COMPARISON OF EFFECTIVENESS OF ISOKINETIC AND ISOTONIC EXERCISE IN QUADRICEPS STRENGTHENING

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ABSTRACT

COMPARISON OF EFFECTIVENESS OF ISOKINETIC AND ISOTONIC EXERCISE IN QUADRICEPS STRENGTHENING

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PURPOSE: It was the general purpose of this study to explore the area of methods of muscular strength development. More specifically this study was designed to compare the efficacy of two such methods, the older isotonic approach and the more recent isokinetic approach.

PROBLEM: Is there a significant difference in muscular strength gain with isokinetic exercises as compared to isotonic exercises in the quadricep muscle group?

PROCEDURE: The sixty subjects used in this study were divided into three different groups: control group, isotonic group and isokinetic group. A total of twenty subjects were in each group. Each group was pre-tested and then post-tested after a six week training period. The testing was done with a cable tensiometer at several different angles in the non-dominant leg knee extension. The comparative difference of strength gained between the pre-test and post-tests at each particular angle, and between groups were analyzed statistically. The statistical method used was the t-test and an analysis of covariance at the .05 level of significance.

RESULTS: There was no significant difference in strength gain between the isotonic method and the isokinetic method with the exception of the 90 degree angle. For the most part then, these two methods of strength development appear to be equal within the limitations of this study.

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Chapter 1

INTRODUCTION

Both man's existence and effectiveness greatly depend upon his muscular strength. One cannot stand, walk, run, climb, or swim without the sequential and controlled contraction of many muscles throughout the body. Smaller muscles perform intricate functions, including writing, playing musical instruments, singing, using hand tools, catching and throwing balls. Larger muscles perform such functions as running, jumping, and swimming. Muscles also perform vital functions of the body such as breathing and digestion, without which such functions could not take place. Even the heart is a muscle and death would occur instantly if it ceased to contract.

The overall conditioning and strengthening of the muscles are essential to man. Too frequently this fact has been ignored in an automated society, as only minimum muscular strength is needed to perform daily functions. Largely because of this automated society, parents and educators have clearly demonstrated their concern for the muscular strength levels of their children, themselves, and others.

Despite the widespread interest in strength and strength building, numerous misconceptions continue to

flourish on precisely how muscular strength is developed and exactly what method of exercise best develops such strength.

Research in strength development is, to say the least, plentiful. Most of this research has centered on two types of exercises, isotonic and isometric. It was Kabet-Kauser Institute of 1946-1957 which developed the basic need of the principles of maximum resistance developed throughout a range of motion (isotonic) (6). With the Delorme method (16) of sets and repetitions, the isotonic principle is utilized through a full range of motion. Such techniques of isotonic training have become the most conventional way to gain in muscular strength. The advantages of the isotonic method of exercises are: 1) the muscle is exercised through the full range of movement, 2) dynamic strength is developed through movement, and 3) strength is measured by the amount of weight one is to lift. Even though the isotonic method of exercising has been looked upon as the better of the two methods specific to strength building, disadvantages still prevail. Some of the disadvantages include: 1) the speed of movement is not held constant, 2) the time required throughout the exercise is greater than isometric exercises, 3) the total amount of weight the person can lift is that which the muscle can handle at the weakest point in the range of movement, 4) the muscle being exercised is not exercised to its maximum throughout its full range of movement, and 5) the muscle experiences ballistic effects at different points during range of motion.

When isometric contractions became fashionable in the early 1960's, researchers were quick to compare this new method of exercises with the conventional isotonic method. Many researchers believed at first that by doing several isometric contractions throughout the full range of motion one could achieve maximum force at every joint angle. Unfortunately, several research projects proved that contracting a muscle without movement builds static strength, (no change in muscle length) but does not significantly improve the dynamic strength (change in muscle length) of the muscle. Further disadvantages to the isometric are: 1) accurate evaluation of muscular effort of the person while performing the exercises is very difficult, 2) the muscle is not exercised throughout the full range of movement, 3) static strength is developed rather than dynamic strength. However, the isometric exercise theory does have certain distinct advantages, including: 1) time required to do exercises is less than that of isotonic exercises, 2) strength is contributed at a specific angle, 3) proper lifting technique is not needed as is necessary in isotonic exercises. But because there is no movement in isometric exercise and as well that static strength is developed rather than dynamic strength, the isometric principle seems to have rapidly diminished in popularity.

The general devaluing of the isometric method furthered the original movement toward the isotonic method. Therefore the full range of movement technique has come to

be considered by most to be the superior method of building strength. For example, Hinson and Rosentswieg (39) agree that isometric exercises, though fast and easy to do, contribute to strength only at the specific angle at which the exercise is performed, not over the full range of motion. If, for instance, the arm muscles are exercised isometrically with the elbow at 90 degrees, the arm muscles probably will gain strength only at this specific angle. Therefore there is no assurance that the arm muscles will show the same or in fact, any, strength gain at any other angle of flexion. The time saved with isometrics may, hence, be more hypothetical than actual.

However, since both methods of exercise still each have their advantages and disadvantages, researchers in the last five years have been looking for a single method of exercise that will incorporate the positive features while eliminating the negative features of both methods. The latest research and most recent advances in the direction of new methods of building strength has revealed a new technique which has claimed to do that very combining of isotonic and isometric techniques. This new method is called isokinetics.

The significant difference between an isokinetic contraction and the other two methods of exercises previously discussed, is that isokinetic exercising attempts to place greater demands on the muscle because the muscle can be loaded maximally at every joint angle in its full range of

motion. The speed of the muscle is also held constant, eliminating the dissipation of energy through acceleration.

THE PROBLEM

Isotonic strength conditioning involves the muscle shortening as it contracts. The most popular source of resistance in isotonic programs is for the subject to lift a weight two-thirds to three-quarters of his maximum capability for three sets of six to eight repetitions. He does this three or four times a week on alternate days. Because of skeletal leverage in most range of motion movements, the middle one-third is usually twice as strong as the weakest third of the range. Therefore, the load must be limited to the maximum amount which can be moved at the weakest joint angle. It is impossible to load muscles to their maximum through a full range of motion. The resistance has its greatest mechanical advantage on the muscle at the extremes of range. Here the lever system is most extended or flexed and the load on the muscle is greatest at these points. Consequently, the total work done is significantly less than maximum capacity over the larger part of any range of motion.

The isokinetic strength technique constantly overloads the muscles to their maximum with each repetition whether or not it is the second or the tenth repetition of the exercise and without overstressing or understressing the muscles at any point. The basic idea is to control the speed of movement rather than controlling the constant weight

as in isotonics, or in lieu of controlling distance moved, as is done in isometrics. By controlling the speed, the weight resistance is controlled because it automatically accommodates to the body or to the limb as it moves through a full range of motion. By controlling the speed of movement, isokinetic exercises prevent energy from being dissipated by acceleration.

Statement of the Problem

Is there a significant difference in muscular strength gain with isokinetic exercises as compared to isotonic exercises in the quadricep muscle group?

Statement of the Hypothesis

There is no significant difference in muscular strength gain when using isokinetic exercises as compared to using isotonic exercises in the quadricep muscle group.

Assumptions

The following were considered assumptions of this study:

1. The work by the subjects in this study was performed dynamically in both isotonic and isokinetic exercises. It is assumed by testing strength gains statically that this will enable an accurate measurement of strength gained dynamically.

2. The work by all subjects in the study was equal.

3. Each subject was working at 80 percent of his maximum throughout the experiment.

4. Each subjects daily outside activity was basically the same.

5. Changes in strength of skeletal muscle which may have resulted from exercises utilizing the overload principle could be measured.

LIMITATIONS OF THE STUDY

The following were considered limitations of the study:

1. The cable tensiometer was the only possible means of measuring strength gains.

2. The sample size was limited to the number of males in the foundations of physical education classes (basic skill classes) at Kansas State Teachers College of Emporia.

Delimitations

The following were delimitations of the study:

1. A six week period of time was allowed for actual exercises to take place.

2. The quadricep muscle group of the non-dominat leg was exercised.

3. All the subjects were college men.

4. The subjects performed three sets of seven repetitions three times a week with one day of rest between exercise periods.

5. The subjects' daily living habits were not controlled.

DEFINITIONS OF TERMS

The following definition of terms apply in this study:

Atrophy. Atrophy refers to a decrease in the muscle fiber circumference from normal.

Cable tensiometer. A cable tensiometer is a device that measures muscular force at varying joint angles (see Appendix I).

Concentric contraction. A concentric contraction is the unresisted shortening of a muscle, as in the rapid, light, rhythmic activity (5:78).

Cybex. The cybex, is a device that consists of a lever against which the exerciser was pushed and which always produce the same amount of force (resistance) that had been exerted against it.

Dynamic. Dynamic is a muscular effort which results in movement, an imprecise usage because the tension of the muscle usually does not remain constant during movement (5:15).

Eccentric contraction. An eccentric contraction is the tension of the antagonistic muscle during lengthening, such as slow, heavy work in a controlled motion, i.e., steering.

Foundation of physical education classes. The foundation of physical education classes are the basic skill classes in physical education at Kansas State Teachers College of Emporia.

Goniometer. This instrument consists of a 180 degree protractor of plexiglass with two attached stationary arms, 15 inches long, which form any angle desired (see appendix L).

Hamstring muscle group. The hamstring muscle group is located on the posterior and medial aspects of the thigh. The muscle group consists of the semimembranosus, semitendinosus, biceps femoris, and the illiotibial band.

Overload principle. In order to promote a gain in strength, the workload for a muscle or muscle group must be greater than that to which the individual is accustomed.

Progressive resistance exercise. Progressive resistance exercise indicate a progressive increase in the exercise load for the subjects.

Quadricep muscle group. The quadricep muscle group is located on the anterior aspect of the thigh. The muscle

group consist of the rectus femoria, vastus medials, vastus laterales, and the vastus intermedius.

Quadricep table. The quadricep table was designed to isotonically strengthen the quadricep muscle group (see appendix G).

Repetitions. Repetitions are the number of consecutive times a particular movement of the exercise is performed.

Set. The number of repetitions of a particular movement or exercise repeated.

Strength. Strength is the pulling force, or tension that can be exerted during contraction. This largely depends on the size and number of muscle fibers.

