A Comparison of Hypertrophy, Strength and Power Changes between Eccentric Isotonic and Eccentric Isokinetic Leg Training

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ABSTRACT

TROJACK, Gail M. A comparison of hypertrophy, strength and power changes between eccentric isotonic and eccentric isokinetic leg training. M.S. in Adult Fitness/Cardiac Rehabilitation, 1986. 79 pp. (P. K. Wilson)

The effects of 6 week eccentric isotonic and eccentric isokinetic training programs on hypertrophy, strength and power development in the quadriceps were compared. Male Ss (N=22) participated including 7 training isotonically (T), 7 training isokinetically (K), and 8 control subjects performing no resistance leg training (C). Ss performed 3 sets of 10 repetitions on Monday, Wednesday and Friday with an additional set on Friday to systematically adjust work load. No group significantly increased thigh girth or body weight. Both groups exhibited carryover of concentric strength from eccentric training in certain tests. (T) improved significantly over (C) in isotonic concentric one repetition maximum, 5 second isometric, and both Margaria Kalaman power tests. (T) improved significantly over (K) in the concentric isotonic one repetition maximum as well. (K) improved significantly over (C) in average concentric peak torque (170°/second) and in the Margaria Kalaman power test at 6 meters. Both groups exhibited carryover of strength when tested at fast speeds from slow speed training programs (60°/second). (T) improved significantly over (C) in average eccentric peak torque (170°/second) and the Margaria Kalaman tests of power. (K) significantly improved over (C) in average concentric peak torque (170°/second), eccentric total work (170°/second) and the Margaria Kalaman power test at 6 meters. Both groups significantly improved over (C) in eccentric isotonic one repetition maximums. Only (K) significantly increased average eccentric peak torque at 60°/second over (C).

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

Much research has been conducted pertaining to the effects of resistance training on muscle. The results of this research are used clinically for effective rehabilitation and injury prevention. Ideal training regimes in terms of number of repetitions and sets, duration of contractions, type of contractions, frequency of training and rest intervals between sets is ever changing and remains elusive.

Effective resistance training can increase the strength of voluntary muscle fibers by increasing mass and enhancing neural control (Gonyea & Sale, 1982; Hakkinen, 1985). The necessary tension development in the muscle to elicit such training responses can be developed through the use of three types of contractions: concentric (muscle shortens), isometric (muscle length remains unchanged), and eccentric (muscle lengthens). The dynamic concentric and eccentric contractions can be controlled by the resistance applied (isotonic) or by the velocity (isokinetic).

Statement of the Problem

The problem of this study compared the effects of a six week eccentric isotonic training program to a six week eccentric isokinetic training program in terms of hypertrophy, power, and strength changes in the quadriceps femoris muscle group of college aged males.

Purpose of the Study

The results of this study may be used to determine if eccentric isotonic or eccentric isokinetic exercise is the more efficient mode of exercise for hypertrophy, power and/or strength enhancement.

Need for the Study

Strength can be operationally defined as the ability of the muscle to generate its maximum tension with an isometric effort (0°/second) or at slow contractile velocities (under 60°/second), and power can be defined as the ability of a muscle to generate its maximum tension at fast contractile velocities (over 60°/second) (Davies, 1984). Strength and power are called upon for many everyday activities and athletic functions, and efficient training programs benefit a variety of people, from those simply performing routine activities of daily life to high performance athletes. Physical therapists, exercise physiologists, strength coaches, fitness instructors, athletes and non-athletes are continually searching for the training techniques that will elicit maximum results in the least amount of time. Although isokinetics came about only nineteen years ago research has shown it to be a reliable testing mode (Johnson & Siegal, 1978) as well as beneficial in the clinical setting (Davies, 1984; Hislop & Perrine, 1967). Eccentric contraction is under investigation as an efficient training mode since it is found to generate greater tension per muscle fiber than the concentric contraction when the two contractions are compared electromyographically (Newham, Mills, Quigley, & Edwards, 1983; Newham, McPhail, Mills, & Edwards, 1983; Johnson, Adamczyk, Tennoe, Stromme, 1976). Prior to the invention of the KIN-COM dynanometry system eccentric contractions could not be evaluated under isokinetic conditions. While several reports are available comparing concentric and eccentric work (Knuttgen, 1971; Komi & Buskirk, 1972; Eloranta & Komi, 1980), and comparing isokinetic and isotonic work (Hinson & Rosentsweig, 1981; Moffroid, Whipple, Hofkosh, Lowman, & Thistle, 1969), as of yet no published reports exist comparing eccentric isotonic and eccentric isokinetic training programs. This study was performed to provide data comparing the two programs performed for six weeks by college aged males.

Hypotheses

The following null hypotheses were tested at the $P < .05$ level of significance:

1. There was no significant difference in hypertrophy changes between the two groups.

2. There were no significant differences in eccentric or concentric power changes when tested isokinetically at high velocity between the two groups.

3. There was no significant difference in power changes between the two groups when scores from the Margaria-Kalaman Power test were compared.

4. There was no significant difference in concentric strength changes when tested isokinetically at low velocity between the two groups.

5. There was no significant difference in concentric strength changes when tested isotonically at low velocity between the two groups.

6. There was no significant difference in eccentric strength changes when tested isokinetically at low velocity between the two groups.

7. There was no significant difference in eccentric strength changes when tested isotonically between the two groups.

8. There was no significant difference in strength changes when tested isometrically between the two exercise groups.

Assumptions

The following assumptions were made regarding this study:

1. Subjects understood procedures and gave maximal effort.

2. Anthropometric changes were due to training.

3. Subjects did not alter their daily living habits (particularly dietary) in any way that would significantly alter the results.

4. No additional resistive leg training exercises were employed during the six week session.

5. Subjects were apparently healthy.

Delimitations

The following were delimitations of this study:

1. Subjects were selected from undergraduate programs at the University of Wisconsin-La Crosse.

2. Hypertrophy was assessed using the following sites; joint line, 10 cm. proximal to joint line, and 20 cm. proximal to joint line.

3. Only the quadriceps muscle group was trained and observed.

Limitations

The following were limitations of this study:

1. Indirect measurements were used to assess hypertrophy.

2. Eccentric work is known to cause delayed muscle soreness and fatigue and may affect work output and maximal efforts during initial training sessions.

3. The testing sample was not randomly selected.

Definition of Terms

The following are definitions of terms used in the text of this study:

Repetition. The full ROM execution of moving the resistance.

Set. The number of repetitions done consecutively without rest.

Contraction. Active use of energy and tension development by the muscle, even if no visible shortening or lengthening occurs.

Load. Mass moved during a contraction.

Force. A push or pull exerted on or by the body.

RM. Repetition maximum. The maximum weight that can be lifted for the indicated number of repetitions.

Hypertrophy. An increase in muscle mass.

Power. The ability of a muscle to generate its maximum tension at intermediate or fast contractile velocities over 60°/second (Davies, 1984).

Strength. The ability of a muscle to generate its maximum tension isometrically or at slow contractile velocities less than 60°/second (Davies, 1984).

CHAPTER 2

REVIEW OF RELATED LITERATURE

Introduction

The review of the related literature for this study has been divided into three major sections. The first section discusses the basic concepts of effective resistance training. The second section discusses the differences between isometric, isotonic and isokinetic training contractions. The third section reviews the current literature on concentric and eccentric exercise and the final section summarizes the chapter.

Muscular Training

It is well established that skeletal muscle size and strength are determined by patterns of physical activity. Strength and hypertrophy occur when a muscle is trained, and atrophy results when a muscle is inactive or immobilized. Weight training a certain muscle or group of muscles can help an individual improve physical performance, acquire new skills, or compensate for disease or injury of other body parts.

Progressive resistance training (PRE) creates a condition in which a muscle or muscle group must work to full capacity against ever increasing resistance. Resistance used in training should increase in proportion to the gains made in strength so that progress will continue. The Daily Adjustable Progressive Resistance Exercise (DAPRE) technique (Knight, 1979) is a weight training regime that provides a systematic approach to determine the optimal resistance load to use in isotonic exercise. This program involves 4 sets of varying repetitions. The first set consists of 10 repetitions at half the estimated working weight. The second set consists of 6 repetitions of 3/4 the working weight. As many repetitions as possible are performed during sets 3 and 4, and guidelines are given to adjust the working weight for the next session based on the repetitions successfully completed. This system minimizes the guesswork in resistance training exercise prescription. Progressive resistance exercise can be a successful method to ensure muscular overload which is a necessary condition to elicit strength gains. Tension in the muscle must be developed during training that is greater than the tension levels that are developed during everyday activities in order to stimulate strength changes (i.e. the overload principal). The muscle must be taxed above what it is accustomed to in terms of load (for strength development) or in terms of repetitions (for endurance development).

Goals of the trainee should be clarified and the training techniques should be specific to his/her needs. Specificity of training refers to the fact that training should simulate the functions of the trainer for maximum benefit. Training adaptations of the neuromuscular system are highly specific, so it is important that strength training reproduce, as closely as possible, the movements for which the training effect is desired (Gonyea & Sale, 1982).

