for the experimental group were apparently nullified in the analysis of covariance treatment by the increases in each of the variables by the control group.

In an overall review of the results found in this study, this writer has concluded that two different interpretations of these data are feasible. The first interpretation involves three assumptions.

These are: (1) the experimental group gained significantly in leg strength, the vertical jump and running speed because of the exercise program; (2) the control group showed increases in leg strength, the vertical jump and running speed, only one of which was statistically significant, because of the motivation and competitiveness factors; and (3) as a result of the control group increases, the analyses of covariance treatment of the vertical jump and running speed data failed to reveal a significant difference between the two groups. The second interpretation involving only one major assumption is: (1) for both the experimental and the control groups, any increase in vertical jumping and running speed were apparently due to error.

Although the latter interpretation is the one accepted for the scientific analysis of data in this study, this writer cannot help but admit the feasibility of the former interpretation. From this doubting emerges a suggestion for further study in this area using much larger samples and equated groups for full comparison purposes.

# CHAPTER VI

## SUMMARY AND CONCLUSIONS

The purposes of this study were: (1) to determine if a program of leg strengthening exercises would affect the vertical jumping and speed of running of college women; and (2) to study the relationships of leg strength, vertical jumping ability, and speed of running both before and after the administration of an exercise program designed to increase leg strength.

The subjects were twenty-nine women physical education majors randomly selected from the freshman, sophomore, and junior classes at The University of North Carolina at Greensboro during the second semester of the academic year, 1964-65.

Fourteen of the subjects were randomly assigned to the experimental condition, and fifteen subjects were randomly assigned to the control condition. After the initial testing of leg strength, vertical jumping and speed of running, the experimental group, Group A, participated in a four-week exercise program designed by the writer to increase leg strength. The control group, Group B, had no organized program of exercises.

Subjects in both groups were administered initial and final tests of leg strength, vertical jumping ability, and speed of running.

A Back and Leg Dynamometer with belt attachment was used to measure leg strength. The raw scores, measured in kilograms, were adjusted according to a calibrated correction chart, and later converted into pounds. Two trials were given for each subject, with the greater trial being used as the subject's score.

The Modified Vertical Power Jump Test was the second test administered. It was used to measure the vertical jumping ability of all subjects. Three consecutive jumps were recorded to the nearest tenth of an inch for each subject. The best height of the three jumps was used as the subject's score.

The final test administered to each subject was the speed of running test. Using an electronic device, each subject was timed for her speed of running a twenty-yard distance without regard to starting reaction time. Each subject ran twice, with the faster time being used as her score.

The first statistical treatment of the data was to determine means and standard deviations of each group for each of the three variables. This writer found that the group means showed an improvement from initial to final testing in leg strength, the vertical jump, and running speed for both Group A and Group B.

An analysis of covariance was computed for each of the three variables to determine if there was a significant difference between the groups. The only F found to be significant was the one computed on the leg strength variable. This was significant at the one per cent level of confidence. Further statistical computation of the adjustment of leg strength means revealed that the experimental group adjusted mean was significantly higher than the control group adjusted mean. Therefore, this writer concluded that the differences between strength means were apparently due to the treatment effect (the exercise program).

The analyses of covariance computed for the vertical jump and speed of running revealed non-significant F's. Therefore, this writer concluded that the observed differences between the groups on these two variables were apparently due to error.

The Product Moment Method of Correlation was used to determine the relationships of leg strength, the vertical jump, and speed of running scores from both the initial and final testing. Correlations significant at the five per cent level of confidence were found for the initial and final relationships of running speed and the vertical jump for Group A. The only significant correlation coefficient for Group B was the correlation between running speed and the vertical jump of the final test. This coefficient was significant at the one per cent level of confidence.

The "z" Test of Differences Between Correlation Coefficients was computed to determine if the changes in correlation from initial to final testing were significant. It was found that there were no significant differences between the initial and final correlations. From these data, the writer concluded that the four-week exercise program did not cause a statistically significant change in the relationships of leg strength, the vertical jump, and speed of running.

Fisher's "t" Test of Significance for Correlated Means was computed to determine if Group A and/or Group B improved significantly from the initial to the final testing. It was found that the exercise group, Group A, improved significantly in leg strength, the vertical jump, and running speed. These increases were significant at the five per cent level. The control group, Group B, improved significantly only in the vertical jump. This improvement was also significant at the five per cent level. The reader should be cautious in his or her interpretation of these data, as the two groups were not initially equated and, therefore, cannot be compared statistically by this "t" test. However, this writer acknowledges that the exercise program could possibly have caused the increases in vertical jumping and running speed which were significant at the five per cent level.