Super mini-gym commander duo exerciser. The super mini-gym commander duo exerciser is a machine which will always produce the same amount of force throughout the range of motion at every joint angle, provided the muscular force remains constant. This machine was developed to exercise the quadricep muscle group isokinetically (see appendix H).

Chapter 2

REVIEW OF RELATED LITERATURE

The review of literature for this study appears in three parts. The first section deals with progressive resistance exercise. The second section reviews strength development using isometric and isotonic exercises. The third section includes literature related to the new isokinetic principle.

PROGRESSIVE RESISTANCE EXERCISES

Physiologists have repeatedly verified the observations that muscles increase in size as a result of regular periods of heavy physical exercise. In a study by Rarick showed that "gains in strength also accompany increases in muscle size although the strength gains are usually proportionately greater than the increases in girth (36:450)." Karpovitch (24) found the increases in size and strength which accompanies training is largely due to the development of latent fibers normally not used. Although it is known that the stimulant for growth of muscle tissue is more closely related to the intensity of the exercise than to the durations, the most effective method of developing strength is a controversial subject.

All common methods of developing strength use the overload principle.

> In order to promote a gain in strength, the workload for a muscle or muscle group must be greater than that to which the individual is accustomed. Use of the muscle beyond normal, increases muscle strength; disuse of the muscle results in atrophy (12:18).

"In progressive resistance exercise overloading is achieved by increasing the magnitude of the weight against which the muscle develops tension (16:10)."

The Delorme (17) system of progressive resistance exercise, based on the overload principle, is perhaps the most widely publicized and used. The method includes three exercise periods. The first period consists of lifting a weight equal to one-half maximum for ten repetitions; the second period consists of lifting a weight equal to three fourths maximum lifted ten times; and the third exercise period consists of lifting a weight to the maximum of the individual capabilities ten times. However, since the Delorme system has been developed many other variations of this basic method have been devised and are used successfully.

MacQueen (27) introduced a new technique of progressive resistance exercise. The initial weight is never less than the maximum which can be lifted ten times. The weight is increased between sets and the number of repetitions decreased. Eventually the weight is lifted only once.

Zinovieff (46) modified the Delorme system of heavy resistance for use in the Oxford Hospital in England. Zinovieff's Oxford technique starts with a maximum load. The weight is gradually reduced for nine successive sets of repetitions.

A rearrangement of the Delorme system was suggested by McMcloy (11). It included starting the first set of ten repetitions with a weight equal to one-half the maximum load. A weight equal to maximum of ten repetitions would be lifted for the second set and a weight equaling three fourths maximum lifted ten times for the third and final set of exercises. Comparing Delorme's and Zinovieff's methods of heavy progressive resistance exercise, McMorris and Eiklens (31) found there was little difference in the development of strength.

Tension was considered by Baer (3) as the determining factor in the developments of muscle strength. Since more tension can be developed by static contractions than by isotonic contractions, static methods should be superior in the building of strength. Rase (38) found that if the quadriceps are exercised by lifting a weight and maintaining it with the maximum extension of the leg for a total duration of five seconds a day, the resulting increase in muscle strength is comparable to that which would have been expected for the traditional Delorme exercise.

Hettinger and Muller (42) explored the mechanism of strength building. Through laboratory tests of subjects

they concluded that one daily six second contraction of two thirds maximum load would cause a muscle to gain sufficiently in strength.

The work of Hettinger and Muller was reviewed by Steinhaus at the 1954 meeting of the College Physical Education Association. The following are Hettinger and Muller's findings as reported at the meeting:

> Muscle strength increases an average of 5 percent, per week when training load is as little as 1/3 or even less, of maximum strength.
>
> Muscle strength increases more rapidly with increasing intensity of training load up to 2/3 of maximum strength. Beyond this, increase in training load has no further effect.
>
> One practice period per day in which the tension was held for six seconds resulted in as much increase in strength as longer periods (up to full exhaustion in 45 seconds) and more frequent practices (up to seven per day) (42).

Muller further stated that one six second contraction performed daily will produce a 12 percent strength gain a week until the limiting strength or maximum potential is approached. He also reported that a one-second maximum contraction every two weeks is sufficient to maintain strength levels.

With the publishing of their findings Hettinger and Muller opened up a whole new area of the strength development program. The next logical step was to investigate the effect of isometric exercises, not only on strength, but on other factors which are involved in fitness and strength development, i.e., reaction time, speed of movement and endurance.

STRENGTH DEVELOPMENT

In 1960, after continued investigation, Hettinger (21) concluded that,

> the maximum improvement in the strength of the muscle group being trained can be obtained by giving daily one maximum voluntary isometric contraction against a resistance for one or two seconds.

However, in recent studies it has been determined that a six second contraction is far more effective than one second contractions.

Sterling (44) reported that a study conducted by Barham, that he was to compare the strength gained by performing one daily six second isometric contraction to strength gained by performing three six second contractions. Fifty-five subjects were divided into three groups: group 1 performed one isometric contraction daily; group 2 performed three isometric contractions daily; and group 3 acted as a control group. The extensors of the leg and back were the muscle groups tested. Barham concluded:

1. Isometric exercises will result in significant improvements in muscle strength.
2. There is no significant difference between the strength gained by employing one isometric contraction daily and the strength gained by employing three daily isometric contractions.

In another study along similar lines, Barham investigated the effectiveness of different frequencies of isotonic and isometric exercises. Three isometric and isotonic groups were utilized with one group from each exercise

method training five days a week, one group from each exercise method training three days a week, and one group from each exercise method training two days a week. The isometric contraction was held for six seconds in training while the isotonic routine was the maximum load that could be lifted five times plus the same isometric training program previously described. Barham reported the following findings:

1. A significant improvement in strength was achieved by the three isometric groups.
2. The addition of isotonic exercise to the isometric routine did not bring about a significantly greater gain in strength.
3. There was not a significant difference in strength gained by exercising three days a week.
4. There was a significantly greater gain in strength by the group exercising five days a week over the group exercising two days a week.

Berger (5:81) divided seventy-eight subjects into two groups, with one group training isometrically and one group training isotonically three times a week for twelve weeks. All subjects were tested both isometrically and isotonically for lower back extensor strength. Both groups improved significantly on tests. However, the isometric groups showed greater improvement when measured isometrically than when measured isotonically. And the isotonic group exhibited greater improvement when measured isotonically than when measured isometrically. Berger concluded that isometric

strength was best measured isometrically and isotonic strength was best measured isotonically.

After training fifty-seven college males statically, three times a week for twelve weeks, and 177 college males with various dynamic programs, Berger (19) found no significant difference in strength improvement between the two groups as wholes. He did find that the sub group which trained dynamically for three bouts did exceed the sub group trained statically in strength improvement, but he also found that the sub group trained dynamically for two bouts and two repetitions was inferior to the sub group trained statically.

The purpose of a study by Marley (28) was to compare isometric and isotonic training in their effectiveness to develop muscular strength, endurance, and girth. An isometric training group, an isotonic training group and a control group were utilized. Marley concluded:

1. Both training programs brought about an increase in strength with little differences existing between the two programs.

2. Isometric endurance and isotonic endurance are developed more effectively by isometric training and isotonic training, respectively.

In another comparison of the effects of isometric and isotonic exercises, Mathews and Kruse (30) concluded that isometric contraction exercises brought about a significant strength gain in more subjects than did isotonic exercises. They further concluded that strength gain was different to the individuals body girth.

Rasch and Morehouse (38:29-34) trained two groups of subjects, one isometrically and one isotonically, three days a week for six weeks. They utilized tests which employed the trained muscles in both a familiar way and unfamiliar way. Although strength gains were shown in the familiar procedure, little or no gains were recorded in the unfamiliar procedure. From their observations, it was stated that, "the findings suggest that the higher scores in strength tests resulting from exercise programs reflected largely the acquisition of skill (38:34)." Also, the group training isotonically showed greater gains in strength and hypertrophy than did the isometric group.

In another study, Rasch (37) trained a group isotonically for six weeks and then tested them both isotonically and isometrically. Upon comparison of the isometric and isotonic strength scores he concluded that "measurements of maximum strength made by use of isometric techniques are valid in expressing isotonic strength (37:85)."

The findings of the studies reviewed above serve to point up the disparity existing in the research pertaining to the relative merits of isometric and isotonic exercises. Most of the studies indicated that both isometric and isotonic training will bring about significant increases in strength. There were individual studies which found that isometric exercises would not increase isotonic strength; isotonic exercises would not increase isometric strength, and

isometric exercises was better for increasing isometric strength and isotonic exercises were better for increasing isotonic strength. Other conflicting findings were in the number of days per week necessary for maximum strength gain, the length of the contractile effort, and the number of repetitions which should be used each training session.

The literature seemed to reveal that the minimum training requirements for isometric strength gains would be a single, six second maximum contraction performed three days a week.

ISOKINETICS

Isokinetic exercising, a new approach to muscle training, provides for the development of human neuro-muscular systems for all critical types of muscular energy output. Isokinetic exercise employs a simple, but largely unfamiliar, physical principle for loading a dynamically contracting muscle, positively controlling the speed of motion produced by the contraction. Isokinetic exercise involves a maximum effort as in isometric exercise but is carried out through a complete range of motion.

Delateur, (15:60-64) and her team of associates at the University of Washington School of Medicine, pre-tested sixty five college women who had no history of joint diseases or trauma, and who were not participants in any formal or informal exercise program, and who had no previous experience

on the Cybex machine. The pre-test was done in order to select a relatively homogenous sample and in order to define fatigue for those exercising on the Cybex. During the pre-test sixty-five subjects came in for one session per-day for a total of five sessions. Each subject was asked to give ten maximal kicks on the Cybex exerciser for each session. For further testing only the subjects whose work output fell within a plus or minus one standard deviation of the mean were used. Forty-four subjects qualified and were randomly divided into four groups. Two of these groups of eleven each trained on the Cybex and two were trained on isotonic weights.

After the completion of eighteen sessions, one of the Cybex groups was shifted to the isotonic task and one of the weight groups were shifted to the cybex task. The subjects then continued for eight more sessions.