Isometrics, Isotonics, Isokinetics

Significant strength gains are achievable through the use of isometric, isotonic and isokinetic training. Each method has advantages and disadvantages to note prior to incorporating it into a training program to enhance strength, power, hypertrophy or as a mode of rehabilitation.

Isometric. An isometric contraction is static. Exercise is performed at 0°/second with no observable joint movement. This is a convenient form of exercise because no special equipment is necessary and contractions can be performed anywhere. Isometric contractions are often prescribed for rehabilitation when joint problems are present since the static contraction does not cause further joint irritation while still stimulating the muscle and retarding atrophy.

While isometric contractions do sufficiently overload the muscle to elicit strength gains, their use for functional performance enhancement may be somewhat limited. No eccentric work is provided which is necessary during sports performance and everyday activities. Additionally, it is not possible to improve the aerobic capability of the isometric trainer without supplemental activities. Finally, researchers state that the strength gained through isometrics is fairly specific to the joint angle at which the exercise was performed (Hinson & Rosentsweig, 1972; Adeyanju, Crews, & Meaders, 1983; Moffroid et al., 1969). Moffroid and co-workers (1969) reported that a muscle loaded at a particular angle in the range of motion increased strength in the range more than in other, less exercised positions. Knapik (1983), however, reported that there is at least a 20° carryover from the angle at which the exercise contractions were performed indicating that the specificity of joint angle may not be as great as once thought. However, the possibility of joint angle specificity should be a consideration.

Isotonic. Isotonic exercise requires moving a constant resistance through a range of motion. While resistance remains constant, muscle tension varies throughout the ROM due to the nature of the lever system. The resistance has its greatest mechanical advantage at the extremes of the ROM, and least at mid-range. Thus, resistance must be selected to accommodate the weakest point in the range of motion which results in maximal resistance for only a short period. The "momentum factor" or "pendulum effect" of isotonic exercise further reduces its effectiveness meaning the exerciser may use the weight of the load to begin the following contraction, rather than relying solely on the muscle being exercised.

The speed of isotonic contractions is variable and is inversely proportional to the resistance. Kanehisa and Miyashita (1983) state most athletic performance requires limb speeds in excess of 180°/second. High speed isotonic exercise utilizing standard equipment such as dumbbells, barbells, hydraulics and machine weights is not advisable. Imitating functional limb speeds (specificity of training) is thus difficult in isotonic exercise.

Positive features of isotonic exercise include the availability of equipment, reasonable cost of equipment, and the fact that work is performed at a variety of angles. To be effective, workloads must be calculated as a percentage of maximum and rules of safety and technique must be followed.

Isokinetic. Isokinetics, the newest of the three modes of contraction, combines the positive features of isometric and isotonic exercise. Velocity, rather than distance moved or resistance, is controlled. Increased muscular output results in increased resistance, rather than acceleration as would occur in isotonic exercise. Energy is not wasted in speed control and is concentrated on force development (Hinson & Rosentsweig, 1972).

Isokinetic exercise mechanically prohibits accelerations and ballistic movement, thus increasing work output. Isokinetic exercise is "accommodating," meaning that the resistance offered matches the exerciser's immediate and specific muscular capacity. Maximum resistance is available at all points in the ROM, but there is never more force than the subject can handle. In a situation of pain or fatigue, the load is decreased due to the accommodating resistance.

Isokinetic exercise enables the exerciser to more closely simulate the speed of performance. It is possible and safe for the isokinetic exerciser to do contractions from 0°/second to 210°/second on the KIN-COM (Chattecx, TN). Objective recordings of work are available in numeric and/or graph form (See Appendix A) and are useful for progress reports and comparisons. Disadvantages for isokinetic exercise include equipment cost and availability.

Isokinetic exercise has been compared to isometric and isotonic (Thistle, Hislop, Moffroid, & Lowman, 1967; Gettman, 1979; Grimby, Gustafsson, Peterson, & Renstrom, 1980; Smith & Melton, 1981; DeLateur, Lehman, Warren, Stonebridge, Funita, Cokelet, & Egbert, 1972; Otis & Goldbold, 1983; Meaders, 1983; Rosentsweig & Hinson, 1972). Even though isotonic and isokinetic exercise are similar in terms of both being dynamic resistance exercise, comparisons to assess superiority of one type are difficult. Work (force X distance) is fairly easy to calculate in the isotonic mode since the load is constant. Work is more difficult to calculate in the isokinetic mode since the load varies throughout the range of motion. Fortunately, isokinetic systems such as the KIN-COM provide work output calculations and it is unnecessary for the technician or exerciser to manually calculate work performed. DeLateur et al., (1972) attempted to equate the two modes in order to make a valid comparison. The researchers required subjects to go to a pre-established fatigue level for pre- and post-test measurements. Isokinetic fatigue was when the subject fell 2 standard deviations below the mean peak torque of the entire sample group. Isotonic fatigue was when the subject could no longer lift the weight. The exercises were made mechanically similar as well. Ballistic movement was prohibited by a backstop for the isotonic lifters. The rate of contraction was the same as well. No differences in strength changes were reported between six weeks of isotonic and six weeks of isokinetic exercise when the two modes were made biologically and mechanically similar.

Meadors and co-workers (1983) found isotonic exercise to be superior to isokinetic exercise. Limitations of the study should be noted, however. Pre- and post-test measurements were made isotonically, allowing the isotonic exercisers an advantage in terms of practicing the movement.

Isokinetic trainees trained at 180°/second, but were tested at slow isotonic speeds. Specificity of velocity of training is important in isokinetic training. Adeyanju and researchers (1983) found fast speed training to increase endurance and power more than slow speed training. Kanehisa & Miyashita (1983) found fast speed training to increase strength only at fast speeds, while slow speed training increased strength at all speeds. Moffroid & Whipple (1969), however, report slow speed training to increase only slow speed strength, and fast speed training increased strength at all speeds. A study comparing slow speed isokinetic, high speed isokinetic and isotonic variable resistance trainers showed high speed isokinetic trainers to be superior in the vertical jump and the 40-yard dash, and for slow speed isokinetic to be superior to isotonic (Smith & Melton, 1981). Isokinetic training effects may be more significant in terms of performance enhancement if training velocity simulates functional performance speed.

Other studies have reported the superiority of isokinetic exercise. Moffroid and co-researchers (1969) found isokinetics to be superior to isometric and isotonic strength enhancement in a 4 week daily training study of 60 subjects. Thistle and associates (1969) similarly found isokinetics to be most effective in a clinical pilot study of hemiplegic patients as compared to two standard isotonic programs.

Rosentsweig and Hinson (1972) compared EMG activity of isometric, isotonic and isokinetic contractions and found isokinetic to elicit significantly greater muscle action potential than the others. They concluded that isokinetics would require the most muscular work and thus would produce the greatest strength gains.

Concentrics and Eccentrics

It is common knowledge that it is easier to descend than to climb stairs and to lower a certain weight than to lift it. The lifting movement is termed "positive" or "concentric" exercise and involves the working muscle shortening during the contraction. The work is "negative" or "eccentric" when the load is lowered and the muscle lengthens during the contraction. Concentric and eccentric work is performed throughout everyday activities as well as in athletics. Common activities such as stair climbing and lifting a grocery bag are concentric movements, and bending over or lowering an object from an overhead cabinet are eccentric. Concentric and eccentric contractions have been compared in regard to the following physiological responses: oxygen consumption, heart rate, rate of perceived exertion, delayed muscle soreness, strength enhancement and hypertrophy.

Oxygen consumption. While both types of contractions elicit significant strength gains, the physiological cost of negative work is much less (Asmussen, 1953; Knuttgen, Bonde-Petersen, Klausen, 1971; Komi & Buskirk, 1972; Abbot, Bigland, & Ritchie, 1952). Abbot and associates (1952) report the oxygen cost of concentric work to be 4-6 times greater than that of negative work. Knuttgen and others (1971) found a 3:7 ratio (eccentric:concentric), and found this ratio to increase with increasing speed of contraction. Force generation increases were found to accompany velocity increases by other researchers as well (Komi & Buskirk, 1972).

Heart rate and rate of perceived exertion. Lower heart rate responses are characteristic of eccentric exercise performed at the same absolute work load (Knuttgen & Saltin, 1972; Thomson, 1969). The rate of perceived exertion is lower as well (Henrikkson, Knuttgen, Bonde-Petersen, 1972). However, higher heart rate and cardiac output do occur at eccentric exercise of the same intensity (oxygen consumption) (Knuttgen et al., 1971; Fergeson et al., 1968). Rate of perceived exertion is greater for negative work done at the same oxygen consumption level as well (Henrikkson et al., 1972; Knuttgen et al., 1971).