On the basis of the results of this study, the following conclusions were drawn:

1. Based on the analyses of covariance data, the four week program designed to increase leg strength had no significant statistical effect on the vertical jumping ability and speed of running of college women.
2. Based on analysis of covariance data, the four week exercise program designed to increase leg strength improved the leg strength of the experimental group significantly.
3. The exercise group, Group A, did show an improvement in mean scores from initial to final testing in leg strength, the vertical jump, and speed of running. All three variable improvements were statistically significant at the five per cent level based on Fisher's "t" Test of Significance for Correlated Means.
4. The control group, Group B, also showed improvement in mean scores from initial to final testing in leg strength, the vertical jump, and speed of running. Only the vertical jump improvement was statistically significant at the five per cent level based on Fisher's "t" Test of Significance for Correlated Means.

5. In Group A, significant correlations between running speed and the vertical jump for both the initial and final test scores were found.

6. In Group B, a significant correlation between running speed and the vertical jump for the final test scores was found.

7. In Groups A and B, there were no significant correlations between leg strength and the vertical jump for either the initial or final test scores.

8. In Groups A and B, there were no significant correlations between leg strength and speed of running for either the initial or final test scores.

9. The four week exercise program did not change any of the correlations significantly for either Group A or Group B.

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# APPENDIX

SAMPLE LETTER

February 16, 1965

Dear ______________________:

You are one of 36 majors randomly selected from the freshman, sophomore, and junior classes for possible participation in my thesis study. Participation in this study is on a voluntary basis, but both my thesis advisor, Dr. Hennis, and I would certainly appreciate your cooperation.

The purpose of my research is to study the relationship of leg strength to vertical jumping ability and speed of running of college women. This will involve an initial testing period in which each subject's leg strength, vertical jumping height, and speed of running a 20-yard distance will be measured. Eighteen of the majors will be randomly assigned to an experimental group. I will meet with this experimental group 3 times a week for 4 weeks in order to administer an exercise program through which, hopefully, leg strength will be increased somewhat. The other eighteen majors will be assigned to a control group which will have no organized program of exercise and no obligations other than participation in the initial and final testing.

After the 4 weeks of exercises, both groups will meet again for a final testing period which will be identical to the initial testing. The initial and final tests will not take more than an hour of your time. For the majors in the experimental group, the exercises will not take more than 20 minutes at each meeting. The 3 exercise periods per week will be arranged at the convenience of the subjects in the experimental group.

I realize some of you are very busy with class work, but this will only take 2 hours of your time over the entire 4-week span if you are in the control group, and 6 hours of your time over the entire 4-week span if you are in the experimental group. If you feel you absolutely do not have enough free time to participate in this study, please tell me before the study gets under way. However, as majors, I feel sure you can understand the necessity and importance of research in Physical Education in order to improve our knowledge of man's physiological behavior, and, as a result of this understanding, will make every effort to participate in this study.

I assure you now that these 12 exercise sessions will not increase the size of your leg muscles noticeably. In fact, I doubt seriously if you will be able to notice any difference in the size of your muscles, but you should be able to notice an increased muscle firmness.

I am enclosing a slip of paper which you may use to indicate your decision. Please check whether or not you will participate in this study. Also, please check whether or not you can attend a short discussion meeting to answer any questions you may have and to set up dates for testing. It is very important that you attend this meeting if at all possible. Please place your answer slip in my box no later than Thursday, Feb. 18 at 3:00 or bring it to the meeting with you on the same day at 4:00 in the Audio-Visual Aids Room in Coleman.

Thanks so much for your cooperation in this.

Sincerely,

Judy Blucker

SAMPLE ENCLOSED SLIP

Check the appropriate boxes:

☐ I will participate in your study and I do understand the amount of time it will involve.

☐ I will not participate in your study.

☐ I will be able to attend the short meeting on Thursday, February 18 at 4:00 in the Audio-visual Room.

☐ I will not be able to attend the meeting. I could meet with you in Coleman Lounge on ________________
(Please fill in free hour & day.)