The results strongly suggested that for simple quadriceps strengthening, the cybex offers no particular advantage over ordinary weights. The Cybex does give immediate feedback which is helpful for reinforcement of progress; however, this can be substituted for nicely by counting and charting either the repetitions or the weight increase or both. The weights proved to be simple, required few or no adjustments, and offered virtually no problem of mechanical failure.

In a preliminary study by Thistle (45) an accommodating resistance exercise was compared with two other

commonly employed exercise technique for muscle strengthening, progressive resistance exercise and isometric exercise. Sixty normal subjects were divided equally into three exercise and one non-exercise control groups. The three exercise groups exercised four days a week and on the fifth day each subject in all four groups was tested with the isokinetic apparatus and torque curves were recorded. This testing was done each week for eight weeks. For the final analysis of results, comparisons were made between the better scores for total work and for maximal force exerted in the final two weeks and in the first two weeks. After these scores were calculated and analyzed it was reported that after the eight week period of exercise, the experimental group using isokinetic exercises showed an improvement of 35.4 per cent in total work ability, while the group using the isotonic method improved only 27.5 per cent and the group using isometric contractions improved 9.2 per cent. The results in peak force ability were even more remarkable with the isokinetic group improving 47.2 per cent, the weight lifting group 28.6 per cent, and the isometric group 12.1 per cent.

One of the observed incidental features in Thistle's study was that pain as a source of complaint may be diminished among subjects performing accommodating resistance exercise (isokinetics). Another feature was the enthusiasm demonstrated by the subjects using the isokinetic device as

opposed to those subjects using the conventional progressive resistance exercise.

Hislop and Perrine (22:113), in researching the isokinetic concept of exercise, stated that:

> The unique factor in the concept of isokinetic exercise is control of the speed of muscular performance. In order to achieve this kind of performance it is necessary to provide an external means of holding the speed of body movements to constant rates irrespective of the magnitude of forces generated by the participating muscles at the same time, an isokinetic device provides suitable mechanical means for receiving the full muscular force potential of a body segment throughout a range of motion, but without permitting acceleration to occur (22:113).

In isotonic exercise, because the load is constant, the speed of the body segment involved will vary with the force applied. Isometric exercise speed is obviously eliminated because of the prevention of motion entirely. In isotonic exercise some energy is utilized by the contraction and much is consumed in the various accelerations of the motion. More energy may be absorbed in isokinetic exercise by muscular exertion because acceleration is controlled mechanically by the device. Therefore, energy is not wasted in speed control and may be concentrated on developing force. With the use of the isokinetic device the muscle is able to maintain a state of maximum contraction through its full range of motion and thereby a maximum demand is required on the work capacity of the muscle. It may be recognized that in this capacity, isokinetic exercise offers the advantages outstanding in both isometrics and

isotonics. Hinson and Rosentswieg (21) headed a Texas Womans University research team designed to compare the effectiveness of this isokinetic technique (using a mini-gym) with both isotonic and isometric methods. They decided that the best indicator of strength was the electrical activity present in the muscle during contraction, as this reflected actual muscular activity rather than mechanical force. Electrodes were placed on the biceps brachii muscle of the dominant arm of fifty two female subjects. Each was asked to stand and complete one maximum isotonic contraction, one isokinetic contraction, and one isometric contraction at four different angles by flexing the elbow against the indicated resistance. The results indicated isokinetic exercises caused significantly more electrical activity than either the isotonic or isometric exercise. The researchers concluded that whereas all three contraction methods produce strength gains, the isokinetic method, which required the most muscular work, produced the greatest gains.

In a study of isokinetic exercise by Moffroid (32) the following conclusions were reached:

> Isokinetic exercises increases the work a muscle can do more rapidly than does isometric exercise . . . . Muscular response to different loading systems tends to be specific; that is, a muscle which is overloading in a partial range of motion will increase significantly more in this range than in other less exercised joint positions (32:6).

Isokinetic exercise does not represent any one type of exercise, but is actually a new training modality which, through the control of exercise speed, makes possible and practical many different types of muscle training. It may serve as its own best means of illustrating the different types of mechanical energy output of which muscle is capable.

SUMMARY

The two traditional overload methods of strength training are called isometric exercises and isotonic exercise, and now a third system "isokinetics" has shown great potential. The two programs differ in the functioning of the muscle while performing each.

Isometric means same length, and is recognized as static contraction because the muscle remains at the same length throughout. Isometric muscular contractions are exerted against a load which is immovable. The muscle may achieve near maximal contraction, but in one position with no physical work being accomplished; work being defined as force times distance or (W=FXD). Hence, isometric exercise is muscular exertion without the Newtonian qualities of work.

The word isotonic means same force, and refers to the contraction of the muscle against a constant force throughout the range of motion. Isotonic exercise is referred to as dynamic. In isotonic exercise while the load of

the weights remains constant through the range of motion, the resistance to the muscle is not constant because varying strengths of the lever systems used in dynamic exertion. The load of the weights has its greatest effect on the muscle at the extremes of range and least effect at the mid-range. Therefore, the maximal demand on the muscle during exercise is required only through a small portion of any range of motion, resulting in the total work done being much less than the maximum capacity. Isotonic exercise limits maximal contraction of a muscle because the force used must not be too great for the weakest point in the range of motion, if the complete motion is to be accomplished.

Isokinetic contractions involved the control of speed throughout the range of motion. In order to achieve this control, an external means of holding the speed of body movements must be provided. An isokinetic device inhibits acceleration while providing the mechanical means of receiving the maximal muscular force throughout a range of motion. The isokinetic concept of overloading may therefore be recognized as a system of accommodating resistance. With the use of the isokinetic device the muscle is able to maintain a state of maximum contraction through its full range of motion and thereby a maximum demand is required on the work capacity of the muscle. It may be recognized that in this capacity isokinetic exercise offers the advantages outstanding in both isometrics and isotonics.

Researchers will continue to look for new methods, new exercises, and new variations of our present exercise and will try to build stronger muscles which will enable man to become bigger and stronger. The introduction of isometric contractions promised a great deal but did not deliver all of its claims. Now the future of strengthening exercises seems headed in another direction, and appears to be promising. However, continued research with isokinetic exercise is needed, particularly in the area of repetitions and frequency of workouts. There is also need to study the optimum rate of speed at which the exerciser should work.

Chapter 3

METHODS AND PROCEDURES

In this study, involving the comparison of effectiveness of isokinetic and isotonic exercises in quadriceps strengthening, foundation of physical education classes were used. Foundation classes are the basic skills classes in physical education.

SUBJECTS

All of the male volunteers from the foundation of physical education classes I and II were used at Kansas State Teachers College of Emporia. All students from the foundation of physical education classes were randomly selected from the class roster. The foundation of physical education class I was made up of forty volunteers from which two experimental groups of twenty were formed. Group one was considered as the isotonic group and group two was considered as the isokinetic group. The foundation of physical education class II was made up of twenty volunteers to form the control group or group number three. A total of sixty subjects took part in this study. Classes were selected on the availability of the classes and by the approval of the instructor. The students in these classes were not required to take part in the study if they did not wish to, only

volunteers were used. All of the subjects in these classes took part in their regular class activity each day they had class. The subjects outside activity was not controlled by this investigator. All subjects were instructed not to take part in any exercises that would directly effect the quadricep muscle group, meaning that no specifice exercises were to be performed by the quadricep muscle group.

EQUIPMENT AND FACILITIES

The study was conducted in the third floor gymnasium of the Physical Education building at Kansas State Teachers College of Emporia. The equipment used in this study was as follows: 1) one isotonic knee extension table (see appendix G); 2) the super Mini-Gym Commander Duo Exerciser (see appendix H); 3) two cable tensiometers, one from the Kansas State Teachers College Physical Education Department (see appendix I) and one borrowed from the Kansas University Physical Education Department; 4) one 12 inch length 3/32 flexible cable was used with a 1 inch loop at the end of the cable, which was secured with a clamp of a size to fit a cable. By use of a 1 1/2 inch clevis, the cable is attached to a light welded link chain (linch links) 12 inches in length. A second clevis was needed for attachment of the cable to the D-ring of the strap; 5) one regulation strap with a 9 inch loop (see appendix J); 6) one specially designed testing table made from a training room table with two eye hooks placed in a position to obtain the desired

angle (see appendix K); 7) one Goniometer, constructed of a 6 inch protractor and two transparent arms 15 inches long, attached to the protractor (see appendix L).

TESTING PROCEDURES

Each class was given an instruction period on exactly how the exercises were to be performed. After this instructional period, each class was given a pre-test with the Cable tensiometer. A Cable tensiometer provided by the Kansas State Teachers College Physical Education Department was used for all pre-testing. The same tensiometer was used for all post-testing procedures except for thirteen subjects. For these thirteen subjects a cable tensiometer was barrowed from Kansas University. The reason for the necessary change in tensiometers was because the tensiometer used for all pre-testing was not calibrated high enough for these few individuals.

In both the pre-test and post-test, the strength of flexion of the quadricep muscle group was measured at three different angles of extention. The three different angles at which strength tests were made were 90 degrees, 135 degrees, and 170 degrees. These three angles were used to determine the effects of the two methods of exercises on the development of strength through the full range of movement in the development of strength. The reason for this was to evaluate the worth of the isokinetic principle of weight training.

Each subject was given instruction on the position they were to use for the pre-test and post-test procedures. Subjects were instructed to take a sitting position at the edge of the testing table with both legs hanging freely over the edge of the table. From this position the subject was instructed to take a slight backward leaning position so as to balance himself when doing the exercise. The arms of each subject were placed to the rear of the table in a locked position with his hands flat on the table. At no time did the subject grasp the sides of the table. Caution was given as not to lift his buttocks and not to flex his arms during the testing. To further prevent this from happening the testors assistant was instructed to put his left hand on the subjects' left shoulder and his right hand around the subjects' left hip in an attempt to hold the subjects buttocks from lifting from the table as well as to keep any other unnecessary movement to a minimum.

To insure that the tests were being made at the prescribed angles, a goniometer was constructed and employed (see appendix L). This device consisted of an 180 degree protractor, 6 inches in length, made from transparent material with two arms, 15 inches long, attached to the protractor. One of these arms was fixed, extending along the zero line of the protractor; the other arm was a moveable arm permitting rotation to the proper angle. The use of a winged nut and bolt placed through an eyelet at the center

of rotation of the moveable arm was used to help maintain set angles of the goniometer (see appendix N).