Delayed muscle soreness. While perceived exertion, oxygen consumption, and heart rate response are lower for eccentric exercise done at the same load, fatigue and delayed muscle soreness are more characteristic of eccentric exercise (Newham et al., 1983; Komi & Buskirk, 1972; Friden, Seger, Sjostrom, & Ekblom, 1983; Talag, 1973). Peak soreness appears approximately 48 hours post exercise (Newham et al., 1983; Komi & Buskirk, 1972). Strength may decrease during the soreness period in the initial weeks of training (Komi & Buskirk, 1972) but is regained when soreness dissipates.

Strength Enhancement. Because the rate of strength development as measured by muscle tension is related to the tension produced in contractions it would seem logical that eccentric training, which elicits the greater tension, would elicit a greater training response when compared to concentric contractions. In a six week training study comparing concentric and eccentric training of the arms and legs in terms of dynamic strength gained, no significant differences were found (Johnson et al., 1976). Friden (1983) found eccentric training dramatically improved eccentric strength (375%), but found concentric strength to be only modestly improved after an eight week eccentric training program on the vastus lateralis of eleven male subjects. However, other reports found eccentric training to improve overall strength more than concentric training (Komi & Buskirk, 1972). They found eccentric training to improve isometric, concentric and eccentric strength, but found concentric training to improve only concentric and eccentric strength. Concentric and eccentric training elicited significant gains for concentric and eccentric work, but the highest tensions were found when performing the contractions for which they trained.

Hypertrophy. Hypertrophic response has been found to differ between the concentric and eccentric exercise in a study by Komi and Buskirk (1972). These researchers found significant hypertrophy over controls in only subjects exercising upper arms eccentrically for seven weeks, as compared to seven weeks of concentric training.

Summary

This chapter was divided into three sections. The first discussed effective muscular training concepts, the second discussed three basic exercise modes used to produce muscle tension, and the final section reviewed concentric and eccentric exercise contractions.

Important muscular training concepts include muscular overload and specificity of training. A muscle is overloaded when a muscle or muscle group works to full capacity against ever increasing resistance. The DAPRE technique systematically determines work loads so that the muscle is sufficiently stimulated as strength is increased through routine training (Knight, 1979). Specificity of training refers to simulating the functions of the trainer as closely as possible during exercise sessions since training adaptations of the neuromuscular system are highly specific (Gonyea & Sale, 1982).

Isokinetic exercise has advantages over isotonic exercise such as functional limb speed simulation and accommodating resistance throughout the range of motion. Moffroid and co-workers (1969) found isokinetic exercise to be superior to isotonic exercise for strength enhancement. Meadors and co-researchers (1983) found isotonic exercise to be superior to isokinetic when subjects were pre- and post-tested isotonically.

Strength enhancement is achievable through the use of concentric and eccentric muscle contractions. The muscle, or muscle group, lengthens during an eccentric contraction. The oxygen cost (Asmussen, 1953), heart rate response (Thomson, 1969), and rate of perceived exertion (Henrikkson, Knuttgen, Bonde-Petersen, 1972) are lower for eccentric work. However, delayed muscle soreness is more characteristic of eccentric work (Newham et al., 1983). More tension is produced per fiber, with fewer fibers being activated when a muscle contracts eccentrically (Newham et al., 1983; Johnson et al., 1976). The eccentric contraction is thus under investigation as a more efficient training contraction.

CHAPTER 3

METHODS

The purpose of this study was to compare the effects of eccentric isotonic and eccentric isokinetic training performed for six weeks by college aged males on strength, power and hypertrophy of the quadriceps. This chapter has been divided into the following sections: 1) subject selection; 2) equipment description; 3) testing procedures; 4) training procedures; and 5) statistical treatment of data.

Subject Selection

Twenty-five male undergraduates from the University of Wisconsin-La Crosse volunteered for this study. No subject had participated in a weight training program more than 2 times per week for 8 consecutive weeks 6 months prior to the study. Three subjects were discontinued during the six week training period due to injury or illness. Each volunteer completed a profile sheet (Appendix B), and those demonstrating high blood pressure, swelling in the knee, prior knee surgery, knee injury six months prior to the study, or any other condition inhibiting 100% effort of the quadriceps were eliminated. Ten control subjects were selected in statified random fashion. Mean age was 22.1 ± 3.9 years. Mean body fat percent was 15.5 ± 5.2. Mean height was 180.5 ± 4.9 centimeters and mean weight was 77.7 ± 9.4 kilograms.

Testing Procedures

Multiple tests for strength and power were utilized for accurate assessment of changes so that any learning effect resulting from training on a testing device was reduced. Pre- and post-testing involved 3 sessions for each subject.

Session 1. As each subject entered the physical therapy laboratory in Cowley Hall of the University of Wisconsin-La Crosse he was handed an informed consent form (Appendix C) to read and sign. Each submitted his research subject profile sheet and unsuitable trainees were eliminated. After reviewing the informed consent form the study was explained, the importance of compliance was stressed and questions were addressed. Each subject then performed the Margaria-Kalaman Power test and an isometric strength test on the KIN-COM. The order of the tests was randomized.

The Margaria-Kalaman Power test began with subjects standing in front of a staircase. Each ran the staircase as rapidly as possible taking three stairs at a time. Practice trials were performed with the subject beginning six feet and six meters in front of the staircase until he became familiar with the procedure. An automatic timer was used to record times to the nearest 100th of a second. The timer was set off as the subject's foot struck a switchmat on the third step and the timer was stopped upon striking another switchmat at the ninth step. Three tests at each distance were recorded. (See Figure 1.)

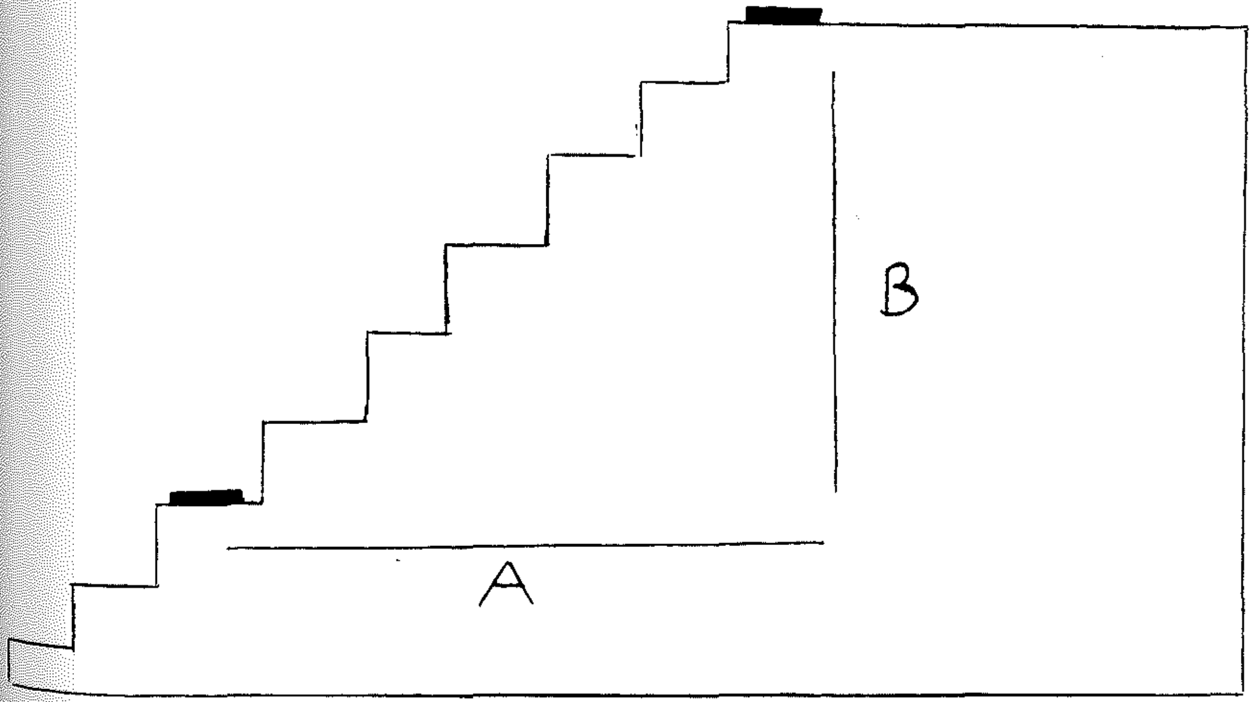
Figure 1. Margaria-Kalaman test procedure.

$$\text{Power} = \frac{\text{FORCE} \times \text{DISTANCE}}{\text{TIME}}$$

Force = Weight of subject

Distance = A + B (Meters)

Time = Seconds from 3rd to 9th step



Each subject was positioned on the KIN-COM for isometric strength testing. The functional axis for knee extension at the lateral joint line was aligned with the dynanometer. The subject was moved back in the seat as far as possible and used the side edges of the seat for stabilization. A torso strap and knee strap were used for further stabilization (See Figure 2.). Each subject exerted a single voluntary maximal effort at $45° \pm 5°$ on the shin pad of the KIN-COM. Shin pad placement was determined by measuring the distance from the center of the patella and lateral malleoli of the ankle and taking 2/3 of that distance. Only the left leg was tested.