Name________________________

Class________________________

SAMPLE SCORE CARD

| | | | |
|---|---|---|---|
| NAME____________________ | CLASS________ | CONTROL________ EXPERIMENTAL________ | |
| INITIAL TEST | FINAL TEST | BEST SCORES INITIAL FINAL | DIFFERENCE |
| ____ ____ STRENGTH | ____ ____ STRENGTH | ____ ____ STRENGTH | ____ |
| ____ ____ ____ VERTICAL JUMP | ____ ____ ____ VERTICAL JUMP | ____ ____ VERTICAL JUMP | ____ |
| ____ ____ SPEED OF RUNNING | ____ ____ SPEED OF RUNNING | ____ ____ SPEED OF RUNNING | ____ |

# EXERCISE PROGRAM

## Running-in-place

Purpose: To develop total leg strength, ankle and knee flexibility, and cardio-respiratory endurance.

Action: Subject runs in place lifting knees as high as possible. Speed of leg movement can be either moderate or fast. Count one each time left foot touches the floor.

## Sprinter (15)

Purpose: To develop strength of thigh muscles.

Starting position: Subject squats, hands on the floor, fingers pointed forward, with left leg fully extended to the rear. Right leg is flexed and brought close to the chest and hands.

Action: Count 1. Subject reverses the position of her feet in a bouncing movement, bringing left foot to the hands and extending right leg backward--all in one motion.
Count 2. Subject reverses the feet again, returning to the starting position.

## Rocker (16)

Purpose: To develop strength of the calves and ankles.

Starting position: Subject stands erect, feet together, with hands on hips.

Action: Count 1. Subject rocks back on heels, keeping legs straight and raising toes off the floor.
Count 2. Subject rocks forward on toes, lifting the heels off the floor.

## Hop-in-place (16)

Purpose: To develop strength of the calves and ankles.

Starting position: Subject stands erect, feet close together, with hands on hips.

EXERCISE PROGRAM (cont'd)

Action: Subject hops lightly on both feet 50 times, on the right foot 25 times, on the left foot 25 times, and on both feet 50 times.

Sit-ups

Purpose: To develop muscles of the thighs.

Starting position: Subject lies on floor on her back, arms flexed with hands interlocked behind the head, legs fully extended with feet securely held.

Action: Count 1. Subject sits up and touches her elbows to her knees. She is instructed to concentrate on pulling up with her thigh muscles primarily, not her abdominal.
Count 2. Subject lies back down on the floor.

Half Knee Bends (15)

Purpose: To increase total leg strength and ankle strength.

Starting position: Subject stands erect, feet apart in balanced position with toes pointed outward, hands on hips.

Action: Count 1. Subject rises up on her toes.
Count 2. Subject bends knees approximately halfway.
Count 3. Subject extends her legs and assumes the position as in Count 1.
Count 4. Subject lets body weight down onto heels and entire foot.

Jump-in-place

Purpose: To increase total leg strength and flexibility.

Starting position: Subject stands erect, feet apart, hands on hips.

Action: Subject jumps vertically into the air, landing on the balls of her feet and allowing her knees to flex. She does not use her arms in helping her jump. She begins jumping at a low height and attempts to build up to her maximum height by the end of the jump requirement.

EXERCISE PROGRAM (cont'd)

Flutter Kick (15)

Purpose: To develop strength of the hamstrings and other leg extensors.

Starting position: Subject lies face down, hands tucked under thighs.

Action: Subject arches the back, bringing the chest and head up, then flutter kicks continuously. Kick is from the hips, with the knees only slightly bent. Count each kick as one.

Prone Arch (15)

Purpose: To develop strength of the leg extensor muscles.

Starting position: Subject lies face down, arms extended to the sides at shoulder level.

Action: Count 1. Subject arches the back, bringing the chest, arms and head up, and raising the legs as high as possible.
Count 2. Return to starting position.