As each subject entered the room they were instructed to take the proper sitting position with their legs hanging over the testing table. The regulation strap (basic strap used in most all cable tensiometer strength tests) was then placed around the non-dominant leg midway between the knee and the ankle joints (see appendix M). The goniometer was then set at the desired angle and placed alongside of the non-dominant leg, with the center of the protractor resting on the lateral collateral ligament of the knee. The arm that was fixed along the zero line then was pointing directly at the lateral aspect of the greater trochanter of the femur and the moveable arm was lined up with the lateral malleolus (see appendix M). After this was accomplished the cable and chain were fastened to the proper hook on the testing table. The leg was now at the precise angle to be tested. Subject was then instructed to put the cable in a taut position for the beginning of the first trial. The tensiometer was then placed on the cable in a ready position. The subject then was given the command to "pull" and hold the contraction for six seconds. After the contraction was completed and the testor said relax, the subject would bring his leg back to a resting position for ten seconds while his score was recorded on his file card (see appendix D). The same procedure was repeated two more times for that particular

angle. After the three contractions were completed the highest score of the three contractions was recorded.

Five days were allowed for the entire pre-test period. During this time each subject was tested at only one angle a day on any day they chose to be tested. All subjects were first tested at 90 degrees, then 135 degrees, and then at 170 degrees. Thus each subject appeared on three separate days for testing, one each day. The post-test procedures were the same as the pre-test procedures. The only necessary change in the post-test procedures was the use of the Kansas University cable tensiometer for the thirteen subjects.

The results of the pre-test and post-test showed that their was no significant difference between the isotonic group as compared to the isokinetic group in strength development, during the six week period of exercise.

TRAINING PROCEDURES

The isotonic group and the isokinetic group are the only two groups that took part in the training procedures during the six week period. The control group only participated in the pre-test and post-test procedures.

An instructional period on exactly how the exercises were to be performed was given to all subjects before the exercises actually started. The exercise used in this study was the knee extension. Subjects were initiated to the exercise in a sitting position at the end of the table with

their legs hanging freely over the edge of the table, leaning backward grasping the sides of the table. The elbows were locked, with their hips being at a 90 degree angle, thus enabling the quadriceps muscles to be more nearly at their full length; and the tension of the hamstrings (the muscle group which is located on the posterior part of the thigh) would not be so great. The non-dominant leg was the only leg exercised during the six week period. The subjects free leg was hanging freely over the table next to the non-dominant leg under the exercise bar (see appendix G). From this position the subject would extend his leg to a 180 degree position, then return the leg to the original 90 degree position pausing for one full second before continuing to the next repetition. The pause was included to prevent any type of swinging motion that could develop.

Each subject using the isotonic quadricep table started at fifty pounds. This was done to allow each subject to determine whether or not they were ready for an increase in weight, and also to enable each subject to start at a weight that they could handle so the exercise could be performed correctly the very first time. A daily chart (see appendix F) was kept with the subjects name, the date, and the amount of weight that he exercised with on that particular day. Each subject would perform three sets of seven repetitions and then allow approximately one to three minutes of rest between sets. When a subject could do ten repetitions on his last set of repetitions he would then increase

his weight ten pounds the very next time he came in to exercise. Each subject was allowed to try for ten repetitions on any day that they felt they were capable of doing ten repetitions. The purpose of this was to make sure each subject was exercising at near maximum.

The resistance on the Super Mini-Gym Commander Duo exercise machine was automatically adjusted within the machine itself. Each subject was asked to complete the quadricep extension in the shortest time that he possibly could. This would require him to use maximum strength at every joint angle in the range of movement of the knee. The dial on the Mini-Gym Commander Duo revealed at all times during the exercise whether or not the subject was working at his maximum. When the subject had finished one set of seven repetitions he was required to take approximately one to three minutes of rest between sets. A daily chart (see appendix F) was also provided for the isokinetic group with the subjects name, the date, and the amount of resistance the subject pulled during the exercise. This was determined by taking the highest reading of the resistance indicator of the Mini-Gym Commander Duo exerciser (see appendix O).

Three times a week the subjects would either go to the knee extension table or the Mini-Gym Commander Duo exerciser, depending on what group they were assigned. The subject would then take the proper sitting position on the table after adjusting the weight to whatever weight or

resistance they were doing at that particular time. After the proper sitting position was obtained the subject would then proceed to extend his non-dominant leg to a 180 degree extension, then return the leg to the original 90 degree position. This was done with a slight pause between repetitions for seven repetitions. Subject would then take a rest for one to three minutes between sets. The subject would then continue on to the next set until he has completed three full sets of seven repetitions. Upon completion of his sets the subject would then mark down next to his name on the chart the date, and the amount of weight or resistance he did on that particular day.

The study continued for a period of eight weeks. Pre-testing and post-testing took place the first and eighth week of the study. Six weeks of the actual experiment were devoted to exercise involving isotonic and isokinetic exercise methods. The Foundation of Physical Education classes, from which the subjects were taking part, met two hours a day on Monday, Wednesday, and Friday of each week. Subjects were strongly requested to do exercises directly before or immediately after their classes were excused. However, this procedure was not required, just so long as the exercises were done sometime during that day. Both the isotonic and isokinetic groups used a slight variation of the Delorme method of sets and repetitions. The isotonic and isokinetic groups performed three sets of seven repetitions three days a week on alternate days of the week,

Monday, Wednesday, and Friday for a period of six weeks. The study was interrupted the fourth week because of spring vacation and because of this no exercises were performed during this time. The experiment resumed that following Monday.

STATISTICAL ANALYSIS

The experimental data in this study was collected to compare strength gains between the isotonic method of strength building and the isokinetic method of strength building.

The first step in the treatment of the data was to determine the difference between the pre-test and the post-test of each group at each particular angle. The next step was to determine the standard deviation of each group at each particular angle between the pre-test and post-test. In order to reject or accept the null hypothesis it was necessary to determine this at the .05 level of significance. This was calculated to see if there was a significant difference between the pre-test and the post-test. To show these effectively a t-table was set up for correlated fields. The formula that was used to determine the t-table for correlated fields was as follows:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1 + n_2 - 2} - 2r \frac{s_1}{n_1} \frac{s_2}{n_2}}}$$

The second step used in the statistical analysis was that of the analysis of covariance. In its most basic form, one might think of analysis of covariance as determining the magnitude and direction of the relationship between the control variable and the criterion variable.

To test the hypothesis of equal means, it is necessary to obtain adjusted sums of squares and mean squares for the criterion variable. The adjusted total sum of squares may be calculated from:

$$SS^{1}_{ty} = SS_{ty} \frac{(SP_t)^2}{SS_{wx}}$$

Where SS_{ty} is total sum of squares for Y.

Similarly, the adjusted sum of squares within groups may be determined from:

$$SS^{1}_{wy} = SS_{wy} - \frac{(SP_w)^2}{SS_{wx}}$$

Where SS_{wy} is sum of squares within for Y.

Finally, the adjusted sum of squares between groups may be calculated as a residual:

$$SS^{1}_{by} = SS_{ty} - SS_{wy}$$

As in the simple analysis of variance, the number of degrees of freedom for the adjusted sum of squares between groups is found by subtracting one from the number of groups (k-1). One degree of freedom is lost by imposing the

restriction that the deviations be computed from the common within groups regression line, and the number of degrees of freedom then for the adjusted sum of squares is (N-2). The adjusted mean of squares between and within are obtained by dividing the sums of squares by their respective degrees of freedom. The test of the hypothesis of equal means is obtained from (40:257):

$$F = \frac{MS^{1}_{by}}{MS_{wy}} \text{ with df} = (K-1), (N-K-1)$$

The third step in the statistical analysis was that of a t-test for two independent samples. The following formula was used:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\approx \bar{X}_1 - \bar{X}_2}$$

Where:

$\bar{X}_1$ = mean of the differences between pre-test and post-test measures of the first group.

$\bar{X}_2$ = mean of the difference between the pre-test and post-test measures of the second group.

$\approx \bar{X}_1 - \bar{X}_2$ = estimated standard error for the sampling distribution of the difference between means.

In order to see if there was a significant difference between groups, thirty eight degrees of freedom was used at the .05 level of significance.

Chapter 4

ANALYSIS OF DATA

The major area of concern in this study was to determine whether there would be a significant difference in strength gain isotonically as compared to strength gained isokinetically in the quadriceps muscle group.

The sixty subjects used in this study were divided into three different groups: control group, isotonic group and isokinetic group. A total of twenty subjects were in each group. Each group was pre-tested and then post-tested after a six week training period.

The comparative difference of strength gained between the pre-test and post-tests at each particular angle, and between groups were analyzed statistically. The statistical method used was the t-test and an analysis of covariance at the .05 level of significance.

TREATMENT OF DATA

The null hypothesis was used in this study. It is hypothesized in the null hypothesis that no differences exist between the three groups. If any significant differences were discovered. The null hypothesis would be rejected. But if the differences were not significant, the null hypothesis would be accepted.

Control Group (90 degrees)

The first step in analyzing the data collected in this study was to add all of the raw scores of all individuals at 90 degrees to find the mean raw score of both the pre-test and the post-test groups. Table 1 (page 40) was designed to indicate the results of the control group at 90 degrees.

When the pre-test and post-test were compared at the 90 degree angle for the control group, there was an 8.95 unit increase between the mean raw score of the post-test as compared to the pre-test.

In looking at the standard deviations of both tests, as a means of variability, there was an increase in strength at 90 degrees of a 19.266 unit, or that the group was more nearly alike at the pre-test than at the post-test. This would indicate that although no direct or controlled exercises were done to directly affect the quadriceps muscle group an increase in strength did occur.

Table 1

t-Test for Control Group at an Angle of 90 Degrees

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Pre-test	20	7.034	152.25	8.95	19	+1.676
Post-test	20	26.3	161.2			

*$t_{19} \geq \pm 2.093$ at the .05 level of significance

In looking at the difference of the mean raw scores, there was a difference of a 8.95 unit between the pre-test and the post-test for a six week period. A t-value greater than or equal to a ±2.093 unit was needed to reject the null hypothesis at the .05 level of significance. Since the obtained value of t(t=1.676) was less than the ±2.093 unit required, therefore, the null hypothesis was accepted. It would be concluded that there was no significant difference within these two populations.