Subjects signed up for another testing session to take place 2 days later as they exited the lab.

Session 2. Subjects were tested isokinetically at 60°/second and 170°/second. The order of the tests was randomized. Subjects were positioned on the KIN-COM as for isometric testing. Eccentric and concentric strength was evaluated. Submaximal warm-ups followed by maximal warm-ups at each speed preceded the actual tests. Five repetitions at each velocity were performed with a 3 minute rest interval between velocities.

Subjects then signed up for a final testing session to take place 2 days later at Cybex Orthopedic and Sports Physical Therapy and Fitness Center in La Crosse.

Figure 2. Subject performing exercise on KIN-COM with stabilization strapping.

Session 3. Percent fat, weight, height and anthropometric measurements were taken. Eccentric and concentric one repetition maximums (1RM) were performed as well on an Eagle leg extension machine.

Body fat was assessed using SKYNDEX calipers (Caldwell, Justiss Company, Fayetteville, AK) at the following sites: scapula, tricep, bicep and abdomen. Weight was taken to the nearest 1/4 pound and height was taken to the nearest 1/2 centimeter. Girth measurements including joint line, 10 centimeters proximal to joint line and 20 centimeters distal to joint line were taken with the subject in relaxed supine position and with quadriceps contracted in supine position. Subjects were then positioned on an Eagle leg extension machine with the functional axis of the knee aligned with the Eagle axis by adjusting the seat back. The leg pad was positioned 2/3 the distance from the center of the patella to the lateral malleolus. After warm-up, consisting of stretches and light leg extensions, the subject performed a concentric 1RM and an eccentric 1RM with the left leg. The concentric 1RM was the heaviest weight the subject could successfully extend with his left leg. The eccentric 1RM was the heaviest weight the subject could completely lower at a controlled rate (a count of "1001, 1002").

Equipment Description

KIN-COM (Chattex, TN). Until the development of the KIN-COM system isokinetic exercise was limited to concentric contractions. The KIN-COM system is a hydraulically powered, computer controlled system which provides isometric, concentric and eccentric resistive exercise and assessment in four modes including velocity (isokinetic), force (isotonic), angle (isometric) and passive. Reports of torque, power and total work are available from data stored on a floppy disk and retrieved through one of two main menus. Work is reported in Newton meters (Nm) and one Nm is equivalent to .741 foot-pounds. Maximum force the KIN-COM of the University of Wisconsin-La Crosse could originally accommodate was 1200 Nm (270 foot-pounds). That force was insufficient for the needs of this study and an adjustment was made involving replacement of the force transducer so that up to 2400 Nm of force could be accommodated. This adjustment, however, decreased the maximum velocity capabilities of the system from 210°/second to 175°/second. To execute an exercise or testing session the operator programmed the system in terms of exercise program selection, velocity of movement, eccentric or concentric loading, number of repetitions, pauses between contractions and maximum and minimum force requirements for each subject for each session. A printer, which was a separate unit, provided graphic and numeric reports of the exercise output and related data.

Subjects exerted force against a shin pad. Those training on the KIN-COM experienced abrasions so a pad was placed between the shin and lever of the machine. (See Figure 3.) The original system provided no strapping for stabilization so Velcro straps were placed around the waist of the subjects and around the thighs. (See Figure 1.)

The KIN-COM has been shown to be a reliable and valid exercise testing device (Farrell & Richards, 1986).

Figure 3. Subject positioned on KIN-COM with additional shin protection.

Eagle Leg Extension Machine. The Eagle leg extension machine is an isotonic resistance system utilizing cams and cables to maneuver the selected resistance. The Eagle system provides accommodation to size of the exerciser through adjustments of the shin pad and seat back. Weight can be adjusted in 5 or 10 pound increments.

Training

Training began the week following pre-testing. All subjects trained on Monday, Wednesday and Friday at the same time each day to prevent diurnal variation. Five of the isokinetic subjects trained between 10:00 a.m. and 12:15 p.m., and two between 2 p.m. and 3 p.m. at the KIN-COM in the physical therapy laboratory. Two isotonic exercisers trained between 8:15 a.m. and 9:30 a.m. and five between 3 p.m. and 6 p.m. at Cybex Fitness Center in La Crosse. Each session took approximately 15 minutes and all sessions were supervised by the investigator.

Isokinetic exercisers trained on the KIN-COM at 60°/second. Three sets of 10 were performed with an additional set of 5 on Fridays to compensate for extra repetitions performed by isotonic lifters to adjust working weight. Each isokinetic subject was stabilized using torso and knee straps. Force values were read to the exercisers from the computer screen to serve as motivation as well as a reference of strength improvement. Concentric force values were monitored as well to keep the concentric effort minimal (below 150 Newtons) while maximizing the eccentric contraction. All subjects trained both legs with the exception of one who sprained his right ankle during the fourth week of training. He continued to train his left leg.

Isotonic lifters performed 3 sets of 10 eccentric contractions while a partner (myself or assistants from the fitness center in which the contractions were performed) performed the concentric contraction. An additional (4th) set was performed each Friday to adjust training weight if necessary for the following week. A "modified DAPRE" was devised by the researcher to accommodate the increasing work potential of the subjects in a systematic fashion. Weight adjustment was based on the number of successful repetitions performed during the final set:

4TH SET REPS	WT. INCREASE
0-3	None
4-8	5#
>8	10#

All isotonic contractions were performed at approximately 60°/second which was controlled by a cadence "1001, 1002" during the eccentric phase.

Eight subjects served as controls and did not participate in any weight training program for the six week period.

Subjects were instructed to avoid resistance training other than that prescribed for the test, but were allowed to engage in other physical activity.

Compliance for the isokinetic trainers was 95% (120/126 total sessions). Compliance for the isotonic group was 94% (119/126 total sessions).

Statistical Treatment

Comparisons were made using analysis of covariance for each of the 21 tests with posttest means as covariate values. The .05 level of significance was chosen to test the hypotheses of this study. The null hypothesis was rejected when the F value exceeded the critical F value of 3.55 with 2 and 18 degrees of freedom. A Sheffe post hoc comparison was used to determine which group means were significantly different. The null hypothesis was rejected when the F value exceeded the critical F value of 7.10. The critical F value was derived by multiplying the original critical F value (3.55) by the total number of groups minus one (3-1).

CHAPTER 4

RESULTS AND DISCUSSION

Introduction

The purpose of this study was to compare the effects of eccentric isokinetic and eccentric isotonic quadricep training programs performed for 6 weeks by college aged males. Each training group consisted of 7 subjects. Eight individuals served as controls and performed no resistance exercise for the six week period. This chapter is divided into the following sections: hypertrophy, power, strength, and discussion of the results.

Hypertrophy

Hypertrophy of the quadriceps muscle group was assessed using the average of 4 measurements taken at each of the three sites including 2 measurements with the subject in relaxed supine position and 2 measurements with the subject in supine position contracting the quadricep. No significant difference in thigh girth occurred in any group. There was no significant difference in percent body fat or body weight for any group as well. Refer to Appendix E for anthropometric summary table.

Power

KIN-COM reports of peak torque, total work and power (all at 170°/second) as well as the Margaria-Kalaman Power test were analyzed to assess power changes.

Peak Torque (170°/second). Peak torque values were supplied for both concentric and eccentric efforts. Additionally, average and maximum values were obtained for each. The isotonically trained group significantly increased over the control group in average eccentric peak torque (Table 1). The isokinetically trained group significantly increased over the control group in average concentric peak torque (Table 2). There were no significant increases in maximum eccentric or maximum concentric peak torque values.

Total work (170°/second). Total work reports were available for both concentric and eccentric contractions.

Table 1

Average Eccentric Peak Torque at 170°/second in Newton Meters

	Isotonic	Isokinetic	Control
Mean	346.34	323.35	207.9
346.34	---	F = .239	F = 9.237*
323.35	F = .239	---	F = 6.424

* Significant at .05 level

Table 2

Average Concentric Peak Torque at 170°/second in Newton Meters

	Isotonic	Isokinetic	Control
Mean	255.09	236.11	148.44
255.09	---	F = .417	F = .445
236.11	F = .417	---	F = 9.496*

* Significant at .05 level

The isokinetic group significantly increased over the control group in total work performed eccentrically at 170°/second (Table 3). No group significantly increased in total concentric work at 170°/second.

Table 3

Total Eccentric Work at 170°/second in Newton Meters

	Isotonic	Isokinetic	Control
Mean	1334.72	1395.85	912.62
1334.72	---	F = .123	F = 6.243
1395.85	F = .123	---	F = 8.182*

* Significant at .05 level

Power 170°/second. Power, in terms of the report supplied by the KIN-COM, refers to the amount of work performed over time. (See Appendix A for example of KIN-COM power report.) No group increased significantly in power output at 170°/second concentrically or eccentrically.