TABLE VIII

CORRECTED SCORES FOR THE BACK AND LEG DYNAMOMETER

| Instrument reading | Corrected reading | Instrument reading | Corrected reading |
|---|---|---|---|
| 5 | 15 | 210 | 227.5 |
| 10 | 20 | 215 | 232.5 |
| 15 | 25 | 220 | 237.5 |
| 20 | 30 | 225 | 242.5 |
| 25 | 35 | 230 | 247.5 |
| 30 | 40 | 235 | 252.5 |
| 35 | 45 | 240 | 257.5 |
| 40 | 50 | 245 | 262.5 |
| 45 | 55 | 250 | 267.5 |
| 50 | 60 | 255 | 272.5 |
| 55 | 65 | 260 | 277.5 |
| 60 | 70 | 265 | 285 |
| 65 | 75 | 270 | 290 |
| 70 | 80 | 275 | 295 |
| 75 | 87.5 | 280 | 300 |
| 80 | 92.5 | 285 | 305 |
| 85 | 97.5 | 290 | 310 |
| 90 | 102.5 | 295 | 315 |
| 95 | 107.5 | 300 | 320 |
| 100 | 112.5 | 305 | 325 |
| 105 | 117.5 | 310 | 330 |
| 110 | 125.5 | 315 | 335 |
| 115 | 130 | 320 | 340 |
| 120 | 135 | 325 | 345 |
| 125 | 140 | 330 | 350 |
| 130 | 145 | 335 | 355 |
| 135 | 150 | 340 | 360 |
| 140 | 155 | 345 | 365 |
| 145 | 160 | 350 | 370 |
| 150 | 165 | 355 | 375 |
| 155 | 170 | 360 | 380 |
| 160 | 175 | 365 | 385 |
| 165 | 180 | 370 | 390 |
| 170 | 185 | 375 | 395 |
| 180 | 195 | 380 | 400 |
| 185 | 202.5 | 385 | 405 |
| 190 | 207.5 | 390 | 415 |
| 195 | 212.5 | 395 | 420 |
| 200 | 217.5 | | |
| 205 | 222.5 | | |

TABLE IX

RAW SCORES FOR GROUP A

| | INITIAL TEST | | | FINAL TEST | | |
|---|---|---|---|---|---|---|
| SUBJECT | STRENGTH | VERTICAL JUMP | RUNNING SPEED | STRENGTH | VERTICAL JUMP | RUNNING SPEED |
| LS | 603 | 11.5 | 2.83 | 944 | 12.8 | 2.73 |
| SWi | 744 | 13.8 | 2.79 | 799 | 14.6 | 2.69 |
| PH | 625 | 13.7 | 2.57 | 792 | 12.7 | 2.54 |
| PMc | 543 | 11.6 | 2.79 | 766 | 12.6 | 2.69 |
| AT | 341 | 12.6 | 2.80 | 744 | 12.4 | 2.78 |
| LH | 722 | 14.3 | 2.54 | 711 | 14.6 | 2.50 |
| TC | 378 | 11.8 | 2.87 | 678 | 13.2 | 2.83 |
| DD | 625 | 14.1 | 2.44 | 662 | 14.5 | 2.42 |
| MJ | 603 | 11.4 | 2.75 | 625 | 12.7 | 2.75 |
| JD | 436 | 11.6 | 2.70 | 603 | 12.4 | 2.71 |
| JB | 592 | 12.1 | 2.81 | 603 | 13.1 | 2.81 |
| MB | 453 | 15.5 | 2.59 | 603 | 15.8 | 2.61 |
| AP | 436 | 10.8 | 2.76 | 581 | 12.0 | 2.75 |
| SWh | 502 | 11.4 | 2.84 | 543 | 12.3 | 2.84 |

TABLE X

RAW SCORES FOR GROUP B

| SUBJECT | INITIAL TEST STRENGTH | INITIAL TEST VERTICAL JUMP | INITIAL TEST RUNNING SPEED | FINAL TEST STRENGTH | FINAL TEST VERTICAL JUMP | FINAL TEST RUNNING SPEED |
|---|---|---|---|---|---|---|
| BM | 810 | 10.0 | 2.75 | 867 | 11.9 | 2.75 |
| SMc | 614 | 11.4 | 2.76 | 799 | 11.2 | 2.80 |
| AH | 614 | 10.2 | 2.97 | 733 | 10.1 | 2.93 |
| BK | 535 | 10.3 | 2.72 | 581 | 11.7 | 2.74 |
| PD | 436 | 17.6 | 2.63 | 543 | 17.6 | 2.63 |
| MRT | 603 | 13.3 | 2.61 | 477 | 14.7 | 2.62 |
| LM | 262 | 12.8 | 2.67 | 453 | 12.9 | 2.66 |
| LMc | 453 | 15.2 | 2.70 | 427 | 14.6 | 2.69 |
| JR | 444 | 9.3 | 2.99 | 407 | 10.1 | 2.92 |
| RT | 398 | 12.4 | 2.79 | 352 | 13.6 | 2.77 |
| SL | 308 | 13.2 | 2.80 | 352 | 14.6 | 2.75 |
| SH | 284 | 13.7 | 2.97 | 284 | 13.8 | 2.95 |
| CW | 308 | 15.5 | 2.85 | 284 | 15.0 | 2.75 |
| CG | 174 | 10.8 | 3.01 | 262 | 10.6 | 2.97 |
| GM | 174 | 11.0 | 2.97 | 218 | 11.6 | 3.00 |