Isotonic Group (90 degrees)

In the isotonic group twenty subjects were pre-tested and then post-tested after a six week exercise period to see if any significant difference in strength would occur. The results of these two tests are found in table two on page forty two.

In examining the table, there was a 30.7 unit increase in the mean of the post-test as compared to the mean of the pre-test. This is an indication that strength did develop during the six week exercise period. After computing the standard deviation of the tests, it was found that an increase of 24.93 from the pre-test did occur. This means that the score of the pre-test were more nearly alike than those of the post-test.

In analyzing table 2, it was noted that a mean difference of a +32.20 was obtained. This indicated that the amount of strength at the post-test was greater than that of

Table 2

t-Test for Isotonic Group at an Angle of 90 Degrees

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Pre-test	20	4.47	151.0	+32.20	19	+6.699
Post-test	20	29.4	181.7			

*$t_{19} \geq \pm 2.093$ at the .05 level of significance

the pre-test. Since a t-value of +6.699 was obtained and a t-value greater than or equal to a ±2.093 unit is needed to reject the null hypothesis at the .05 level of significance, the null hypothesis in this case was rejected. It would be concluded that there was a significant difference between these two populations.

Isokinetic Group (90 degrees)

The isokinetic group was the third group involved in the same six week exercise period. Twenty subjects were again pre-tested and post-tested to see if there was any increase in strength at the 90 degree angle. The mean raw score of the pre-test was 146.85 unit and the mean raw score of the post-test was 161.85 unit. This indicates that after a six week period only a difference of 15 unit in the mean raw score of the post-test as compared to the pre-test occured. The standard deviation of the pre-test was a 11.07 and a 28.46 was the standard deviation of the post-test.

This means that a 17.39 unit increase in the standard deviation of the post-test occured after the six week period of exercises.

Table 3

t-Test for Isokinetic Group at an Angle of 90 Degrees

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Pre-test	20	11.07	146.85	+15.00	19	+2.968
Post-test	20	28.46	161.85			

*$t_{19} \geq \pm 2.093$ at the .05 level of significance

A mean difference of a +15.00 was an indication that strength did increase. However, the increase in strength with the isotonic group at 90 degrees in table 2 on page 42 was greater. This would indicate that at 90 degrees the isotonic method of exercise seemed to increase in strength faster than did the isokinetic method. Despite this a t-value of ± 2.968 was obtained, meaning, that the null hypothesis was rejected because a t-value greater than or equal to a ± 2.093 was required to reject the null hypothesis at the .05 level of significance. Therefore, it would be concluded that there was a significant difference between these two populations.

Control Group (135 degrees)

The control group consisted of twenty subjects which were pre-tested and post-tested at the 135 degree angle but with no six week exercise period involved. The mean raw score of the pre-test was a 145.5 units and the post-test was a 143.75 units a difference of a 1.75 units. This is an indication that no strength was developed at the 135 degree angle. Since no exercises were done to improve the strength of the quadriceps muscle group, the post-test truly indicated this. When the standard deviations of the control group were computed it was found that a 9.74 standard deviation occured at the pre-test and a 7.58 standard deviation occured at the post-test, indicating that the scores were more closely together at the post-test than they were at the pre-test. Thus, the strength of this group had a tendency to decrease at the 135 degree angle.

Table 4

t-Test for Control Group at an Angle of 135 Degrees

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Pre-test	20	9.47	145.5	-1.75	19	+1.421
Post-test	20	7.58	143.75			

*$t_{19} \geq \pm 2.093$ at the .05 level of significance

A -1.75 was the mean difference of the raw score between the pre-test and the post-test for a six week period.

A t-value greater than or equal to a ±2.093 was needed to reject the null hypothesis at the .05 level of significance. Since the obtained value of t(t=+1.421) was less than the ±2.093 at 19 degrees of freedom, the null hypothesis in this case was accepted.

Isotonic Group (135 Degrees)

The isotonic group was pre-tested prior to exercising the quadriceps muscle group for six weeks. After the six weeks, the twenty subjects involved in the isotonic exercises were post-tested to see if strength was developed. The mean raw score of the pre-test at the 135 degree angle was a 144.15 units while the post-test was a 167.45 units. A change of a 23.30 units from the pre-test.

In looking at the standard deviation of both tests, a 13.54 standard deviation of the pre-test occured, while a 20.73 standard deviation occured at the post-test, showing a difference of a 7.19 units.

Table 5

t-Test for Isotonic Group at an Angle of 135 Degrees

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Pre-test	20	13.54	144.14	+23.30	19	+6.400
Post-test	20	20.73	167.45			

*$t_{19} \geq \pm 2.093$ at the .05 level of significance

An obvious difference of 23.30 of the mean difference of the post-test as compared to the mean of the pre-test was indicated in the table. This would mean that strength did occur during the six week period. A t-value greater than or equal to a ±2.093 was needed to reject the null hypothesis at the .05 level of significance. Since the obtained value of t(t=+6.40), was greater than a ±2.093, the null hypothesis was rejected for the isotonic group at 135 degrees. Therefore, it can be again concluded that there was a significant difference between these two populations.

Isokinetic Group (135 degrees)

Twenty subjects exercised for a six week period being pre-tested before, and post-tested after. After completion of the pre-test a 144.9 units mean raw score was obtained, while a 163.5 units was obtained from the post-test. This would mean that from the mean raw score obtained an increase in strength during the six week period did occur. However, the strength gained by the isotonic group, (refer to table 5, page 45) was greater at the 135 degree angle. The standard deviation of the pre-test was a 16.25 unit and the standard deviation of the post-test was a 28.85 units. This would indicate that the scores of the pre-test were closer together than that of the post-test.

In analyzing table 6 an increase of a +18.60 unit of the mean difference of the mean scores between the pre-test

and the post-test were derived. This would indicate that the strength of the individuals during the six week period did improve. However, compared to the isotonic group (page 45) the strength change was less, meaning that strength developed faster during the six week period with the isotonic method than did the strength of the individuals using the isokinetic method. Since the t-value of +4.519 was greater than a ±2.093 at the .05 level of significance the null hypothesis was rejected at the 135 degree angle for the isokinetic group.

Table 6

t-Test for Isokinetic Group at an Angle of 135 Degrees

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Pre-test	20	16.25	144.9	+18.60	19	+4.519
Post-test	20	28.85	163.50			

*$t_{19} \geq \pm 2.093$ at the .05 level of significance.

Control Group (170 degrees)

The mean score of the control group which was pre-tested at the 170 degree angle was a 105.75 units. The post-test mean score was a 97.75 units. These two scores indicated a decreased in strength at the post-test period.

It is interesting to note that the standard deviation of the pre-test was a 25.83, as for the post-test it was a

24.71 unit, a 1.12 change. This would indicate that all subjects basically remained the same during the entire six week period.

Table 7

t-Test for Control Group at an Angle of 170 Degrees

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Pre-test	20	25.83	105.45	+7.70	19	+2.331
Post-test	20	24.71	97.75			

*$t_{19} \geq \pm 2.093$ at the .05 level of significance

In looing at the table, the mean difference of the pre-test and the post-test was a +7.70 unit, meaning that after six weeks the control group declined in strength. A *t*-value greater than or equal to a ± 2.093 was needed to reject the null hypothesis at the .05 level of significance. Since the obtained value of *t*(*t*=+2.331), was greater than the ± 2.093, the null hypothesis was rejected, It was concluded that there was a significant difference between these two populations.

Isotonic Group (170 degrees)

The isotonic group exercised the quadricep muscle group for a period of six weeks. Prior to this six week period they were pre-tested which led to a mean score of

85.45 units. After the six week period of exercises were up all subjects were post-tested in which a mean score of 103.55 units was obtained.

The standard deviation of the two tests were also taken. The standard deviation of the pre-test was a 24.57, and the standard deviation of the post-test was a 25.42 units. This suggests that the scores of both groups remained fairly close together.

Table 8

t-Test for Isotonic Group at an Angle of 170 Degrees

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Pre-Test	20	24.57	85.45	+18.00	19	+4.528
Post-Test	20	25.42	103.55			

*$t_{19} \geq \pm 2.093$ at the .05 level of significance.

A mean difference of 18.10 was obtained between the pre and post-tests. This indicates a slight increase in strength during the post-test period. The t score of +4.528 is greater than the ±2.093 score at the .05 level of significance, which requires that the null hypothesis be rejected.

Isokinetic Group (170 degrees)

The mean raw score of the isokinetic pre-test was a 108.50 units where as the post-test was a 129.90 units. At

this particular angle the isokinetic group improved slightly more than the isotonic group did in table 8 on page 49.

Looking at the standard deviation of the pre-test 27.07 and the standard deviation of the post-test a 17.09, would indicate a closer collection of scores at the pre-test period.

Table 9

t-Test for Isokinetic Group at an Angle of 170 Degrees

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Pre-test	20	27.07	108.50	+20.50	19	+4.494
Post-test	20	17.09	129.90			

*$t_{19} \geq \pm 2.093$ at the .05 level of significance.

The mean difference of both the pre and post-test was a +20.50. This would indicate an increase in strength over the six week period. A t-value greater than or equal to a ± 2.093 was needed to reject the null hypothesis at the .05 level of significance. Since the obtained value of t(t=+4.494), was greater than the required ± 2.093 the null hypothesis in this case was rejected. It was concluded that there was a significant difference between these two populations.

Analysis of Covariance

The second part of the analysis of data in this study was that of an analysis of covariance. In brief, analysis of covariance may be used when a relationship is being studied between a dependent variable and two or more groups representing an independent variable. This technique allows the researcher to statistically equate the independent variable groups with respect to one or more variables which are relevant to the dependent variable. To put it another way, analysis of covariance allows the researcher to study the performance of several groups which are unequal with regard to an important variable as though they were equal in this respect.

In table 10, the sum of squares of the pre-test between groups was a 41068.38 unit. There as the sum of squares between groups for the post-test was a 5431.3 unit. In looking at the table the sum of products between groups was a 354.95 unit. Within the groups the sum of squares of the pre-test was a 417450.3 unit. The sum of squares of the post-test within groups was a 47381.95 unit. It was also found that the sum of products within the groups was a 11861.55 unit. The F-table was used at fifty-six degrees of freedom.