<u>Margaria-Kalaman Power Test</u>. The isotonically trained group significantly reduced their times performing this test over the control group at both 6 meters and 6 feet. The isokinetic trainers improved over the controls at 6 meters only (Tables 4 and 5). Refer to Appendix F for summary table of power changes.

Table 4

Margaria Kalaman Power Test Beginning 6 FEET from Staircase in Kilogram Meters per second

	Isotonic	Isokinetic	Control
Mean	183.94	174.6	154.52
183.94	---	F = 1.241	F = 13.134*
174.6	F = 1.241	---	F = 6.118

* Significant at .05 level

Table 5

Margaria Kalaman Power Test Beginning 6 METERS from Staircase in Kilogram Meters per second

	Isotonic	Isokinetic	Control
Mean	212.35	203.51	173.99
212.35	---	F = .791	F = 15.883*
203.51	F = .791	---	F = 8.818*

* Significant at .05 level

Strength

Strength changes were assessed using the results of a 5 second isometric effort on the KIN-COM, concentric and eccentric peak torque (60°/second), and concentric and eccentric total work (60°/second). Additionally, concentric and eccentric one repetition maximums (isotonic) were compared.

Isometric. Each subject completed a 5 second isometric effort on the KIN-COM at 40° ± 5° limb angle. Maximum values were read from the KIN-COM screen from a graphic overlay. The isotonic exercisers improved significantly over the control group (Table 6).

Table 6

Maximum Isometric Force in Newton Meters

	Isotonic	Isokinetic	Control
Mean	1037.1	998.52	855.59
1037.1	---	F = .347	F = 8.204*
998.52	F = .347	---	F = 5.087

* Significant at .05 level

Peak Torque (60°/second. Maximum and average peak torque values were supplied for both concentric and eccentric efforts. The isokinetic group significantly increased over the control group in average eccentric peak torque. No group significantly increased in average concentric peak torque, maximum eccentric peak torque or maximum concentric peak torque at 60°/second (Table 7).

Table 7

Average Eccentric Peak Torque at 60°/second
in Newton Meters

	Isotonic	Isokinetic	Control
Mean	334.06	350.55	225.23
334.06	---	F = .123	F = 5.720
350.55	F = .123	---	F = 7.585*

* Significant at .05 level

Total work 60°/second. No group increased significantly in total eccentric or concentric work performed at 60°/second.

Isotonic 1 Repetition Maximums. A final assessment of strength changes was concentric and eccentric one repetition maximums on the Eagle Leg extension machine. The isotonically trained group increased significantly over both the isokinetic and control groups in concentric one repetition maximums (Table 8). Both the isotonic and the isokinetic groups increased over the control group in eccentric one repetition maximums (Table 9).

Refer to Appendix G for summary table of strength changes.

Table 8

Concentric Isotonic One Repetition Maximum in Pounds

	Isotonic	Isokinetic	Control
Mean	116.56	92.08	86.19
116.56	---	F = 7.104*	F = 11.662*
92.08	F = 7.104*	---	F = .439

* Significant at .05 level

Table 9

Eccentric Isotonic One Repetition Maximum in Pounds

	Isotonic	Isokinetic	Control
Mean	157.64	142.61	123.52
157.64	---	F = 5.154	F = 28.329*
142.61	F = 5.154	---	F = 8.868*

* Significant at .05 level

Discussion of Results

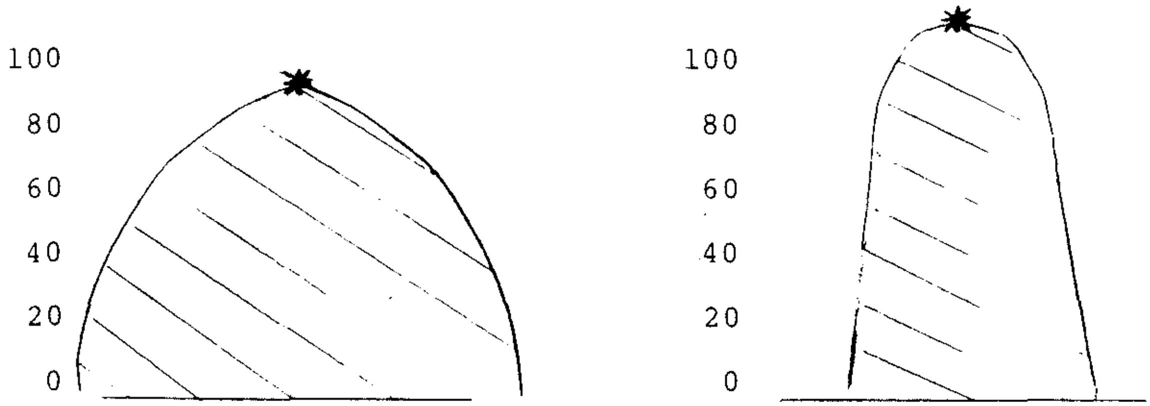
This section will discuss the results of the tests used to assess hypertrophy, power and strength changes.

Hypertrophy. No group significantly increased body weight or thigh girth measurements. Thus strength and power enhancement occurred with no concommitant increase in muscle cross sectional area. These improvements may be attributed to neurophysiological factors that included improvements in synchronization, recruitment and firing rates of motor units that occur as the body becomes accustomed to performing an exercise. These neural factors or "learning effect" are thought to be largely responsible for strength enhancement in the early stages of a training program while actual increases in muscle cross-sectional area become more of a factor later in the training period (Gonyea & Sale, 1982; Hakkinen, 1985). Moritani & deVries (1979) state that neural factors account for strength gains in the first 3-5 weeks of training and hypertrophy becomes more of a factor after that. It is possible that the trainers required a longer training period for a hypertrophic response to occur.

Power. For the purposes of this study power was defined as the ability of a muscle to generate maximum tension at fast contractile velocities (over 60°/second) (Davies, 1984). Various reports are available from the KIN-COM when a subject is tested isokinetically including peak torque, total work and power reports. Maximum peak torque represents the single highest point on the graphically produced torque curve elicited by a single contraction. Average peak torque represents the average peak torque of the 5 test contractions performed by each subject. (See Appendix A.) Peak torque is the most commonly used and frequently reported parameter in isokinetic research.

Total work represents the amount of torque generated for all 5 test repetitions and was available for both concentric and eccentric contractions. All work, represented by the entire area under the torque curve is taken into account. Figure 4 represents the difference between peak torque and total work and shows that it is possible for a subject to elicit a higher peak torque and perform less total work than a subject manifesting a lower peak torque and more work.

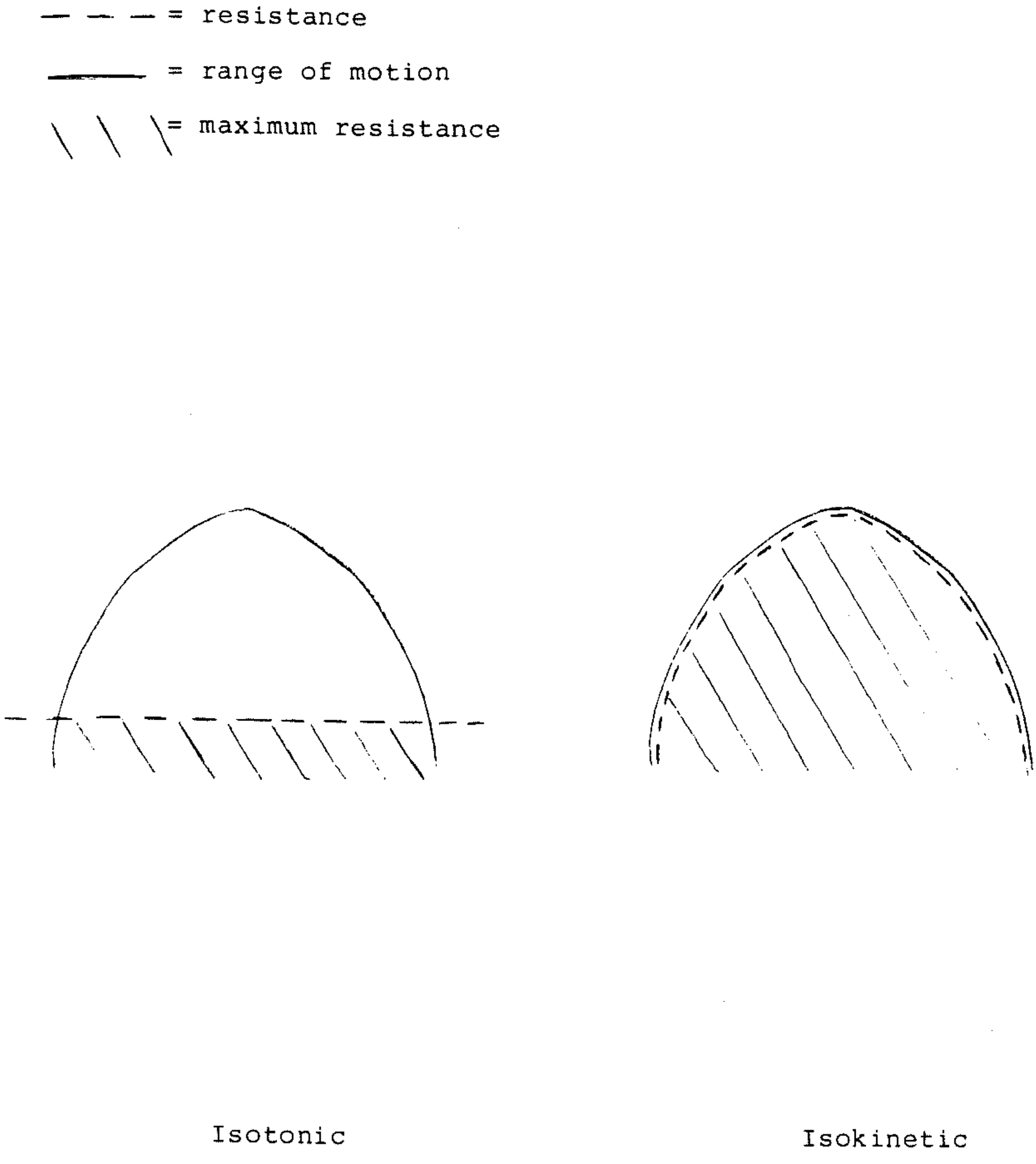
Figure 4. Peak torque vs. total work.