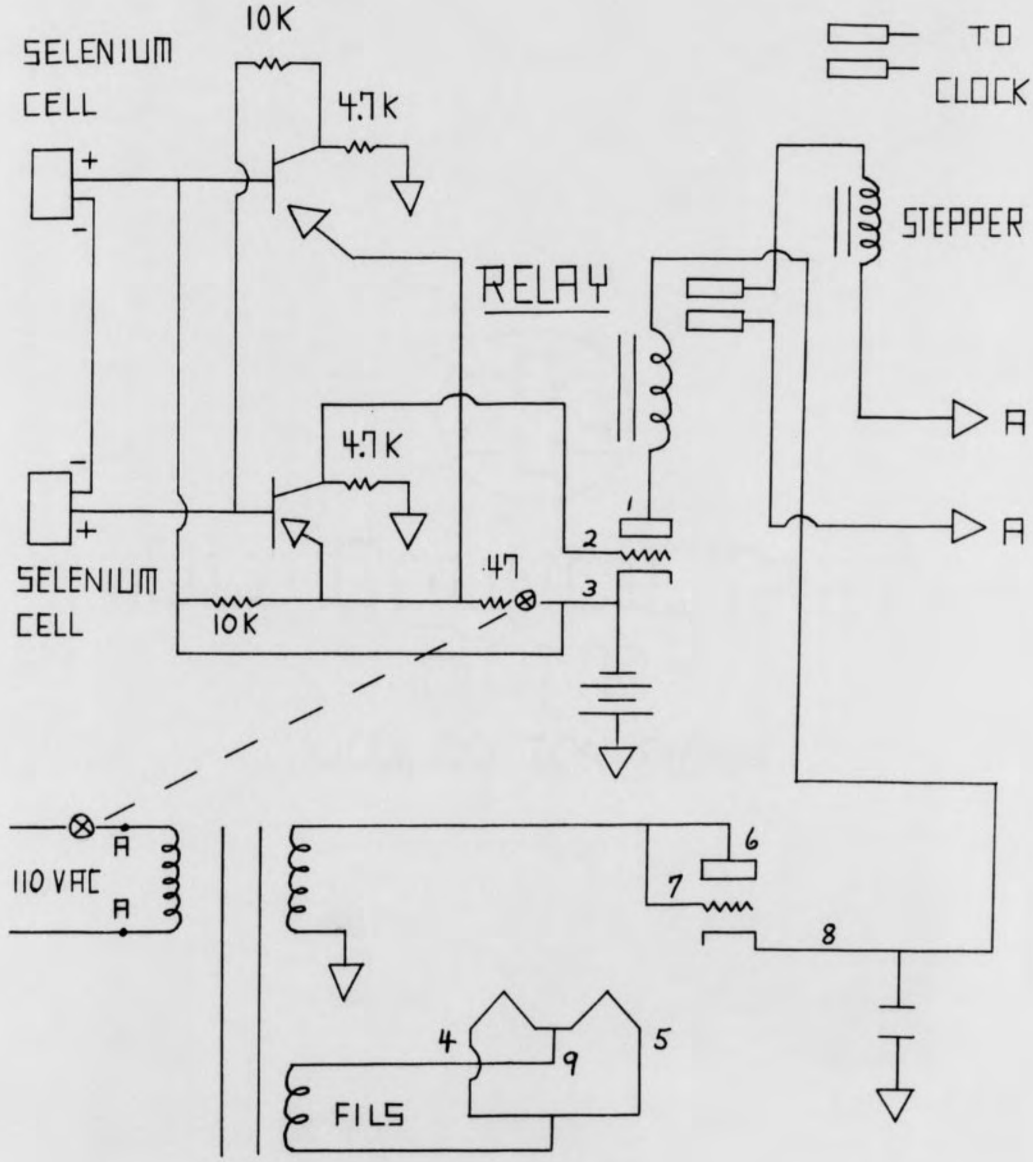


FIGURE 1

CIRCUIT DIAGRAM OF ELECTRONIC TIMING DEVICE

FIGURE 2

BACK AND LEG DYNAMOMETER

FIGURE 3

VERTICAL JUMP TEST