In analyzing table 10, the adjusted sum of squares between groups was a 5410.83, and the adjusted mean squares for between groups was a 2705.41 unit. Within groups the

adjusted sum of squares was a 46994.91 unit. The adjusted mean squares for within the groups was a 839.19 unit.

Table 10

Summary Table for Analysis of Covariance at the 90 Degree Angle

Source	df	SS_x	SP	SS_y	SS_y	MS_y
Between	2	410680.38	354.95	5431.3	5410.83	2705.41
Within	56	417450.3	11861.55	47331.95	46994.91	839.19

$F_{2,56} \geq \pm 3.22$ at the .05 level of significance.

The F-table was used at two and fifty-six degrees of freedom to evaluate the obtained F-value. An F-value greater than or equal to a ± 3.23 ($F_{2,56} \geq +3.23$), at the .05 level of significance was needed to be significant for the 90 degree angle. Since a value of 3.223 was obtained this value was considered significant and the null hypothesis was rejected. It was concluded that there was a significant difference between the differences (changes) of the pre and post-test measures of the three groups. In order to assertain which of these three groups differed with respect to change the t-test for independent samples was used as described in the following section.

t-Test for Independent Samples

A t-test for independent samples not related was set up for the change of the control group and the isotonic

between their pre-test and post-test scores. This was also done for the isokinetic group.

Control Group vs Isotonic Group Change (90 degrees)

The control mean was a 8.950, where as the isotonic mean was a 31.70 unit. In looking at the standard deviation of the control group, a 23.27 unit was obtained. The standard deviation of the isotonic was a 20.49 unit.

Table 11

t-Test for the Change of the Control Group and Isotonic Group Between the Pre-Test and Post-Test at the 90 Degree Angle

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Control	20	23.27	8.950	22.75	38	3.1983
Isotonic	20	20.49	31.70			

*$t_{38} \geq \pm 2.042$ at the .05 level of significance.

The mean difference of the change of the isotonic group with the change of the control group was a 22.75 unit. At thirty eight degrees of freedom, a t-value greater than or equal to a ± 2.042 was needed to reject the null hypothesis at the .05 level of significance. Since the value of t(t*+3.1983), was greater than the ± 2.042, the null hypothesis was rejected. It was concluded that there was a significant difference with these two populations.

Isotonic Group vs Isokinetic Group (90 degrees)

The isotonic group mean for the change that took place between the pre-test and the post-test was a 31.70, where as the isokinetic group mean was a 15.00 unit. The standard deviation of the isotonic group a 20.49 unit was obtained. The isokinetic group standard deviation was a 22.03 unit. Both of these groups exercised three times a week for a six week period.

Table 12

t-Test for the Change of the Isotonic Group and Isokinetic Group Between the Pre-Test and Post-Test at the 90 Degree Angle

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Isotonic	20	20.49	31.70	16.70	38	2.420
Isokinetic	20	22.03	15.00			

*$t_{38} \geq \pm 2.042$ at the .05 level of significance.

In analyzing table 12 the mean difference was a 16.70 unit. This would indicate that the change of the isotonic group was greater than that of the change of the isokinetic group. Since the t-value of 2.420 was greater than the required ± 2.042, the null hypothesis in this case was rejected at the .05 level of significance. Therefore there was a significant difference between these two populations.

Analysis of Covariance (135 degrees)

In table 13, the sum of squares of the pre-test was a 18.30 between groups, while the sum of squares of the post-test between groups was a 6449.28. The sum of products between groups was a -312.05 unit and within the groups the sum of products was a 12595.15 unit. The F-table was used at two and fifty six degrees of freedom.

Table 13

Summary Table for Analysis of Covariance at the 135 Degree Angle

Source	df	SS_x	SP	SS_y	SS_y	MS_y
Between	2	18.3	-312.05	6449.28	7164.83	3582.42
Within	56	10849.35	12595.15	26389.45	11767.58	210.14

$F_{2,56} \geq \pm 3.23$ at the .05 level of significance

Studying table 13, the adjusted sum of squares between groups was a 7164.83 unit, and the adjusted mean squares for between groups was a 3582.42 unit. Within the groups the adjusted sum of squares was a 11767.58 unit. The adjusted mean squares for within the groups was a 210.14 unit.

At two and fifty-six degrees of freedom on the F-table, an F value greater than or equal to a ± 3.23 ($F_{2,56} \geq \pm 3.23$), at the .05 level of significance was needed

to be significant. Since a value of 17.048 unit was obtained, this value was considered significant.

Control Group vs Isokinetic Group Change (135 degrees)

In table 14, the mean score of the control group was a -1.75 unit, where as the mean score of the isokinetic group was a 18.6 unit. The standard deviation of the control group was a 5.37 unit and the standard deviation of the isokinetic group was a 17.94 unit. These values obtained in the control group, were direct result of twenty subjects in each group being pre-tested and post-tested after a six week period.

Table 14

t-Test for the Change of the Control Group and Isokinetic Group Between the Pre-Test and Post-Test at the 135 Degree Angle

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Control	20	5.37	-1.75	+16.85	38	-4.737
Isokinetic	20	17.94	18.60			

*$t_{38} \geq \pm 2.042$ at the .05 level of significance.

In analyzing table 14, the mean difference between the control group and the isokinetic group was a +16.85. A t-value greater than or equal to a ± 2.042 was needed to reject the null hypothesis at the .05 level of significance.

Since the value of t(t=+4.737), was greater than the ±2.042 the null hypothesis in this case was rejected. It was concluded that there was a significant difference between these two populations.

Control Group vs Isotonic Group Change (135 degrees)

Twenty subjects exercised for a six week period in the isotonic group, while the twenty subjects in the control group did no exercises at all. The results of these two groups are shown in table 15. The mean score of the control group was a -1.75 unit, where as the mean score of the isotonic group was a 23.3 unit. The standard deviation of the control group was a 5.37 unit and the standard deviation of the isotonic was a 15.87.

Table 15

t-Test for the Change of the Control Group and Isotonic Group Between the Pre-Test and Post-test at the 135 Degree Angle

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Control	20	5.37	-1.75	+21.55	38	-6.518
Isotonic	20	15.87	23.3			

*$t_{38} \geq \pm 2.042$ at the .05 level of significance.

The mean difference of the control group and isotonic group was a +21.55 unit. At thirty eight degrees of freedom

a value of a -6.518 was obtained. Since a t-value greater than or equal to a ±2.042 was needed to reject the null hypothesis at the .05 level of significance, the obtained t-value of -6.518 was greater and therefore the null hypothesis was rejected. It was then concluded that there was a significant difference between these two populations.

Analysis of Covariance (170 Degrees)

The sum of squares between groups was a -715700.3 units of the pre-test. The post-test sum of squares between groups was a 11743.9 units. Within ghe groups the sum of squares was a 40076.9 units of the pre-test, where as the sum of squares of the post-test was a 30972.5 units. Upon further investigation of the table the sum of products between groups was a 3929.5 units and the sum of products within the groups was a 26768.3 units.

Table 16

Summary Table for Analysis of Covariance at the 170 Degree Angle

Source	df	SS_x	SP	SS_y	SS_y	MS_y
Between	2	-715700.3	3929.5	11743.9	6109.41	3054.70
Within	56	40076.9	26768.3	30972.5	13093.33	233.81

$F_{2,56} \geq \pm 3.23$ at the .05 level of significance.

The adjusted sum of squares between groups was a 6109.41 units, and the adjusted mean squares between groups

was a 3054.70 units. Within the groups the adjusted sum of squares was a 13093.33 units, and the mean squares within the groups was a 233.81 units. The F-table was used at two and fifty-six degrees of freedom. An F-value greater than or equal to a ± 3.23 ($F_{2,56} \geq \pm 3.23$), at the .05 level of significance was needed to be significant at the 170 degree angle. Since a value of 13.064 was obtained, this value was considered significant.

Control Group vs Isotonic Group Change (170 degrees)

In the t-test the mean score of the control group was a -7.7 units, where as the mean score of the isotonic group was a 17.60 units for the change that took place during the pre-test and post-test period. The standard deviation of the pre-test was a 14.39 units and the standard deviation of the isotonic group was a 16.87 units.

Table 17

t-Test for the Change of the Control Group and Isotonic Group Between the Pre-Test and Post-Test at the 170 Degree Angle

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Control	20	14.39	-7.7	+9.90	38	-4.973
Isotonic	20	17.60	17.60			

*$t_{38} \geq \pm 2.042$ at the .05 level of significance

The mean difference of the control group and isotonic group was a +9.90 units. At thirty eight degrees of freedom a t-value of -4.973 units was obtained. A t-value greater than or equal to a ±2.042 was needed to reject the null hypothesis at the .05 level of significance. Since the value of t(t=+4.973), was greater than the ±2.042, the null hypothesis was rejected. It was concluded that there was a significant difference between these two populations.

Control Group vs Isokinetic Group Change (170 degrees)

The mean score of the control group was a -7.7, as compared to the isokinetic mean of a 21.40 units. The standard deviation of the control group was a 14.39 units, and the standard deviation of the isokinetic group was a 19.10 units.

Table 18

t-Test for the Change of the Control Group and Isokinetic Group Between the Pre-Test and Post-Test at the 170 Degree Angle

Group	Number	Standard Deviation	Mean Score	Mean Difference	df	t*
Control	20	14.39	-7.7	+13.70	38	-5.303
Isokinetic	20	19.10	21.40			

*$t_{38} \geq \pm 2.042$ at the .05 level of significance.

In analyzing table 18, the mean difference was a 13.70 from the control group compared to the isokinetic group. At thirty eight degrees of freedom a $\underline{t}$-value greater than or equal to a ± 2.042 was needed to reject the null hypothesis at the .05 level of significance. Since the value of $\underline{t}(\underline{t}=-5.303)$, was greater than the ± 2.042 the null hypothesis was rejected. It was concluded that there was a significant difference between these two populations.

Chapter 5

SUMMARY, CONCLUSIONS, RECOMMENDATIONS, AND DISCUSSION

This chapter contains a summary of the study, conclusions drawn from statistical data, and recommendations for further studies. A discussion on the study was also included.