* = peak torque

The isotonically trained group significantly increased over the controls in average eccentric peak torque (170°/second). However, the isokinetic group significantly increased in total eccentric work at 170°/second. This may be reflective of the fact that the isokinetic trainers routinely exercised using near maximum resistance throughout the range of motion, while the isotonic trainers experienced less resistance at mid point in the range of motion. See Figure 5.

Figure 5. Isokinetic vs. Isotonic ROM curve.



The isokinetic group had a carryover of average concentric peak torque as well. Other concentric power tests included the Margaria Kalaman tests. The isokinetic group improved significantly over the control group at 6 meters. The isotonic group improved significantly over the control group at both 6 feet and 6 meters. Carryover of concentric strength from eccentric training is not in agreement with Friden et al (1983), who found only a modest increase in concentric strength (non-significant) after 8 weeks of training.

Both training groups significantly improved in certain fast speed tests as a result of slow speed training programs. The carryover of strength from slow speed training to fast speed testing is not in agreement with a study of Moffroid and Whipple (1970) who found slow speed training to elicit strength gains only when tested at slow speeds. Those researchers found a carryover of strength to occur only when trained at high speed and tested at lower speeds. The results of this study do, however, agree with the findings of Kanehisa and Miyashita (1983) who found slow speed training to increase all test speed strength. Those researchers found fast speed training to increase only fast speed exercise ability.

No significant increases were seen in KIN-COM reports of power in which power was calculated as work divided by time.

Strength. For the purposes of this study strength was defined as the ability of a muscle to generate its maximum tension at slow speeds (below 60°/second) (Davies, 1984).

All strength tests were performed at or below 60°/second. Both training groups significantly improved certain strength test scores. The isokinetic group significantly improved over the control group in average eccentric peak torque at 60°/second. While the isotonic group trained with similar eccentric contractions, the strength enhancement did not carryover when tested isokinetically. Both training groups significantly improved over the control group in eccentric isotonic one repetition maximum lifts. The isotonic group had significant concentric carryover at slow speed testing as well. The isotonically trained group improved significantly over the control and the isokinetic groups in isotonic concentric one repetition maximum lifts. That group also improved significantly over the control group in isometric strength.

The isometric effort was performed at 40° $\pm$ 5° limb angle which is a more efficient point in the range of motion as opposed to the end points in the range of motion. The isokinetic lifters trained that point with maximal resistance while the isotonic subjects trained with a less than maximum weight to accommodate weaker points in the range of motion. It would seem the isokinetic exercisers would have had the advantage in that respect.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The purpose of this study was to compare the effects of six weeks of eccentric isotonic and eccentric isokinetic quadricep training on hypertrophy, power and strength. Hypertrophy changes were assessed with thigh anthropometrics, percent body fat and weight measurements. Power changes were assessed with reports provided by the KIN-COM including peak torque, total work, and power (all tested at 170°/second). In addition, the Margaria-Kalaman power test was utilized with subjects starting trials at 6 feet in front of the staircase and 6 meters as well. Strength was assessed using the peak torque and total work reports from the KIN-COM at a test speed of 60°/second. Additional modes of strength assessment included an isometric effort, a one repetition maximum concentric isotonic lift and a one repetition maximum eccentric isotonic lift. Twenty-two college aged males completed the study including 7 isotonic trainers, 7 isokinetic trainers and 8 subjects performing no resistance training during the six week period serving as a control group. All subjects trained 3 times per week at the same time each day.

All sessions were supervised by the investigator. Three sets of 10 repetitions were performed with an additional set on Fridays to systematically adjust work load.

No group significantly increased thigh girth or body weight. No hypertrophic response occurred as a result of either eccentric training program.

Slow speed training (60°/second) effects carried over to certain fast speed (170°/second) tests for each group. The isotonic group increased significantly over the control group in tests of average eccentric peak torque and both Margaria Kalaman power tests. The isokinetic group improved significantly over the control group in average concentric peak torque, eccentric total work and the Margaria Kalaman power test at 6 meters.

Additionally, each training group improved significantly over the control group in certain concentric strength tests exhibiting a carryover of eccentric training effects to concentric strength. The isotonic group improved in concentric isotonic one repetition maximum lifts and the 5 second isometric test. The isotonic group improved significantly over the control group in the concentric isotonic one repetition maximum as well. The isokinetic group showed no concentric carryover at slow speed tests. The isokinetic group significantly improved over the control group in both average eccentric peak torque and eccentric isotonic one repetition maximum lifts. The isotonic group improved significantly in eccentric isotonic one repetition maximum as well. Refer to summary tables in Appendices E, F and G.

Conclusions

The following conclusions are made based on the results of this study:

1. An eccentric isotonic or eccentric isokinetic training program produces no significant hypertrophic response after six weeks.

2. Eccentric training effects carryover to certain concentric performance capabilities from eccentric isokinetic and eccentric isotonic training programs.

3. Slow speed training effects carryover to certain fast speed performance capabilities from eccentric isokinetic and eccentric isotonic training programs.

4. Eccentric isotonic exercise may be more beneficial than eccentric isokinetic exercise for functional concentric movements (in which the body moves a fixed resistance.) at slower speeds.

Recommendations

The following recommendations are made for future research:

1. It is recommended a similar study be conducted with the addition of fast speed isokinetic eccentric training.

2. It is recommended that a similar study be conducted using different muscle groups.

3. It is recommended a similar study be conducted using athletes and using performance as strength and power assessments.