SUMMARY

The purpose of this study was to investigate the amount of strength gained isotonically compared to the amount of strength gained isokinetically in the quadricep muscle group during a six week period of exercise. It was thought that knowledge of such strength gain would prove valuable to coaches, physical educators, trainers, and others interested in strength development.

In order to test the hypothesis to see if their was any significant difference in muscular strength gain when using isokinetic exercises as compared to using isotonic exercises in the quadricep muscle group, sixty college males were randomly selected from the foundation of physical education classes I and II, at Kansas State Teachers College of Emporia. From these sixty students three groups of twenty students were formed into a control group, an isotonic group, and an isokinetic group. The quadricep muscle group of the

non-dominant leg was used. All groups were pre-tested and post-tested with a cable tensiometer. For a six week period of time the isotonic group and isokinetic group exercised their non-dominant leg three times a week. The control group only took part in the pre-test and post-test period. During the testing period each student was tested at three different angles; 90 degrees, 135 degrees, and 170 degrees. Three, six second contractions were allowed at each angle for each group. From these three contractions, the highest score was recorded. After the raw score of the pre-test and post-test were finished, the scores were calculated at each particular angle with each particular group. Statistical treatment was used to see if there was any significant differences between the groups.

A t-test of correlated fields was set up to test the difference of the pre-test and post-tests of each group at each particular angle. A significant difference was found at the .05 level of significance. Only twice was the null hypothesis accepted during the test, which was with the control group. Both the isotonic group and isokinetic group had significant changes from the pre-test and the post-test period.

In order to investigate the data even further, an analysis of covariance was employed to determine the magnitude and direction of the relationship between the control variable and the criterion variable. This was done to test

the hypothesis of equal means. The F-table was used to test the significance of each group at the .05 level of significance. All groups had a significant difference at each particular angle.

The third area of statistical analysis was that of a t-test for two independent samples. This was designed to compare the change that took place from the pre-test and post-test of each particular group at each particular angle. The .05 level of significance was used to determine the significant difference of each group at the 90 degree angle, 135 degree angle, and the 170 degree angle. Only at the 90 degree angle did the isotonic group improve significantly over the isokinetic group. At no other angle did the isotonic group improve in strength better than the isokinetic group. This would indicate that from this researcher's findings, there was no significant difference as to what method of exercises one should use in the developing of strength in the quadricep muscle group.

CONCLUSIONS

Within the limitations of this study, the following conclusions appear to be justified:

1. There was a significant increase in strength at the 90 degree, 135 degree, and 170 degree angles with the isotonic group as compared to the pre-test and post-test.

2. There was a significant increase in strength at the 90 degree, 135 degree, and 170 degree angles with the isokinetic group as compared to the pre-test and post-test.

3. Both the isotonic group and the isokinetic group improved significantly in strength as compared to the control.

4. There was no apparent advantage to exercising isotonically as compared to exercising isokinetically, except at the 90 degree angle where the isotonic group was significantly better.

5. Strength increased at the 135 degree and 170 degree angle equally between the isotonic method of exercises, and the isokinetic method of exercises.

DISCUSSION

Based on the findings of this study in relation to strength development with isotonic and isokinetic method of training, it was concluded that the cable tensiometer was not the best method of measuring strength development. The investigator believes that an instrument that accurately measures strength is in great need, and until such a time the most effective way of developing strength might not be found. However, the investigator feels that a true measure of strength is not easly determined. Also, the investigator felt it was difficult to determine whether or not each individual was working at his maximum strength output throughout the study, and during the pre and post-test periods.

Many different methods of strength building are employed in various forms throughout the world. Because of this, the investigator at this time would be inclined to agree with those methods that have been successfully used and tested. The isotonic method of developing strength has been the most widely used method of developing strength along with being the most successfully tested. For this reason and based on personal experience, this investigator favors the isotonic method of developing strength.

The isokinetic method of exercises shows great promise however, the investigator feels that isotonics not only develop strength but adds to the balance and coordination of the individual, which is of added importance in the development of strength. In order for this investigator to accept isokinetics as the superior method of developing strength further research is greatly needed in strength development.

RECOMMENDATIONS

Based on the findings of the present study the following recommendations for further studies are made:

1. A replication of this study should be conducted using three sets of five repetitions instead of seven repetitions to provide for a more maximum load on the muscle group.

2. A replication of this study using other muscle groups such as, the biceps brachii and the hamstring muscle group.

3. A similar study using another type of instrument for measuring strength such as; the use of electrodes placed on a particular muscle group to measure the amount of electrical activity present in the muscle during contraction.

4. A study using injured athletes who have damaged their knee and put them either on a six week isotonic or isokinetic rehabilitation program of exercises. Then compare the amount of strength gained isotonically as compared to the amount of strength gained isokinetically.

5. A replication of this study should be conducted over a twelve week period testing each individual every three weeks at all three angles to see how much strength was gained.

6. A replication of this study should be conducted using a cable tensiometer model number T60 and a 1/16 flexible cable.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Allen, Henry E. and Frank Deck. "Isokinetic Exercise," British Journal of Sports Medicine, Vol. IV, 12 (1968).

2. Astrand, Per-Olof. Textbook of Work Physiology. Englewood Cliffs, New Jersey: McGraw-Hill Book Company, 1956.

3. Bauer, A.P., J.W. Gerste, B.M. Robertson, and Harold Denken. "Effect of Various Exercise Programs on Isokinetic Tension, Endurance, and Reaction Time in the Human," Archives of Physical Medicine and Rehabilitation, XXXVI (1955), 495.

4. Berger, Richard A. "Comparison of Static and Dynamic Strength Increases," Research Quarterly, XXXIII (1962), 329-333.

5. _____. "Effects of Isometric Training," Physical Educator, XXII (1965), 81.

6. Chu, Donald A. and Gerald Smith. "Isokinetic Exercise: Controlled Speed and Accommodating Resistance," The Journal of the National Athletic Trainers Association, Vol. 6 No. 1, Spring 1971.

7. Chui, Edward. "The Effects of Systematic Weight Training on Athletic Power," Research Quarterly, XXI, 10(1950), 108-109.

8. Clarke, D. and Harrison H. Clarke. Development and Adapted Physical Education. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1963.

9. Clarke, Harrison H. Application of Measurement to Health and Physical Education. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., Fourth Edition, 1967.

10. _____. Muscular Strength and Endurance in Man. Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1966.

11. _____. "Development of Volitional Muscle Strength as Related to Fitness," Athletic Institute, (1960), 209.

12. Clarke, Harrison H., Ruth Lindsey and Homer Tolson. Concepts in Physical Education With Laboratories and Experiments. Dubuques, Iowa: WM. C. Brown Company, (1970), 17-35.

13. Counsilman, James E. "Isokinetic Exercises: A New Concept in Strength Building," Swimming World, Vol. 10, No. 9, March 1971, 4-6.

14. _____. "Isokinetic Exercise: A New Concept in Strength Building," Swimming World, Vol. 10, No. 9 November 11 (1969), 4-15.

15. _____, and Hal Egbert. "Comparison of Effectiveness of Isokinetic and Isotonic Exercises in Quadricep Strengthening," Archives of Physical Medicine and Rehabilitation, 53, 2 February (1972), 60-64.

16. DeLorme, Thomas L. Progressive Resistance Exercise. New York: Appleton-Century-Crofts Inc., 1951, 10.

17. _____. "Techniques of Progressive Resistance Exercise," Archives of Physical Medicine, 29, May (1948), 263.

18. Funk, Henry. "Stabilizing the Knee Joint Through Thigh Muscle Development," Manitoba Medical Review, 26, 6, July (1946), 403.

19. Hellebrandt, F.A. and S.J. Houtz. "Mechanisms of Muscle Training in Man," Physical Therapy Review, 36, (1956), 371-383.

20. Heltinger, Theodor. Physiology of Strength. Springfield, Illinois: Charles C. Thomas, Co., (1961),44.

21. Hinson, M. and J. Rosentswieg. "Comparing the Three Best Ways of Developing Strength," Scholastic Coach, March 1972.

22. Hislop, H.J. and J.J. Perrine. "The Isokinetic Concept of Exercise," Physical Therapy, 47, February (1967), 114-117.

23. Homola, S. Muscle Training For Athletes. New York: Parker Publishing Company, Inc., (1968).

24. Karpovitch, P.B. Physiology of Muscular Activity. Philadelphia: Saunders, (1953), 340.

25. Klafs, C. and D.D. Arnheim. Modern Principles of Athletic Training. C.V. Mosby Company, second edition, (1969).

26. Laycoe, R.R. and Ronald G. Martenuik. "Learning and Tension as Factors in Static Strength Gains Produced by Static and Eccentric Training," Research Quarterly, 42, 3, October (1971), 299-306.

27. MacQueen, I.J. "Recent Advances in the Technique of Progressive Resistance Exercise," British Medical Journal, November, (1954), 1193-1198.

28. Marley, William P. "The Comparative Effectiveness of Isometric Exercises and Isotonic Exercises In the Development of Muscular Strength, Endurance, and Girth," Unpublished Master Thesis, University of Maryland, (1962).

29. Mathews, D.K. and Fox, E.L. The Physiological Basis Of Physical Education and Athletics. Philadelphia, London, Toronto: W.B. Saunders Company, (1971).

30. _____, and Robert Kruse. "Effects of Isometric and Isotonic Exercises on Elbow Flexor Muscle Groups," Research Quarterly, 27 March (1957), 26.

31. McMorris, Rex O. and Earl Elkins. "A Study of Production and Evaluation of Muscle Hypertrophy," Archives of Physical Medicine and Rehabilitation, 35, July (1954), 420-426.

32. Moffroid, M. and H.J. Hislop. "Comparative Effectiveness of Isokinetic Exercise," Unpublished paper read at the annual conference of American Physical Therapy Association, Miami Beach, June (1967), 6.

33. _____, and Howard Thistle. "A Study of Isokinetic Exercise," Physical Therapy Journal, 49, July (1967), 735-746.

34. Murray, J. and P.V. Karpovitch. Weight Training in Athletics. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1956.