4. It is recommended a similar study be conducted with a longer training period so a hypertrophic response may occur.

5. It is recommended that concentric contractions be an additional training mode for comparison.

6. It is recommended that delayed onset of muscle soreness between the two eccentric programs be compared.

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REFERENCES CITED

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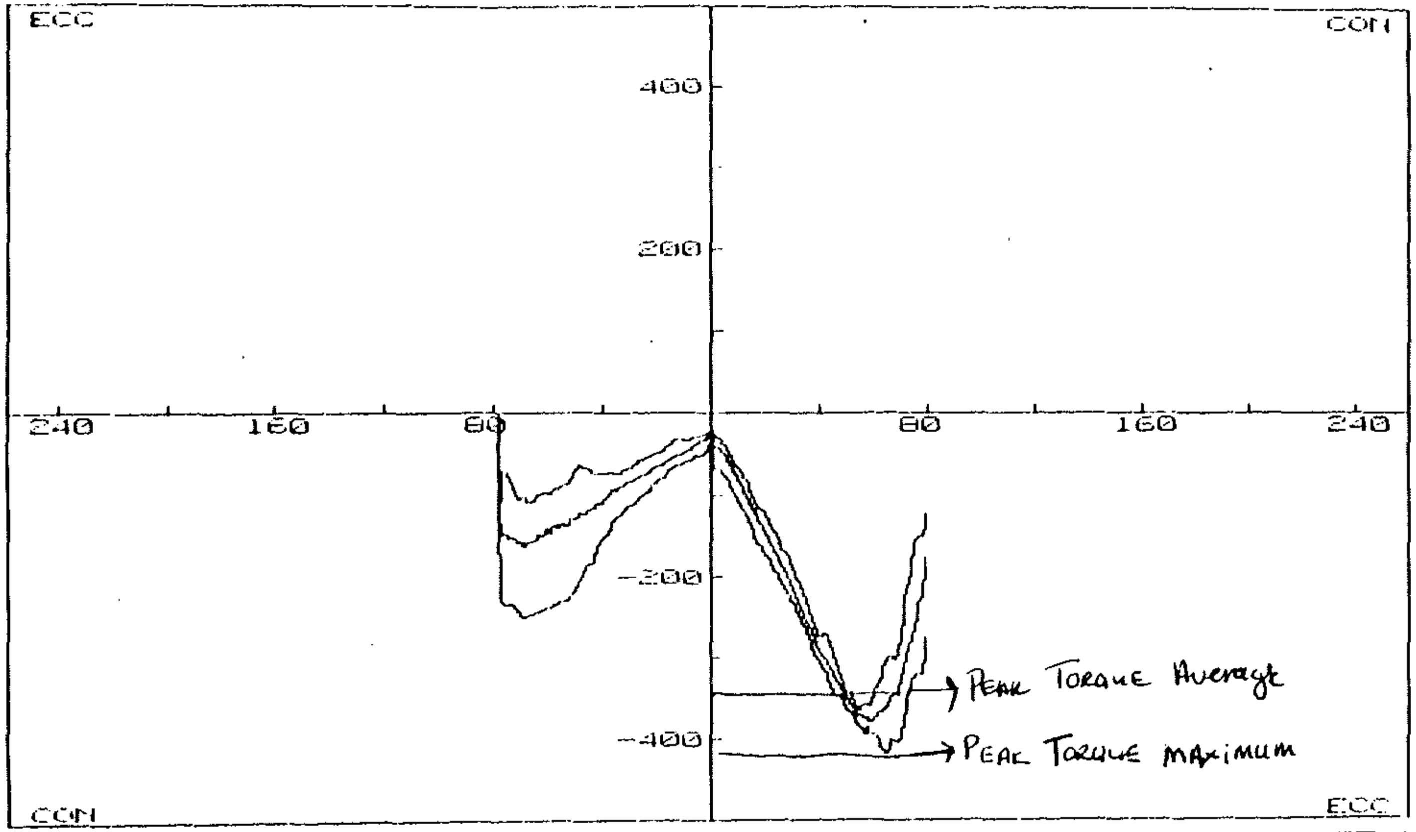
APPENDICES

APPENDIX A

PATIENT: ______________________ TEST # ________ DATE: ________

DOCTOR: ______________________ TIME: ________



EXERCISE MODE VELOCITY

DISK FILE F:ISK60.DC

JOINT TESTED: L R ____________

MOTION: ______________________

EXERCISE PARAMETERS

START ANGLE	185	RETURN ANGLE	265
NUMBER OF STOPS	1	POSITIVE VELOCITY	60
NEGATIVE VELOCITY	-60	POSITIVE FORCE	-20
NEGATIVE FORCE	-20	REPETITIONS	5
STOP DURATION	0	LEVER RADIUS	310
GRAVITY ANGLE	175	REFERENCE ANGLE	175
GRAVITY FORCE	0		

NOTES: GRAVITY COMPENSATED YES

	MIN	AVG	MA
ECCENTRIC			
8	-64.4	-77.2	-102
16	-117.4	-132.6	-160
24	-160.5	-182.4	-205
32	-214.8	-242.0	-259
40	-270.9	-298.0	-315
48	-340.3	-348.0	-360
56	-358.3	-375.4	-386
64	-299.4	-354.2	-415
72	-201.2	-283.1	-338
80	0.0	0.0	0
CONCENTRIC			
-80	0.0	0.0	0
-72	-105.3	-158.2	-243
-64	-98.8	-150.0	-243
-56	-89.6	-134.8	-231
-48	-69.5	-122.0	-193
-40	-74.2	-102.7	-148
-32	-69.4	-85.6	-113
-24	-54.1	-72.6	-94
-16	-38.6	-56.9	-68
-8	-31.9	-42.9	-56

ANATOMICAL REFERENCE

angle	minimum	average	maximum
-80	0.0	0.0	0.0
-79	-106.9	-135.3	-170.1
-78	-70.9	-149.4	-230.6
-77	-71.3	-147.0	-235.9
-76	-78.3	-153.2	-234.3
-75	-85.9	-150.7	-233.6
-74	-93.3	-152.6	-234.3
-73	-101.8	-154.5	-239.3
-72	-105.3	-158.2	-243.4
-71	-102.6	-157.6	-248.7
-70	-103.9	-162.6	-251.1
-69	-109.1	-158.8	-248.8
-68	-109.4	-156.7	-246.1
-67	-106.9	-156.1	-247.0
-66	-102.3	-154.6	-245.7
-65	-99.5	-149.0	-245.8
-64	-98.8	-150.0	-243.9
-63	-97.8	-149.5	-240.8
-62	-96.1	-141.8	-238.3
-61	-98.4	-147.6	-238.1
-60	-95.1	-138.9	-236.7
-59	-93.3	-136.9	-233.7
-58	-93.3	-140.7	-234.0
-57	-91.6	-137.8	-231.6
-56	-89.6	-134.8	-231.5
-55	-88.9	-139.9	-231.1
-54	-86.9	-137.4	-228.7
-53	-81.9	-129.5	-223.7
-52	-72.9	-129.4	-219.1
-51	-68.1	-126.4	-213.[illegible]
-50	-65.7	-121.5	-206.5
-49	-67.0	-123.0	-200.1
-48	-69.5	-122.0	-193.3
-47	-69.4	-119.3	-187.6
-46	-70.5	-116.5	-185.0
-45	-74.5	-117.5	-182.5
-44	-74.0	-110.9	-170.1
-43	-74.0	-108.8	-161.7
-42	-75.7	-110.8	-155.9
-41	-75.3	-104.4	-151.9
-40	-74.2	-102.7	-148.8
-39	-72.5	-99.1	-143.5
-38	-72.8	-95.5	-132.6
-37	-74.0	-94.1	-128.9
-36	-75.0	-93.8	-126.4
-35	-74.2	-91.8	-125.8
-34	-71.3	-90.4	-121.8
-33	-71.0	-87.3	-117.8
-32	-69.4	-85.6	-113.4
-31	-68.3	-85.3	-112.8
-30	-64.7	-82.6	-110.2
-29	-62.9	-80.1	-106.9
-28	-59.0	-79.9	-103.8
-27	-58.2	-77.9	-101.8
-26	-56.4	-76.1	-98.2
-25	-55.0	-75.6	-97.4

APPENDIX B

INFORMED CONSENT FORM

University of Wisconsin-La Crosse
La Crosse, Wisconsin 54601

Project Title: ______________________________

____

Principal Investigator: ______________________________

1. Each subject will be required to perform 3 maximal concentric knee extentions on the KIN-COM at 60°/second and 120°/second, 3 maximal eccentric knee extentions on the KIN-COM at 60°/second and 120°/second, an eccentric isotonic 10RM, a concentric isotonic 10RM, a single maximal isometric contraction, and the Margaria-Kalaman power test for both pre- and post-tests. During the 6 week training session, each subject will perform 3 sets of 10 contractions (eccentric isotonic, eccentric isokinetic, concentric isotonic or concentric isokinetic) 3 times per week. A 4th set of varying repetitions will be performed to determine future training weight for isotonic lifters. A 4th set of 5 repetitions will be performed by the isokinetic lifters.

2. Risk and discomfort to the subject should be minimal. The subject may feel fatigued after completing a training session, but should not experience serious joint or muscle pain.

3. The subject may experience slight delayed muscle soreness 24 to 48 hours after an exercise session.

4. The subject may notice a slight increase in strength, power and muscle size as a result of the training period.

1. I, ______________________, being of sound mind and ____ years of age, do hereby consent to, authorize and request the person named above to undertake and perform on me the proposed pro dure, treatment, research or investigation (herein called "Proceedure").

2. I have read the above document, and I have been fully advised of the nature of the Proceedure and the possible risks and complications involved in it, all of which risks and complications I hereby assume voluntarily.

3. I hereby acknowledge that no representations, warranties, guarantees or assurances of any kind pertaining to the Proceedure have been made to me by the University of Wisconsin-La Crosse, the officers, administration, employees, or anyone acting on behalf of any of them.

4. I understand I may withdraw from the program at any time.

Signed at ______________________ this ___________ day of 1986, in the presence of the witnesses whose signatures appear below opposite my signature.

______________________ ______________________
Subject

____

APPENDIX C

RESEARCH SUBJECT PROFILE

NAME: AGE:
ADDRESS:

PHONE:
MAJOR:
PLEASE LIST REGULAR PHYSICAL ACTIVITY (jogging, basketball, racquetball, tennis. . .)

	YES	NO
KNEE SURGERY		
KNEE SWELLING		
KNEE INJURY		
ANY CONDITION INHIBITING 100% EFFORT OF QUADRICEPS		

DO YOU HAVE HIGH BLOOD PRESSURE? YES NO

APPENDIX D

Table 10

Analysis of Covariance: Body Weight in Kilograms

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	.623	2	.312	.922	.912
Error	60.820	18	3.379		
Total	61.443	20			

Correlation Coefficient between covariate and dependant variable = .980

Table 11

Analysis of Covariance: Body Fat Percentage

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	357.646	2	178.823	1.091	.357
Error	2949.740	18	163.874		
Total	3307.386	20			

Correlation Coefficient between covariate and dependant variable = .362

Table 12

Analysis of Covariance: Knee Joint Girth in Centimeters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	1.595	2	.797	.482	.625
Error	29.789	18	1.655		
Total	31.384	20			

Correlation Coefficient between covariate and dependant variable = .807

Table 13

Analysis of Covariance: Thigh Girth 10 cm. Proximal to Joint Line in Centimeters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	19.078	2	9.539	1.890	0.180
Error	90.866	18	5.048		
Total	99.944	20			

Correlation Coefficient between covariate and dependant variable = .786

Table 14

Analysis of Covariance: Thigh Girth 20 cm. Distal to Joint Line in Centimeters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	7.600	2	3.800	0.550	.587
Error	124.455	18	6.914		
Total	132.055	20			

Correlation Coefficient between covariate and dependant variable = .739

Table 15

Analysis of Covariance: Average Eccentric Peak Torque at 170°/second in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	79435.436	2	39717.718	5.126	0.017
Error	139426.207	18	7745.900		
Total	218861.643	20			

Correlation Coefficient between covariate and dependant variable = .743

Table 16

Analysis of Covariance: Average Concentric Peak Torque at 170°/second in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	45500.767	2	22750.383	7.529	0.004
Error	54393.294	18	3021.850		
Total	99894.061	20			

Correlation Coefficient between covariate and dependant variable = .729

Table 17

Analysis of Covariance: Maximum Eccentric Peak Torque at 60°/second in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	54514.924	2	27257.462	2.847	0.084
Error	172318.054	18	9593.225		
Total	226833.978	20			

Correlation Coefficient between covariate and dependant variable = .634

Table 18

Analysis of Covariance: Maximum Concentric Peak Torque at 170°/second in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	36162.177	2	18081.088	2.534	0.107
Error	128359.592	18	7131.088		
Total	164521.769	20			

Correlation Coefficient between covariate and dependant variable = .495

Table 19

Analysis of Covariance: Total Eccentric Work at 170°/second in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	1049894.358	2	524947.179	4.927	0.020
Error	1917814.096	18	106545.228		
Total	2967708.454	20			

Correlation Coefficient between covariate and dependant variable = .785

Table 20

Analysis of Covariance: Total Concentric Work at 170°/second in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	231983.350	2	115991.675	1.913	0.176
Error	1091194.788	18	60621.933		
Total	1323178.138	20			

Correlation Coefficient between covariate and dependant variable = .440

Table 21

Analysis of Covariance: Eccentric Power (170°/second) in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	510737.871	2	255368.936	3.079	0.071
Error	1492821.688	18	82934.538		
Total	2003559.559	20			

Correlation Coefficient between covariate and dependant variable = .519

Table 22

Analysis of Covariance: Concentric Power (170°/second) in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	31808.432	2	15904.216	0.781	0.473
Error	366346.264	18	20352.570		
Total	398154.696	20			

Correlation Coefficient between covariate and dependant variable = .442

Table 23

Analysis of Covariance: Margaria Kalaman Power Test Beginning 6 Feet from Staircase in Kilogram Meters per second

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	3032.433	2	1516.216	6.163	0.0009
Error	4428.571	18	246.032		
Total	7561.004	20			

Correlation Coefficient between covariate and dependant variable = .854

Table 24

Analysis of Covariance: Mararia Kalaman Power Test
Beginning 6 Meters from Staircase
in Kilogram Meters Per Second

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	5689.573	2	2844.787	8.223	.003
Error	6225.802	18	345.878		
Total	11815.375	20			

Correlation Coefficient between covariate and dependant variable = .801

Table 25

Analysis of Covariance: Average Eccentric Peak
Torque at 60°/second in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	63216.411	2	31608.205	4.089	0.034
Error	139143.882	18	7730.216		
Total	202360.293	20			

Correlation Coefficient between covariate and dependant variable = .787

Table 26

Analysis of Covariance: Average Concentric Peak Torque at 60°/second in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	11494.926	2	5747.463	1.107	0.352
Error	93418.507	18	5189.917		
Total	104913.433	20			

Correlation Coefficient between covariate and dependant variable = .640

Table 27

Analysis of Covariance: Maximum Eccentric Peak Torque at 60°/second in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	32231.656	2	16115.828	2.149	0.146
Error	134966.561	18	7498.142		
Total	167198.217	20			

Correlation Coefficient between covariate and dependant variable = .768

Table 28

Analysis of Covariance: Maximum Concentric Peak Torque at 60°/second in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	3039.767	2	1519.884	0.234	0.794
Error	117090.183	18			
Total	120129.950	20			

Correlation Coefficient between covariate and dependant variable = .487

Table 29

Analysis of Covariance: Total Eccentric Work at 60°/second in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	651794.830	2	325897.415	1.787	0.196
Error	3283072.107	18	182392.895		
Total	3934866.937	20			

Correlation Coefficient between covariate and dependant variable = .694

Table 30

Analysis of Covariance: Total Concentric Work at 60°/second in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	251993.425	2	125996.713	1.952	0.171
Error	1161762.357	18	64542.353		
Total	1413755.782	20			

Correlation Coefficient between covariate and dependant variable = .604

Table 31

Analysis of Covariance: Eccentric Isotonic One Repetition Maximum in Pounds

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	4263.983	2	2131.992	13.896	0.000
Error	2761.585	18	153.421		
Total	7025.568	20			

Correlation Coefficient between covariate and dependant variable = .921

Table 32

Analysis of Covariance: Concentric Isotonic One Repetition Maximum in Pounds

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	3327.444	2	1663.722	5.635	.013
Error	5314.802	18	295.267		
Total	8642.246	20	1958.989		

Correlation Coefficient between covariate and dependant variable = .642

Table 33

Analysis of Covariance: Maximum Isometric Force in Newton Meters

Source of Variation	Sum of Squares	df	Mean Squares	F	Tail Probability
Group	135567.672	2	67783.836	4.521	.026
Error	289861.904	18	14992.328		
Total	425429.576	20			

Correlation Coefficient between covariate and dependant variable = .778

APPENDIX E

Summary of anthropometric changes

VARIABLE	ISOTONIC	ISOKINETIC	CONTROL
BODY WEIGHT (kg.)	-	-	-
PERCENT FAT	-	-	-
JOINT LINE GIRTH (cm.)	-	-	-
10 cm. PROXIMAL JT LINE (cm.)	-	-	-
20 cm. PROXIMAL JT LINE (cm.)	-	-	-
N	7	7	8

(X = Significant at .05 level)

Note. Significant differences after 6 weeks of eccentric isotonic, eccentric isokinetic, or no quadricep training. Level of significance = .05

APPENDIX F

<u>Summary of power changes</u>

VARIABLE	ISOTONIC	ISOKINETIC	CONTROL
CONCENTRIC AVERAGE PEAK TORQUE (170°/second)	-	X	-
CONCENTRIC MAXIMUM PEAK TORQUE (170°/second)	-	-	-
ECCENTRIC AVERAGE PEAK TORQUE (170°/second)	X	-	-
ECCENTRIC MAXIMUM PEAK TORQUE (170°/second)	-	-	-
CONCENTRIC TOTAL WORK (170°/second)	-	-	-
ECCENTRIC TOTAL WORK (170°/second)	-	X	-
CONCENTRIC POWER (170°/second)	-	-	-
ECCENTRIC POWER (170°/second)	-	-	-
MARGARIA-KALAMAN (6 meters)	X	X	-
MARGARIA-KALAMAN (6 feet)	X	-	-
N	7	7	8

(X = Significant at .05 level)

<u>Note</u>. Significant differences in various tests of power in subjects training 6 weeks with eccentric isotonic, eccentric isokinetic or no quadricep resistive training. Level of significance = .05

APPENDIX G

Summary of strength changes

VARIABLE	ISOTONIC	ISOKINETIC	CONTROL
ECCENTRIC ISOTONIC 1 RM	X	X	-
CONCENTRIC ISOTONIC 1 RM	X	-	-
CONCENTRIC AVERAGE PEAK TORQUE (60°/second)	-	-	-
ECCENTRIC AVERAGE PEAK TORQUE (60°/second)	-	-	-
CONCENTRIC PEAK TORQUE MAXIMUM (60°/second)	-	-	-
ECCENTRIC PEAK TORQUE MAXIMUM (60°/second)	-	X	-
CONCENTRIC TOTAL WORK (60°/second)	-	-	-
ECCENTRIC TOTAL WORK (60°/second)	-	-	-
ISOMETRIC	X	-	-
N	7	7	8

(X = Significant at .05 level)

Note. Significant increases in various tests of strength after 6 weeks of eccentric isotonic, eccentric isokinetic, or no quadricep resistive training. Level of significance = .05