35. Perrine, J.J. "Isokinetic Exercise and the Mechanical Energy Potentials of Muscle," Journal of Health, Physical Education and Recreation, 40, 4 May (1968).

36. Rarick, Lawerence G. "Exercise and Growth," Science and Medicine of Exercise and Sports, New York: Harper and Brothers, (1960), 450.

37. Rasch, Philip J. "Relationship Between Isometric Tension and Maximum Isotonic Elbow Flexion," Research Quarterly, 28, (1957), 85.

38. Rasch, Philip J. and L.E. Morehouse. "Effects of Static and Dynamic Exercises on Muscular Strength and Hypertrophy," Journal of Applied Physiology, November (1957), 29-34.

39. Rodgers, Donald D. "The Development of Strength by Means of Static and Concentric Muscle Contraction," Unpublished Master's Thesis, State University of Iowa, 14.

40. Roscoe, John T. Fundamental Research Statistics for the Behavioral Sciences. New York: Holt, Rinehart and Winston, Inc., (1969), 257.

41. Rose, Donald L., Stantgy F. Rodzymenski, and Ralph R. Beatly. "Effects of Brief Maximal Exercises on the Strength of the Quadriceps Femores," Archives of Physical Medicine and Rehabilitation, 38, March (1957), 164.

42. Steinhouse, Arthur H. "Athletic Training," Unpublished minutes of lecture given in Walla Walla, Washington under the auspices of Washington State College.

43. _____. Unpublished notes from the College of Physical Education Associations 57th Annual Proceeding, New York City, 1954, 5-7.

44. Sterling, Diane Ray, "Isometric Strength Position Specificity Resulting from Isometric and Isotonic Contractions as a Determinant in Performance," Unpublished Dissertation, Louisiana State University, 1938.

45. _____, and Edward Lowamn. "Isokinetic Contraction: New Concept of Resistive Exercise," Archives of Physical Medicine and Rehabilitation, 48, June (1967).

46. Williams, M. and L. Stutzman. "Strength Variations Through the range of Motion," The Physical Therapy Review, 39, March (1959), 145-152.

47. Zinovieff, A.N. "Heavy Resistance Exercise: The Oxford Technique," British Journal of Physical Medicine, 14, June (1951), 129.

APPENDIXES

APPENDIX A

RAW SCORES OF ALL GROUPS AT THE 90 DEGREE ANGLE

Subject	Control pre	Control post	Diff.	Isotonic pre	Isotonic post	Diff.	Isokinetic pre	Isokinetic post	Diff.
1	157	154	- 3	160	216	+56	160	196	+36
2	145	144	- 1	148	158	+10	122	135	+13
3	156	153	- 3	153	158	+ 5	118	120	+ 2
4	153	154	+ 1	118	131	+13	153	158	+ 5
5	160	231	+71	160	216	+46	148	153	+ 5
6	153	148	- 5	122	144	+22	148	151	+ 3
7	153	148	- 5	148	153	+ 5	153	181	+28
8	147	144	- 3	160	221	+61	160	211	+51
9	160	216	+56	144	153	+ 9	151	154	+ 3
10	154	157	+ 3	151	216	+65	131	140	+ 9
11	160	157	- 3	139	154	+15	148	153	+ 5
12	153	154	+ 1	160	191	+31	152	156	+ 4
13	148	153	+ 5	160	196	+36	144	131	-13
14	160	221	+61	160	206	+46	151	211	+60
15	160	148	-12	160	206	+46	145	135	-10
16	153	144	- 9	144	148	+ 4	153	216	+63
17	155	158	+ 3	153	216	+63	144	135	- 9
18	144	148	+ 4	160	194	+34	152	154	+ 2
19	139	148	+ 9	160	206	+46	160	194	+34
20	135	144	+ 9	160	181	+21	144	153	+ 9

APPENDIX B

RAW SCORES OF ALL GROUPS AT THE 135 DEGREE ANGLE

Subject	Control pre	Control post	Diff.	Isotonic pre	Isotonic post	Diff.	Isokinetic pre	Isokinetic post	Diff.
1	153	151	- 2	153	157	+ 4	160	206	+46
2	153	146	- 7	144	150	+ 6	101	110	+ 9
3	153	144	- 9	151	158	+ 7	112	122	+10
4	147	147	0	131	148	+17	153	158	+ 5
5	148	139	- 9	160	206	+46	139	148	+ 9
6	144	148	+ 4	110	144	+34	152	160	+ 8
7	135	139	+ 4	126	153	+27	160	216	+56
8	148	145	- 3	153	153	0	160	206	+46
9	122	126	+ 4	144	158	+14	153	206	+53
10	153	151	- 2	153	187	+34	135	153	+18
11	153	154	+ 1	153	181	+28	144	148	+ 4
12	135	139	+ 4	151	158	+ 7	150	154	+ 4
13	154	151	- 3	152	181	+29	153	160	+ 7
14	160	151	- 9	148	158	+10	160	189	+29
15	158	148	-10	144	153	+ 9	153	151	- 2
16	139	135	- 4	114	148	+34	160	194	+34
17	148	146	- 2	160	211	+51	139	153	+14
18	141	144	+ 3	153	206	+53	122	131	+ 9
19	135	145	+10	144	181	+37	153	154	+ 1
20	131	126	- 5	139	158	+19	139	151	+12

APPENDIX C

RAW SCORES OF ALL GROUPS AT THE 170 DEGREE ANGLE

Subject	Control pre	Control post	Control Diff.	Isotonic pre	Isotonic post	Isotonic Diff.	Isokinetic pre	Isokinetic post	Isokinetic Diff.
1	126	122	- 4	101	110	+ 9	148	151	+ 3
2	122	122	0	90	105	+15	68	118	+50
3	68	63	- 5	57	68	+11	103	110	+ 7
4	79	83	+ 4	68	90	+22	104	114	+10
5	144	118	-26	68	79	+11	118	131	+13
6	118	126	+ 8	57	68	+11	135	148	+13
7	126	122	- 4	35	46	+11	139	144	+ 5
8	114	90	-24	102	90	-12	150	156	+ 6
9	122	101	-21	101	110	+ 9	68	126	+58
10	101	101	0	110	114	+ 4	68	135	+67
11	57	57	0	90	101	+11	118	144	+26
12	114	101	-13	68	110	+32	120	148	+28
13	90	110	+20	46	90	+44	131	153	+22
14	148	135	-13	122	131	+ 9	81	122	+41
15	126	110	-16	101	105	+ 4	79	101	+22
16	110	68	-42	90	126	+36	103	105	+ 2
17	68	57	-11	118	135	+17	131	139	+ 8
18	118	122	+ 4	84	153	+69	126	126	0
19	68	79	+11	122	135	+13	110	122	+12
20	90	68	-22	79	105	+26	70	105	+35

APPENDIX D

FILE CARD OF PRE-TEST AND POST-TEST RESULTS

NAME _____ Group _____ Time _____

PRE-TEST

90 Degrees	135 Degrees	170 Degrees
1. _____	1. _____	1. _____
2. _____	2. _____	2. _____
3. _____	3. _____	3. _____

POST-TEST

90 Degrees	135 Degrees	170 Degrees
1. _____	1. _____	1. _____
2. _____	2. _____	2. _____
3. _____	3. _____	3. _____

APPENDIX E

DAILY CHART FOR ISOTONIC GROUP

NAME	26	28	2	5	7	9	12	14	16	19	21	23	26	28	30	2	4	6						
	3x7 50	3x7 50	3x7 50	3x7 50																				

APPENDIX F

DAILY CHART FOR ISOKINETIC GROUP

Name																							

APPENDIX G

ISOTONIC KNEE EXTENSION TABLE

APPENDIX H

SUPER MINI-GYM COMMANDER DUO EXERCISER

APPENDIX I

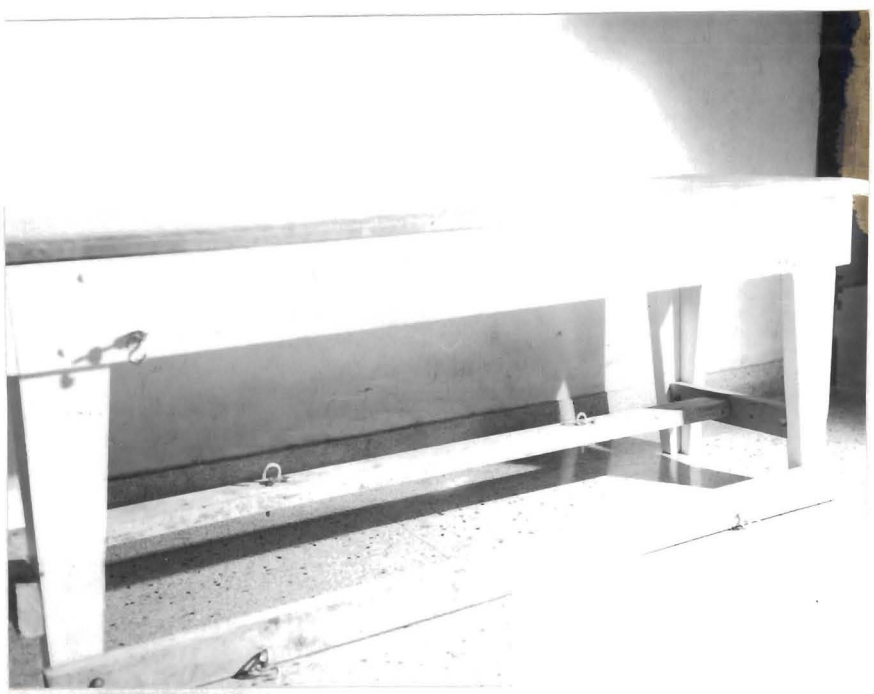
CABLE TENSIOMETER

APPENDIX J

REGULATION STRAP

APPENDIX K

SPECIALLY DESIGNED TESTING TABLE



APPENDIX L

GONIOMETER

APPENDIX M

REGULATION STRAP PLACED AROUND NON-DOMINAT LEG MIDWAY BETWEEN KNEE AND ANKLE JOINTS

APPENDIX N

GONIOMETER SET AT DESIRED ANGLE PLACED ALONGSIDE OF NON-DOMINAT LEG

APPENDIX O

RESISTANCE INDICATOR ON COMMANDER DUO EXERCISER